>

Report on the LRAIC Model and User Guide

Revised Hybrid Model (version 3.1)

IT- og Telestyrelsen
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1. Introduction

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1.1 Background

In 2002, the National IT and Telecom Agency (NITA) commenced regulation of a number of TDC's wholesale prices in accordance with the LRAIC pricing methodology. To facilitate this process, an Excel-based model was constructed in collaboration with the industry (including TDC) with the intention of incorporating suitable inputs both from a Top Down as well as a Bottom Up perspective. This so-called "Hybrid" model has since been updated annually.

In addition to the annual updates to the model, NITA is committed to consider every three years whether there are suitable grounds for a more extensive update. Since the last major review in 2005, the pace of change and progress in the telecommunications market has continued unabated. In particular:

- The trend of decreasing prices for the conveyance of traffic (both voice and non-voice) shows no sign of stopping, even though there is now a declining volume of traditional telephony traffic being carried over the legacy circuit-switched network.
- New services, such as IPTV, are progressively being introduced that are centred on the broadband (that is, packet switched) network. These services also cover displacement services such as VoIP which are acting as an additional driver for the decline in use of equivalent services carried over the legacy network.
- The development of the packet-switched network has reached the stage where it is now commonplace for industry observers to reflect on the need for a final migration of all remaining circuit-switched services to an all-IP core network, resulting in the so-called "Next Generation Network" (NGN).
- The demand for increased bandwidth to the end subscriber is also driving deployment of advanced technologies and techniques into the access network, resulting in the deployment of so-called "Next Generation Access" (NGA) networks. These typically revolve around the deployment of fibre into the access network, either as a means of reducing the overall length of the final copper connection, or as a means of displacing it entirely with Fibre to the Home/Building (FTTH/FTTB).

During 2008 NITA concluded a consultation process where it elicited the views of the industry participants regarding the need for a more extensive revision of the current Hybrid model. As part of this process, NITA impressed on the industry the implications of the use of an LRAIC pricing methodology, namely that it required the modelling of an efficiently operated company making use of an optimally structured network infrastructure based on latest generation equipment. The methodology thus seeks to minimise, if not remove, the effects of outdated technological solutions and inefficient operating practices.

One important conclusion that NITA arrived at was that there now needs to be a complete updating of the modelled network to one based on packet-switching technology. NITA believes that prices based on such a network should be incorporated into the price regulation starting from 1 January 2010, accepting that consideration might still need to be taken of the fact that TDC could not be expected to have completed an NGN migration by that time.

1.2 The use of LRAIC price estimation methods

By using the LRAIC price estimation method, the total price for an interconnection product cannot exceed the sum of long run average incremental costs of producing the relevant interconnection product, as stated in § 14, section 2, of Executive Order no. 930.

The LRAIC price estimation method consists of a spreadsheet model developed in Microsoft Excel, which is published on NITA's website. The model – named the LRAIC Hybrid Model – is the basis for the determination of LRAIC-based prices for various interconnection products.

All material that has previously been part of the development of the LRAIC price estimation method is – with due respect to the rules concerning exceptions from the right of access to documents in the Act on Right of Access to Documents ("Offentlighedsloven") – published on the NITA website.

1.3 The Hybrid Model

As stated in § 14, section 2, of Executive Order no. 930, NITA is required to develop a LRAIC price estimation method for the following products:

- Exchange of traffic between telecommunications nets or services
- Lease of Unbundled Local Loop
- Co-location costs from common use of buildings, switching equipment, etc.

As a consequence of § 15 of Executive Order no. 930, the first version of the Hybrid Model cost base was estimated as a combination of two cost analyses:

- A Top-Down cost analysis conducted by the suppliers of public telecommunications nets or services, who are obliged to offer interconnection products at LRAIC-regulated prices (in this case TDC), cf. § 15, section 3, of Executive Order no. 930.
- A Bottom-Up cost analysis conducted by the suppliers of telecommunications nets or services wanting access to interconnection products at LRAIC-regulated prices, cf. § 15, section 3, of Executive Order no. 930. The suppliers in question have formed a formalised network – known as the LRAIC Working Group – in order to conduct this analysis.

In accordance with § 15, section 7, of Executive Order no. 530, NITA established criteria and minimum requirements for the two cost analyses. These criteria and requirements were laid down in a Model Reference Paper prior to the development of the original Hybrid Model. This reference paper consists of three parts:

- Common Guidelines for the Top-down and Bottom-up Cost Analyses
- Guidelines for the Top-down Cost Analysis
- Guidelines for the Bottom-up Cost Analysis

An updated version of the Model Reference Paper has been published on NITA's website and forms the basis of the current revised version of the Hybrid Model.

1.4 The purpose of this report

This report sets out to describe the overall methodology underpinning the Hybrid Model. It also provides detailed documentation on the different components of the Hybrid Model — access, core, co-location, and other LRAIC services — as well as information on how costs were determined. In particular, it documents revisions that have been introduced up to version 3.1 of the Hybrid Model.

In addition, the report incorporates a user guide. This offers practical guidance to interested parties about how the models work and on the nature and role of each of the spreadsheets. A general introduction to the model is provided in Chapter 7, and more specific guidance for each individual model (Core, Access, Colocation and Consolidation) is included in the relevant chapters in Sections 8 to 11.

Furthermore, in relation to the revision of the hybrid model, NITA has on 14 November 2008 updated a draft note on the identification of "Other services", that are included in the co-location model. In this consultation NITA received comments from TDC, the Danish Energy and LRAIC Working Group which the agency has considered in a consultation response dated 14 January 2009, released on 19 January 2009. NITA has now completed the work to clarify the content and work for "other services" for the review of LRAIC model for 2010. The updated note is annexed to this report (Appendix D).

2. Overview of Methodology Used to Build the Hybrid Model

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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. Use of the LRAIC cost estimation method therefore demands a more detailed definition of the terms ‘long run’, ‘average’, ‘increment’, and ‘forward-looking’.

‘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 demands. ‘Average’ denotes that costs connected to the production of the relevant interconnection services are divided by the total traffic in order to return an estimate of the average incremental costs. There are several definitions of the term ‘increment’, which is why this subject is discussed in detail below. When talking about ‘forward-looking’ costs, the actual meaning depends on what is meant by ‘forward-looking’ and on the computational assumptions that lie behind the optimisation function within the LRAIC method used. Of special importance is the scorched node assumption, which is explained below. Finally, it must be decided which specific services should be included in the LRAIC price estimation. This is also discussed below.

2.1 Defining the increment

In principle, there are an infinite number of different sized increments that could be measured. However, these increments can effectively be grouped into three different categories:

- A small change in the volume of a particular service
- The addition of an entire service
- The addition of an entire group of services.

The first definition of the increment refers to the economic concept of marginal costing, i.e. it measures the cost associated with adding a single unit of output. In the case of a fixed network a single unit – such as a call minute or byte of data traffic – is so small that the costs of providing it are effectively zero. This makes the approach impractical for modelling purposes and makes it necessary to increase the size of the increment.

The second definition may apply to services of very different sizes, such as interconnection, local calls, and premium-rate calls (e.g. 70, 80, and 90 numbers). This definition may also be referred to as service-based LRIC.

The Hybrid Model adopts a variant of the third definition. The two main increments modelled are the sum of all services in the access network (the access increment) and all services in the core network (the core increment). These are described in detail in Chapters 8 and 9, respectively. The LRAIC methodology is based on these main increments.

The incremental costs of the core increment are those incurred when adding a core network when the access network is already present; similarly, the incremental cost of an access network are the costs incurred when adding an access network when the core network is already in place. The LRAIC of co-location is the cost incurred when providing co-location services. These definitions include the services provided by the SMP operator's network division to its own retail division as well as services provided to other operators.

The unit costs typically increase following the increment size. This is due to the large proportion of the operator's cost base that changes less than proportionally with changes in output. If your current output is different from zero, the marginal duct costs will be very small for almost all changes in the output. For this reason, the unit costs will be largest in the third definition of the increment and smallest in the first definition. Unit costs in the second definition will be closer to the first than the third definition.

The definition of the increment used for LRAIC means that fixed costs[1] specific to either the core or access networks are included. These costs include a large proportion of optical fibre costs and the trenching and duct costs in either the access or core networks, but not the trenching and duct costs used by both networks (defined as common costs). Costs that are shared by a number of services using a network will comprise a significant proportion of an operator's cost base. The difference between shared and common costs is explained below.

2.1.1 Shared and common costs

Common costs are defined here as the costs of those inputs necessary to produce one or more services in two or more increments, where it is not possible to identify the extent to which a specific increment causes the cost. This is in contrast to shared costs, which are defined here as the costs necessary to produce one or more services within a single increment.

Box 1 describes the relationship between directly attributable, shared and common costs. The first definition of the increment, as outlined in the previous section, would only include some of the directly attributable costs in the core and access networks. The second definition would include all directly attributable costs. But the variant of the third definition taken to be the increment in LRAIC would include all directly attributable and shared costs in the core and access networks. Only common costs would be excluded.

There are two main types of common costs between access and core that need to be considered. First, there are the costs associated with trenching and ducting which is shared by the access and core networks. By implication any knock-on costs associated with this trenching, e.g. maintenance costs, are also common costs. Secondly, there are certain fixed costs associated with host and remote subscriber stages and DSLAMs, such as installation costs. Again, any knock-on costs associated with these common fixed costs are also common fixed costs.

The treatment of common costs in the Hybrid Model is described in Chapter 3.

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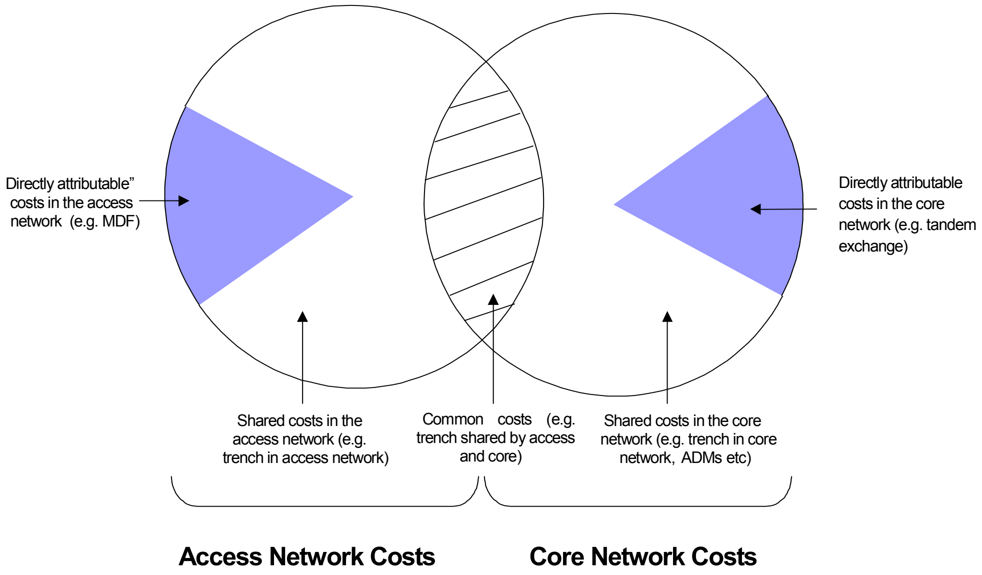
[1] Fixed costs are defined here as costs that do not change with the level of output

Box 1: The Relationship Between Cost Concepts



Directly attributable costs are those costs that are incurred as a direct result of the provision of a particular service in a particular increment. These costs fall into two types. First, the costs of some inputs vary with the level of output, so that even if the output of more than one service requires this input, the extent to which a single service causes the costs can be calculated. Second, there are assets and operating costs which are fixed with respect to the level of output but which are service specific.

Shared costs are the costs of those inputs necessary to produce two or more services within the same increment, where it is not possible to identify the extent to which a specific service causes the cost. Examples of shared costs in the core network include optical fibre, transmission equipment and related overheads, all used by voice, data and video services.

Common costs are the costs of those inputs necessary to produce one or more services in two or more increments, where it is not possible to identify the extent to which a specific increment causes the cost. Trenching costs provide a good example of the difference between shared and common costs. The costs of trenching specific to the access network (or the core network) will generally be a shared costs, since the trenching is likely to be used by two or more services. However, some trenching will be used by both the access and the core network. In these instances, the costs will be common costs.

2.1.2 Defining the core and access increments

The advent of new technology is increasingly blurring the boundary between the core and access networks. Nevertheless, the traditional definitions of core and access, described below, provide a useful basis for measuring the costs of the two main increments.

2.1.2.1 Core

Costs in the core network are primarily driven by the volume of traffic and by the number of call attempts, whereas costs in the access network primarily are driven by the number of subscribers. In practice, the number of subscribers and the volume of traffic will be correlated. Nevertheless, it is possible to consider the implications of increased volume of traffic by keeping the number of subscribers constant (implying an increase in the usage rate) or to consider an increased number of subscribers by keeping the volume of traffic constant (implying a decrease in the usage rate).

Assets within the core network typically include:

> Exchanges and exchange equipment (e.g. traffic related costs of DSLAMs/MSANs, core and edge routers, aggregration switches, media gateways)

> Transmission links between the exchanges (IP network, DWDM)

> Trenching and duct between all levels of exchanges.

2.1.2.2 Access

As defined above, costs in the access network primarily depend on the number of subscribers and only to a very limited extent on the number of calls or volume of traffic. Consistent with this, an alternative definition of access is that it is the service allowing the subscriber to send and receive traffic.

Both definitions suggest that the access network includes all cable and trenching costs associated with subscriber lines between the customer’s premises and the concentrator/DSLAM. The definitions also suggest that the access network includes analogous costs for other lines, such as those for public call boxes between the customer’s premises and the concentrator. Furthermore, the definitions suggest that the access network includes subscriber related costs (such as the line card) within the active network equipment (for example, the concentrator and/or DSLAM). This is consistent with the first view since, for example, 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 essential to sending and receiving traffic.

Assets within the access network typically include:

> The dropwire to the subscriber

> Trench (including any duct) between the concentrator and the subscriber’s premises

> Street cabinets

> Copper cable and optical fibre in this part of the network

> Other assets such as manholes, poles and overhead cables (if used); etc.

> Network Termination Points (NTP)

> Subscriber related costs, such as line cards, in the active network equipment such as concentrators/DSLAMs.

2.1.3 Other increments
In practice, there will be several other increments in addition to the core and access increment. Examples include a retail increment for the access and core networks; an increment for premium rate services; an increment for the mobile network; and an increment for other services.

In the LRAIC Hybrid Model these other increments are not modelled explicitly. The model identifies the costs that are common between other increments and the core and access network increments.

2.2 Other main assumptions

The LRAIC Hybrid Model is based on a Bottom-up Cost Model, which has been built according to a number of specifications or assumptions. The most important of these is the scorched node assumption. An optimal network structure has thus been built under the restriction that all exchange sites in the existing network are populated with equipment; however, this will be modified as a consequence of more effective technology.

The use of the scorched node assumption is described below.

2.2.1 The scorched node assumption
The legislation in Denmark requires the LRAIC price estimation method to adopt the scorched node approach to modelling. In § 2, section 4, of the Executive Order, it is stated that:

> *"The cost analyses [...] shall start from the basic geographic network structure at providers of public electronic communications networks or services that are subject to price regulation following the LRAIC price estimation method. This implies that exchange equipment or similar equipment shall be placed at the geographical sites of the providers' network architecture (scorched node)."*

This implies that the optimisation in the LRAIC Hybrid Model is constrained by the existing number of sites and their geographical locations. The scorched node assumption does not imply that the transit net – cable, duct, trench, etc. – is constant. Nor does it imply that the geographical sites shall be populated with the same number or types of exchanges as in the existing network structure.

As a consequence of this assumption, the following types of exchange sites in TDC's network comprise the constraint in the Hybrid Model:

- A Remote Subscriber Stage
- A local switch
- A transit or tandem switch

> A DSLAM/MSAN

> A site containing Layer 2 switching and/or Layer 3 Routing equipment.

In Denmark, a number of buildings are referred to as ‘technical houses’. To the extent that these houses contain a concentrator and hence line cards they are accordingly deemed to fall within the definition of the scorched node.

2.2.2 A Network Element approach

The Hybrid Model adopts a network element approach to costing. This means that the costs of network elements are estimated and the network elements bundled together to create the relevant interconnection products. The actual bundling of the products will be determined by the routing factors for the particular services’ use of network elements.

2.3 Services in the LRAIC Hybrid Model

Telecommunications operators typically carry a wide range of services over their networks. In addition to voice services, operators provide leased lines, broadband and other data services, and other services such as cable TV. The proportion of data-related traffic has grown rapidly, largely because of the growth in internet traffic. This trend is likely to continue.

The models need to account for all of these services. To exclude some would result in an under-dimensioned network and increased costs for the remaining services as shared costs, such as duct, would be allocated to fewer services.

The core and access models categorise services under the three broad headings – PSTN (including ISDN) and broadband (including bitstream); leased lines; and other services – described below.

2.3.1 Voice and broadband data services

Voice services include standard call services that originate and terminate on exchange lines. Broadband services include both broadband to own customers and wholesale (bitstream) services. Table 2.1 lists the most important services.

Table 2.1: Voice and broadband services

Core	Access
Local calls	PSTN Line Rental
National calls	ISDN 2 Line Rental
International calls – Inbound	ISDN 30 Line Rental
International calls – Outbound	Wholesale Line Rental**
International calls – Transit	Shared Access**
Fixed to mobile calls	Full Access**
Mobile to fixed calls	Other Access (including fibre and wireless technologies)**
IN Basic	
IN Advanced	**Broadband**
Interconnection – Transit Within Area	
Interconnection – Transit Between Areas	Broadband to own customers
Interconnection – Local Area	Bitstream access
Interconnection – Within Area	Other broadband based services (such as VoIP and IPTV)
Interconnection – Between Areas	
Operator Services	
Other calls	

**Where the demand for these services has not been included in other categories, such as PSTN or ISDN line rentals. The purpose is to estimate demand for all access lines, avoiding double counting.

2.3.2 Leased lines

Users of leased lines may be classified in the following three groups:

> *Retail subscribers*, who usually require leased lines to provide a permanent connection between subscriber premises

> *Other operators*, who usually require leased lines to provide a permanent connection between networks

> *The network operator,* who requires leased lines for a variety of reasons.

SMP operators may carry some other services, such as data services over leased lines.

2.3.3 Other services

Other services using the core network will increase in importance over time. Examples include IPTV, packet-switched Virtual Private Networks (VPN) and video-on-demand. The costs of servicing and supply of dedicated equipment for these services are not modelled. However, the capacity effect on the PSTN/IP Core Network increment is taken into account. Due to the effect of cost-volume relationships, this increased capacity reduces the average cost per unit of products and services using that capacity.

3. Costs

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This chapter describes the assumptions made by NITA regarding unit costs (direct and indirect) and operating costs.

This is followed by a chapter discussing the assumptions and the approach used to annualise these costs.

3.1 Defining costs

There are two methods of defining costs within the core and access increments.

The first method is to look at costs that are directly attributable to services within the increment. For example, ADSL line cards are directly attributable to the xDSL part of the access service within the access increment. However, because of the significant extent of fixed and shared costs in telecommunications networks, there will be relatively few directly attributable costs. Most costs will be considered to be “shared” costs (that is shared by a number of different services in the increment, such as leased lines and voice traffic). “Common” costs arise only when two increments (for example, access and core) actually share costs. This is discussed in Section 2.1.1 above.

Another method to use when looking at costs is to consider how they relate to the network. For example, costs could be defined as:

- Direct network costs (such as processors, ports, ducts, and fibres)
- Indirect network costs (such as power, accommodation, and maintenance)
- Interconnection specific costs (such as billing and billing systems)
- Overheads (such as the human resources department).

Network costs measure the cost of those inputs necessary for the network to run. They can be divided into direct and indirect network costs. A direct network cost is defined as one where the volume of inputs – and therefore the cost – depends on factors exogenous to the network, such as the level of demand. For example, the number of line cards, and therefore their total cost, will depend on the number of subscribers.

In contrast, an indirect network cost is one where the volume of inputs, and hence cost, depends on choices made concerning other (direct) inputs. An example is racks, since the number and size of racks necessary will depend on the choices made concerning ports and line cards.

Interconnection-specific costs comprise costs which may be associated with supplying interconnection services at the wholesale level. These are typically subscriber-related costs such as billing and billing system costs.

Overheads cover those costs that are not necessary to run a network, but must nonetheless be incurred in order for the network operator to function.

The approach used to estimate these types of costs is presented below. Table 3.1 shows how the different costs have been treated in the Hybrid Model.

Table 3.1: Definition of Costs Used in the Hybrid Model

Cost Category	Examples of Costs Included
Direct costs	Trench Line cards Copper cable Ports Fibre
Indirect capital costs	Accommodation
	Power
	Security
	Air-conditioning
Operating costs - direct	Installation, operation, and maintenance of the network – FA costs
Operating costs – indirect	Travel and management costs
Overheads	Executive
	Business planning and development
	Accounting, finance, and audit
	External relations
	Human resources
	Information management
	Legal
	Procurement
	Other general administration
Interconnection specific costs	Subscriber related costs
	Billing and billing systems

3.2 The treatment of common costs

There are various approaches for dealing with common costs. Mark-ups can be either additive or multiplicative and similarly be either differentiated or uniform. A (uniform) additive mark-up implies that common costs are divided by the number of increments and the resultant total is added to each increment (thus, if common costs were 2,000, 1,000 would be added to both the core and access increments). An additive mark-up implies that the allocation of common costs is independent of the total costs of the various increments.

A multiplicative mark-up implies that common costs are split in relation to the relative level of incremental costs of each of the increments. For example, if the Incremental Cost of Access is 75% of total incremental costs and the Incremental Cost of Core is 25% of these costs, then the access increment would be allocated 75% of common costs and the core increment 25% of these common costs. Multiplicative mark-ups are sometimes referred to as equi-proportionate mark-ups.

More sophisticated forms of mark-ups are also possible. However, these methods can be information sensitive and be subject to subjective judgements. For that reason, mainly equi-proportionate multiplicative mark-ups (EPMU) are used in regulatory cost models. In a few cases additive mark-ups are used. In the current LRAIC Hybrid Model, the EPMU method is used for non-network related common costs and wholesale costs, whereas network related common costs and shared costs are allocated on the basis of cost causality.

3.3 Unit costs

One of the most challenging tasks when developing a Hybrid Model is to collect robust cost estimates. This section reviews the data sources and volumes used and discusses the approach taken to populate the Hybrid Model with cost information.

3.3.1 Sources of cost estimates

The cost estimates used in the Hybrid Model are based on a number of sources including TDC, the LRAIC Working Group, various equipment suppliers, and benchmarking data from comparable models (such as the Swedish LRIC Hybrid Model) plus publicly available data sources (including Statistics Denmark).

3.3.2 Cost estimates in the Hybrid Model

According to NITA, the cost data used in the Hybrid Model should – to the extent possible – be recent, robust, and relevant to a national network in Denmark.

Therefore, NITA has obtained cost estimates from the various sources listed above and developed a consolidated estimate based on all the information available. However, more emphasis or weight has been placed on estimates accompanied by robust and documented evidence.

The choice of price data used in the revised version of the Hybrid Model has been based on a qualitative assessment of the estimates and documentation available. Where NITA has found the documentation for certain estimates to be less substantial, only limited weight has been put on the estimate in question.

Estimates from the Swedish LRIC Hybrid Model have been used as a documented benchmark for equipment prices on several occasions. This model is comprised of both publicly available data and confidential data. Where the equipment price used as a benchmark is publicly available, it is used without further adjustments.

The Swedish telecommunications regulator (PTS) has informed NITA that the confidential data used in the model are the actual equipment prices masked by randomly applying an uplift in the range of +/- 10 percent.

Furthermore, NITA has access to various international benchmark prices that may be appropiate for use in the Danish LRAIC Hybrid Model. Documented and evaluated price information from the Swedish model as well as other benchmarks have, therefore, been used as a basis of comparison with the estimates from other sources.

NITA has not been able to identify installation costs separately in all the equipment prices available. Therefore, it has been necessary to integrate installation costs in the model in one of the following three ways:

> As a documented cost (when information on specific installation costs has been available)

> As an estimated mark-up on equipment prices (when only the latter have been available)

> As an empty entry in the model (when only the sum of equipment and installation costs has been available).

3.3.3 Data input and confidentiality

NITA takes the view that the cost data used in the Hybrid Model should — to the extent possible — be transparent and accessible for all parties in the process. Transparency in the data input makes it possible for all parties to use the Hybrid Model, to comment on the data input used, and to supply NITA with further estimates and documentation that could enhance the quality of the LRAIC Hybrid Model.

For these reasons, the **data input on unit costs** (e.g. equipment prices) used in the Hybrid Model is – whenever possible – transparent and accessible to all parties involved in the process.

Nevertheless, in some instances it is necessary to ensure the confidentiality of the data on unit costs. This is done using the following procedures:

> The method for evaluating the data or their sources is not stated explicitly. This means that it is not possible to identify the implicit weight of different inputs used by NITA and thereby to get access to the underlying confidential data.

> Moreover, when the cost data used are based on confidential data, NITA has estimated the cost for a particular type of equipment where cost information is available from several suppliers.

This is a continuation of the procedure that was used for the first draft version of the LRAIC Hybrid Model.

For **data inputs other than unit costs**, NITA has – whenever possible – followed the same principles as when dealing with unit costs. However, in one instance it has not been possible to let the actual data inputs be accessible to all parties, since they are highly dependent on confidential data supplied by TDC. As a consequence, NITA has chosen to submit a public version of the model containing masked data instead of the underlying values used in the model. This is done by adjusting the actual data inputs to the model by a random factor (negative or positive). In the published version of the Hybrid Model, it is indicated explicitly by the use of a specific colour code when data is masked.

The very limited use of masked data makes it possible to use the model with ’almost accurate’ data input. The random adjustments to the published model produce only very small deviations from the model producing the correct non-masked data.

3.4 Operating costs

In previous publications, NITA has acknowledged the difficulty in modelling operating costs in a bottom-up model, and noted that only sparse documentation and justification had been provided for the mark-ups used in earlier versions of the model.

To improve transparency and model operating expenditures more directly, NITA chose to adopt a Functional Area approach in the Hybrid Model, which was based on the FA method used in the Swedish LRIC Hybrid Model.

The FA method identifies a number of major cost categories that are based on the basic functional areas of a telecommunications provider, as shown in Table 3.2.

This approach to the modelling of operating expenditures is comparable to the method normally used by providers developing business plans.

LRAIC operating, overhead, and annualised indirect capital costs or FA costs should, thus, comprise the costs that are relevant for the wholesale provider in the core and access increments. Any cost being directly related to end user activities should be excluded. This ensures that costs for other increments not modelled directly in the Hybrid Model are excluded from the model. Moreover, costs that are modelled indirectly (e.g. non-PSTN costs) are also excluded from the final allocation of costs to specific interconnection services.

The method is based on two main steps:

> Statement of costs per functional area

> Allocation of costs.

These steps are described in detail below.

3.4.1 Statement of costs per Functional Area

The cost categories are defined in accordance with the overview in Table 3.2.

Table 3.2 Detailed Summary of the Functional Areas

	Costs			
	Network related on-going costs	Network related one-off costs	Non-network related cost	Interconnection specific and commercial operating costs
Area	IMS management and planning IMS maintenance Network Management System Core infrastructure management and planning Core infrastructure maintenance Core DWDM equipment management and planning Core DWDM equipment maintenance IP network management and planning IP network maintenance DSLAM management and planning DSLAM maintenance Access infrastrucuture management and planning Access infrastructure maintenance	IMS installation Core infrastructure installation Core DWDM installation IP Network installation DSLAM installation Access infrastructure installation	Corporate Overheads Human resources Finance Support systems Administration	Customer oriented costs Billing Debtor handling Other IC specific costs

The cost categories summarised in Table 3.2 represent a significant departure from those used in version 2.4 of the Hybrid Model. This was necessary to take account of the considerable differences in the underlying network structure and hierarchy resulting from the adoption of an IP-based core network.

Costs are split into continuous and one-time costs. Personnel demand is calculated per FA area, and the total wage costs are calculated using a standard price for the pre-defined position categories. This is based on the following three standardised personnel categories:

> Technicians

> Administration (e.g. secretaries)

> Academics (professionals such as solicitors, engineers, etc)

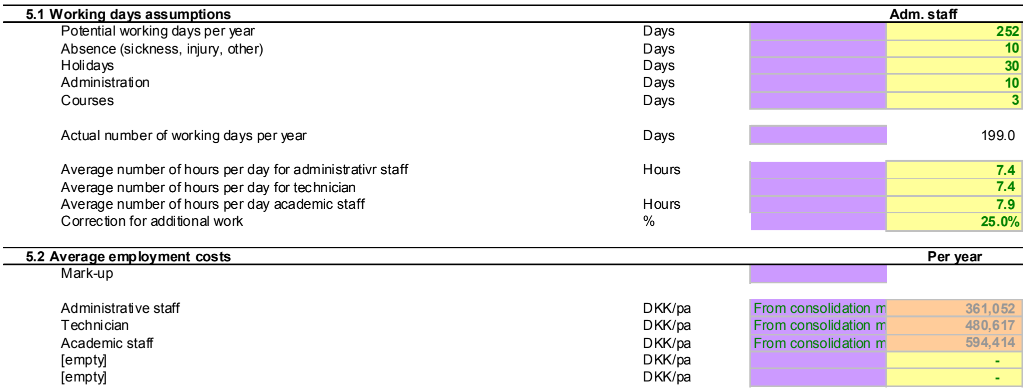
NITA has estimated an average yearly gross wage (including employer or employee paid pension) for each of these categories. Estimates for gross wages are based on publicly available data drawn on the 1st of October, 2005, adjusted to reflect 2009 costs.

Data from the Danish Metalworkers Union (Dansk Metal) was used for the technicians, and for the academic employees, data was collected at The Association of Danish lawyers and Economists (Danmarks Jurist- og Økonomforbund) and The Society of Danish Engineers (Ingeniørforeningen i Danmark).

On the basis of these estimates, an effective hourly wage for each type of position was calculated. Assumptions have been made regarding the number of possible working days per year, weekly working hours and corrections for days off and other absences – including illness, training courses, and general administrative activities. Furthermore, extra costs such as higher wages for managers have been taken into account by effectively moving 10% of technical staff into the higher academic wage bracket.

The input parameters are shown in Table 3.3 below.

Table 3.3: Staff Cost Calculations



5.1 Working days assumptions			**Adm. staff**
Potential working days per year	Days		252
Absence (sickness, injury, other)	Days		10
Holidays	Days		30
Administration	Days		10
Courses	Days		3
Actual number of working days per year	Days		199.0
Average number of hours per day for administrativr staff	Hours		7.4
Average number of hours per day for technician			7.4
Average number of hours per day academic staff	Hours		7.9
Correction for additional work	%		25.0%
5.2 Average employment costs			**Per year**
Mark-up			
Administrative staff	DKK/pa	From consolidation m	361,052
Technician	DKK/pa	From consolidation m	480,617
Academic staff	DKK/pa	From consolidation m	594,414
[empty]	DKK/pa		-
[empty]	DKK/pa		-

Source: Co-location model, I_Costs

Any use of time on activities that are not directly work related such as transport, waiting time, and other relevant "wasted time" is taken into account when calculating time usage for each specific activity, e.g. installation of raw copper. Moreover, new service categories have been added in the revised Hybrid Model to account for unsuccessful customer visits and unproductive fault handling.

Regarding services/tasks in which area the estimated cost is based on the number of hours and wage level, a mark-up of the hourly wage is needed to take into account the indirect costs derived from other types of personnel who, indirectly, contribute to time expenditure for that activity.

For example, a problem on an access line will primarily need a technician, who will use a certain amount of time on repairs and testing, but the same problem will also result in extra use of administrative and managerial hours. Similarly, an academic employee negotiating with a provider about a relevant interconnection contract will also draw upon administrative and managerial resources.

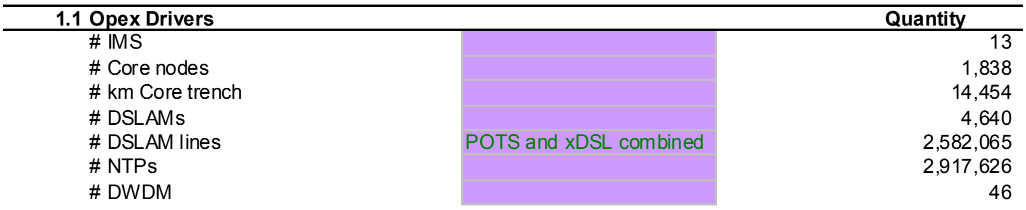
To consider this extra indirect cost derived from other personnel’s time consumption, a 25 percent mark-up has been applied to all three wage categories.

In version 2.4 of the model, the list of functional areas was clearly based on an underlying circuit switched network and thus for the revised model the areas needed to be adapted to reflect an underlying packet switched network.

Furthermore, the staffing levels in version 2.4 were fixed for each functional area which is now felt to be no longer appropriate, given the more rapidly changing nature of both the quantities and types of equipment in IP-based networks. In addition to updating the list of functional areas to reflect the IP-based network modelled, the fixed quantities of staffing have been replaced with variables that can flex to some degree with underlying demand.

From version 2.5, for each functional area it is now possible to specify a minimum level of staffing, together with an additional number of staff per “so many” of a given driver. The list of drivers currently in the model is illustrated in Table 3.4, but could easily be adapted should more suitable drivers be identified later in consultation with the industry.

Table 3.4: List of Opex Drivers



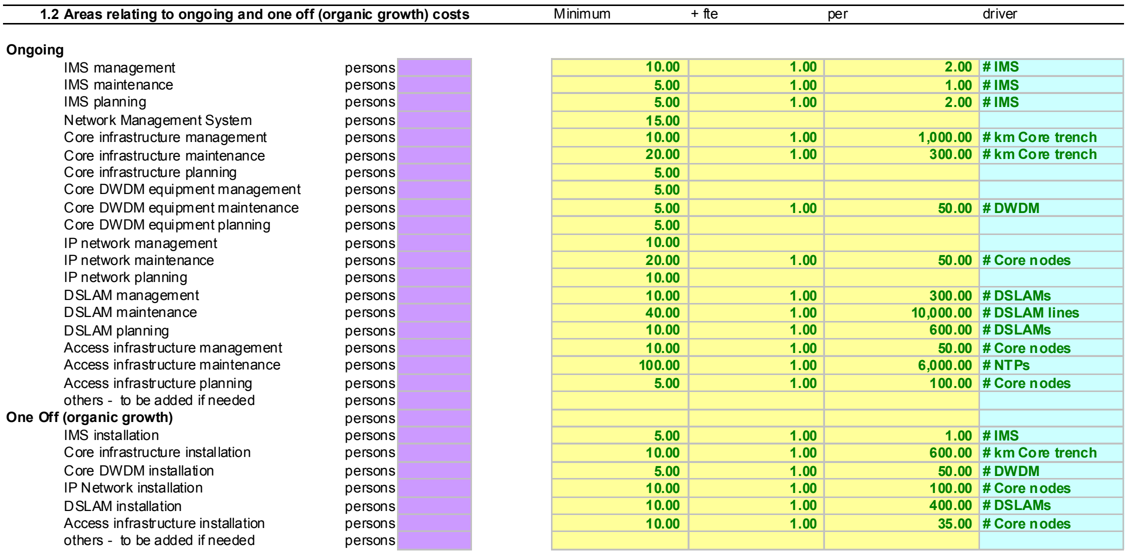
1.1 Opex Drivers		Quantity
# IMS		13
# Core nodes		1,838
# km Core trench		14,454
# DSLAMs		4,640
# DSLAM lines	POTS and xDSL combined	2,582,065
# NTPs		2,917,626
# DWDM		46

Source: Consolidation model, I_FA_Costs

The initial entries in the functional area staffing input table have been based on an assessment of the staffing levels in version 2.4, together with experience of inputs used in other such models. The overall level of staff covered by the complete set of functional areas has been kept broadly constant with the total in version 2.4 (1,435 in the release for 2009 of version 2.4 compared with 1,426 in the final revised model version 2.5).

The complete new list of functional areas, together with the staffing level input drivers, is illustrated in Table 3.5.

Table 3.5: Functional Area Staffing Levels



1.2 Areas relating to ongoing and one off (organic growth) costs			Minimum	+ fte	per	driver
Ongoing						
IMS management	persons		10.00	1.00	2.00	# IMS
IMS maintenance	persons		5.00	1.00	1.00	# IMS
IMS planning	persons		5.00	1.00	2.00	# IMS
Network Management System	persons		15.00			
Core infrastructure management	persons		10.00	1.00	1,000.00	# km Core trench
Core infrastructure maintenance	persons		20.00	1.00	300.00	# km Core trench
Core infrastructure planning	persons		5.00			
Core DWDM equipment management	persons		5.00			
Core DWDM equipment maintenance	persons		5.00	1.00	50.00	# DWDM
Core DWDM equipment planning	persons		5.00			
IP network management	persons		10.00			
IP network maintenance	persons		20.00	1.00	50.00	# Core nodes
IP network planning	persons		10.00			
DSLAM management	persons		10.00	1.00	300.00	# DSLAMs
DSLAM maintenance	persons		40.00	1.00	10,000.00	# DSLAM lines
DSLAM planning	persons		10.00	1.00	600.00	# DSLAMs
Access infrastructure management	persons		10.00	1.00	50.00	# Core nodes
Access infrastructure maintenance	persons		100.00	1.00	6,000.00	# NTPs
Access infrastructure planning	persons		5.00	1.00	100.00	# Core nodes
others - to be added if needed	persons					
One Off (organic growth)	persons					
IMS installation	persons		5.00	1.00	1.00	# IMS
Core infrastructure installation	persons		10.00	1.00	600.00	# km Core trench
Core DWDM installation	persons		5.00	1.00	50.00	# DWDM
IP Network installation	persons		10.00	1.00	100.00	# Core nodes
DSLAM installation	persons		10.00	1.00	400.00	# DSLAMs
Access infrastructure installation	persons		10.00	1.00	35.00	# Core nodes
others - to be added if needed	persons					

Source: Consolidation model, I_FA_Costs

3.4.2 Allocation of costs

Three types of operational costs are to be allocated:

> Network related costs, which are directly related to operating the network – e.g. network management, equipment maintenance or access installation.

> Interconnection related costs, which are directly related to the commercial operation of interconnection – e.g. subscriber support and interconnection accounting systems.

> Non-network related costs or other operational costs, which are necessary for running an organisation. For example, HR costs, Board of Directors'costs, legal assistance, etc.

3.4.2.1 Allocation of network related costs

The division into FA areas may not be used directly for allocating the network related costs. Therefore, a model is used whereby the costs are first transformed or allocated to network elements and then to services, using the traditional routing table method.

For this, the model uses an allocation table and the operational costs that are already allocated to network elements by use of mark-ups and, in the access model, the event-driven method. The allocation table is comprised of the values of zero (do not allocate costs) and one (allocate costs). By using this table, and the costs that are already allocated to each network element, the model calculates FA costs for each network element. The formula used is:

$$FA_j = \sum_i \frac{FA_i \times NE_j^{opex} \times \alpha_{ij}}{\sum_j NE_j^{opex} \times \alpha_{ij}}\text{, where}$$

- > FA_j = FA costs for network element j
- > FA_i = FA costs for area i
- > NE_j = operational cost allocated to network element j by use of mark-ups and, in the access model, the event-driven method
- > α_{ij} = allocation scale for network element j and area i

In the model, this transformation is developed in the consolidation model in the 'C_FA_Costs' sheet.

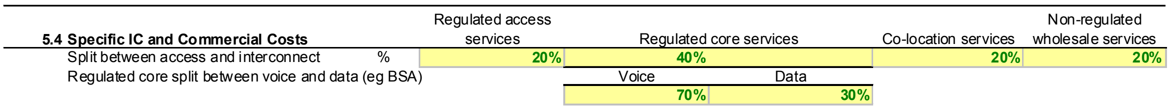
3.4.2.2 Allocation of interconnection specific costs

Some costs relate specifically to the exchange of traffic or wholesale access services. According to Table 3.2 above, these costs consist of:

- > Customer related costs
- > Billing and billing systems
- > Debtor administration
- > Other interconnection specific costs

Even though these costs constitute a relatively modest part of the modelled total costs, they are still important for the final costs. These costs are allocated exclusively to switched interconnection services and wholesale access services. The costs are summed up as a total and then allocated between the two service categories using a distribution scale, as shown in Table 3.6:

Table 3.6: Allocation of Interconnection Specific Costs



5.4 Specific IC and Commercial Costs		Regulated access services	Regulated core services		Co-location services	Non-regulated wholesale services
Split between access and interconnect	%	20%	40%		20%	20%
Regulated core split between voice and data (eg BSA)			Voice	Data		
			70%	30%		

Source: Consolidation model, I_FA_Costs

The costs are allocated to the services using a multiplicative mark-up. The mark-up is calculated from the interconnection specific costs for the increment in relation to the overall operating costs for the increment.

3.4.2.3 Allocation of non-network related costs

The LRAIC cost base also contains non-network related costs – that is, costs which are necessary for running a telephone company, but which may not be allocated immediately to the individual network elements. These elements are allocated directly to the services by use of a mark-up method.

The mark-ups used in the hybrid model are shown in Table 3.7.

Table 3.7: Mark-up for Other Annual Indirect Common Costs, incl. Operational Capital

	Mark-up (pct.)
Services in the access network	13.2
Services in the core network	15.0
Co-location services	13.8
Other services	15.0

These mark-ups are based on calculation of a common mark-up for all the services. The common mark-up was found to be 13.80 percent. It has subsequently been adjusted for working capital (see the paragraph below) for the individual categories. This results in four individual different mark-ups.

3.4.2.4 Estimation of FA costs

FA costs in the model are based on an offline analysis of the available data from the existing LRAIC model, TDC's latest cost statement, TDC's previous top-down model, and other benchmarking data, such as the Swedish LRIC model.

However, these data may not be used directly. To consider the actual, modelled network and the FA method's cost categories, it was necessary to make a series of corrections of the data material available. The method is, therefore, an iterative process; consequently, both a bottom-up and a top-down approach have been used, with a subsequent calibration.

The bottom-up approach is based on dimensioning factors defined by experience, such as number of employees per central or installation time for a certain type of equipment, converted into personnel hours. This approach is typically used for development of business plans and investment analysis. The top-down approach is, however, based on general key numbers such as maintenance's share of GRC.

After convergence of the results of the two methods, a reasonability and/or consistency check is performed by e.g. comparing with the numbers from the current LRAIC model, to see whether a correction should be made.

The relationship between personnel and non-personnel costs is predominantly based on TDC's data from the original top-down model.

It should be noted that the network based FA costs do not include annual costs for premises, power, and cooling. These costs are modelled directly in the core model and then transferred to the consolidation model.

3.4.3 Working capital

The cost of the working capital is a percentage of the total working capital. The percentage value used is assumed to be the same Cost of Capital percentage that is used to define the return on fixed assets. The same modelling method is used as was in the previous version.

The Required Level of Working Capital (RLWC) is defined as the current assets less current liabilities. Thus:

(1) RLWC = Stock + debtors – creditors + cash

Stock is assumed to be negligible. (1) can subsequently be calculated as:

(2) RLWC = (Debtor days * sales – creditor days * total creditor related costs) / 365 + cash

Sales are the sum of the sales revenue of Co-location, Core PSTN and Access network services. These are calculated in the model assuming a cost-oriented sales price is used.

The total trade creditor related costs are made up of:

> Wages
> Power
> Other payments to suppliers, such as support contracts and equipment suppliers

The bottom-up guidelines indicate that a percentage increase in the debtor days may be used instead of a figure for the amount of cash required by a prudent operator. Cash could also be defined as a percentage increase in sales revenue (in the equation (2) above, and these are seen as being equivalent).

The working capital given by company accounts may not correspond to the working capital an efficient operator would need. For example, the adjustments to operating cost would affect the level of working capital by altering the level of creditors. Further, the efficient operator may have a smaller level of working capital due to better management of debtors, creditors, cash and the supply chain. However, given that the cost of working capital is likely to be small in relation to other costs, such inefficiencies might not be material.

3.4.3.1 How the working capital is used in the model

The total Working Capital (WC) is determined using the method outlined above.

Next, the total WC value is multiplied by the cost of capital, to find the actual *cost* of WC. The cost of WC is then calculated as a fraction of the total costs (sum of costs of Core, Access and Co-location). This is then converted into a percentage value that is used to “uplift” the cost of services. The percentage value used in the model also includes the effect of common business costs, as well as WC.

Working capital is calculated differently for Core and Access to show the difference in payment method for the usage of net services. This variation is taken into account through different assumptions for the number of debtor days. The model assumes that the average number of debtor days is -15 for Access and 105 for Core. This difference highlights the difference in payment methods. Raw copper is prepaid quarterly, whereas interconnection services in the overall net are paid after the end of a quarter (billed after being registered).

Mark-up for working capital is added to mark-up for other indirect costs to give a total overhead cost mark-up.

The estimates in the model are shown in Table 3.8.

Table 3.8: Estimates for Working Capital used in the Hybrid Model

Type of cost	Estimate
Core services	1.17%.
Access services	-0.58%.

3.5 Building costs for exchanges and technical houses

To ensure that the value of the property used for housing equipment, such as exchanges and technical houses reflects the real costs, NITA has developed a method to assess property values that is more precise than the direct use of public valuations. Using this method, the public property values as informed by TDC have been adjusted by a factor representing the difference between the market price and the public valuation in each geographical area.

3.5.1 Calculation of the real property costs

TDC has supplied a set of data with the property records, including the value of the land, property area in m^2, land area in m^2 and postcode for each site. Information concerning the cost of land is primarily based on the public assessment from 2004, however, in a few cases, the details for 2004 were not available; here, the valuation from 2002 has been used.

In order to correct the public assessment property data from TDC, NITA obtained data from Statistics Denmark illustrating the difference between market prices for factory and storage properties and the public valuation through four quarters, from the second quarter in 2004 through to the first quarter in 2005. For version 2.5 of the model, updated market values were obtained from Denmark Statistics for the period from the second quarter 2005 to the second quarter 2008 (the most recent available) to bring the TDC data up to date.

NITA has calculated a correction factor at county level, whereby it has been possible to make an adjustment for the public assessment value data from TDC for exchanges and technical houses in the counties with sufficient data available.

Building costs per m^2 are calculated in the hybrid model and have simultaneously been split into indoor and outdoor costs, primarily because land and buildings have different salvage values, asset lives, and price trends. Another reason is so that the outdoor co-location area can be modelled.

The following calculations have been performed:

- The average building costs per m^2 and the average land costs per m^2, for each geotype.
- The market value of buildings in each geotype is calculated as the average building costs minus the average land costs.
- Annual costs per m^2 for land and buildings, respectively, based on parameters such as asset life, salvage value, and price trends.
- Land costs per m^2 are allocated to outdoor area in m^2 in a 1:1 ratio for each geotype.
- Land costs per m^2 are allocated to indoor property costs per m^2 in relation to land area per building area for each geotype.

Co-location occurs at exchanges and not in technical houses, making it necessary to calculate a separate price per m^2 for co-location which excludes technical houses. Technical houses are included in the price per m^2 for the rest of the model.

In the revised model, a number of additional adjustments had to be made to the building values analysis in order to derive updates for 2008.

As of 1 January 2007, the county structure in Denmark was reformed, whereby the former 13 'Amter' were reorganised into 5 Regions. These in turn are subdivided into 11 'Landsdele' (or subregions). In order to derive a continuous data set for market values from Denmark Statistics, the old Amter had to be mapped to the new Landsdele. This was done by reallocating municipalities from the old Amt areas to the new Landsdel areas, based on a transition table provided by Denmark Statistics.

Adjustments also had to be made for the different levels of source data available. The previous data set for Q2 2004 – Q1 2005 contained sales volume and growth data at municipality (or city) level. From Q2 2005, data were only available at 'Amt' level, and from Q1 2006 data were available at Landsdel level. Therefore the data were grouped into three distinct periods:

- Period 1: Q2 2004 – Q1 2005
- Period 2: Q2 2005 – Q4 2005
- Period 3: Q1 2006 – Q2 2008

A correction factor was calculated for each period by the following methods:

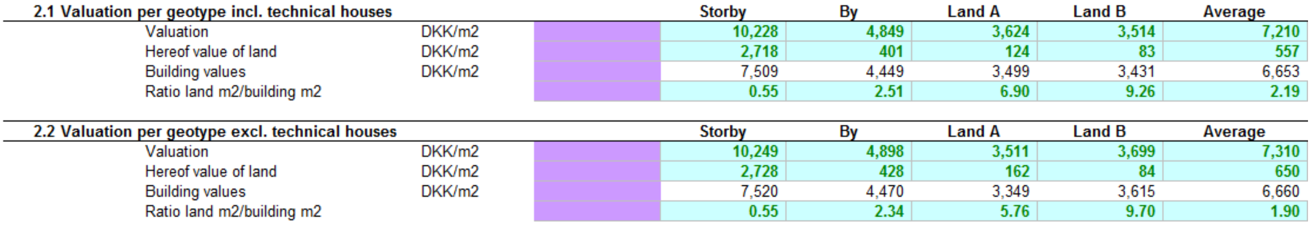
- Period 1: Obtained from the 2006 model for each municipality and averaged for new Landsdele.
- Period 2: Projected for each municipality based on 2005 average growth per Amt. The data were then averaged for the new Landsdele as for Period 1.

- Period 3: A correction factor was calculated by the same method as for the original analysis, using Landsdel-level data from Denmark Statistics.

To derive the final continuous correction factor for Q2 2004 – Q2 2008, the correction factors for the three periods were averaged, weighted by the number of quarters in each period. Finally, the new correction factor was applied to the TDC data to derive updated building values. This was done by applying the average Landsdel correction factor to each property located within the Landsdel, using an updated postcode lookup table obtained from the Danish Post Office.

The building values used in the revised Hybrid Model are shown in Table 3.9:

Table 3.9: Building Values by Geotype



2.1 Valuation per geotype incl. technical houses			**Storby**	**By**	**Land A**	**Land B**	**Average**
Valuation	DKK/m2		10,228	4,849	3,624	3,514	7,210
Hereof value of land	DKK/m2		2,718	401	124	83	557
Building values	DKK/m2		7,509	4,449	3,499	3,431	6,653
Ratio land m2/building m2			0.55	2.51	6.90	9.26	2.19

2.2 Valuation per geotype excl. technical houses			**Storby**	**By**	**Land A**	**Land B**	**Average**
Valuation	DKK/m2		10,249	4,898	3,511	3,699	7,310
Hereof value of land	DKK/m2		2,728	428	162	84	650
Building values	DKK/m2		7,520	4,470	3,349	3,615	6,660
Ratio land m2/building m2			0.55	2.34	5.76	9.70	1.90

4. Annualisation Assumptions

>

This chapter sets out to describe the assumptions and methods used for converting Gross Replacement Costs (GRCs) derived in the Hybrid Model to annual capital charges (annualised costs).

The major assumptions affecting the annualised costs are:

- Cost of Capital (CoC)
- Asset lives
- Price trends
- Output trends.

4.1 Annualisation methodologies

4.1.1 The FCM principle

The Financial Capital Maintenance (FCM) principle is used when the annualised costs for assets in the Hybrid Model are estimated.

The concern of FCM is to maintain the financial capital of the company. This maintenance is achieved when the value of shareholder funds is the same in real terms at the start and end of the period. Using the FCM method implies adding a holding gain or loss to the annualised cost when the price of the asset changes during the course of the year.

A number of annualisation methods may be used in combination with the FCM principle. These include:

- Straight line depreciation
- Standard annuity
- Tilted annuity
- Economic depreciation

The following sections give a brief outline of each method. To ensure maximum flexibility, the Hybrid Model allows users to apply any of these four annualisation methods to individual asset classes or to the model as a whole. The method preferred by NITA (the default setting in the model) complies with the principles set out in the MRP and is described in Section 4.2 below.

4.1.2 Straight line depreciation

Straight line depreciation is the method most commonly used in financial accounts. It simply spreads the original cost of an asset evenly across its economic lifetime, so that an asset costing 5000 would be recovered over 5 years by charging 1000 to depreciation each year. The method is popular because of its simplicity, but is criticised for not reflecting economic reality, as assets typically lose most of their value in the early years. It also ignores the cost of capital, which must be calculated separately.

4.1.3 Standard annuities

Annuity methods also spread the cost of an asset over its economic life, but in addition take account of the opportunity cost of capital, ie. the interest forgone which would have been earned had the cash been invested elsewhere. Therefore annuities consist of two separate elements: the annualised cost of the asset (depreciation), and a financing or cost of capital charge. In a standard annuity, the annual charge remains constant over the life of the asset. Again, the method has been criticised for failing to reflect the true depreciation profile of the asset and for assuming constant asset prices.

Standard annuity formula:

$$\text{Annuity} = \frac{\text{Purchase\_Price} * \text{WACC}}{1 - (1/(1+\text{WACC}))^{\text{Lifetime}}}$$

4.1.4 Tilted annuities

Tilted annuities relax the assumption of constant prices. In fixed networks, asset prices tend to fall over time, whereas infrastructure costs (digging trenches for example) tend to rise over time. If, for example, the annualisation method ignored falling prices, Entrant 2 would have an advantage over Entrant 1 as it would benefit from lower asset prices and consequently lower depreciation charges. When asset prices are falling, a tilted annuity recovers more of the capital value in the early years (and vice versa), which ensures that two entrants with an identical asset base, though acquired in different periods, have identical depreciation charges.

Tilted annuity formula:

$$\text{Annuity} = \frac{\text{Purchase\_Price} * (\text{WACC}-\text{Price\_Trend})}{1 - ((1+\text{Price\_Trend})/(1+\text{WACC}))^{\text{Lifetime}}}$$

A tilted annuity is consistent with the use of the FCM method. As with a standard annuity, the tilted annuity should still result in charges that, after discounting, recover the asset's purchase price and financing costs.

4.1.5 Economic depreciation

The main drawback of the tilted annuity method is that it ignores output trends. This is addressed by economic depreciation, the method which most closely reflects economic reality and is widely considered the theoretically correct annualisation method to use in LRAIC models. Economic depreciation is defined as the period-by-period change in the market value of an asset. The market value of an asset is equal to the present value of the net cashflows that the asset is expected to generate over the remainder of its useful life. As net cashflows vary with output, assets are depreciated at a rate consistent with use, resulting in a true depreciation profile.

As with tilted annuities, economic depreciation ensures that two entrants have the same depreciation charges, regardless of when their assets were acquired.

4.2 Annualisation methods used in the Hybrid Model

According to the legislation, NITA will set the prices using the LRAIC Hybrid Model for one year at a time.

During the first year in which the LRAIC prices were determined (2003), the Hybrid Model produced results based on information relevant for the year 2002. Prices for the following years were determined on updated versions of the model, reflecting any changes in equipment prices and volumes. This principle will also be used for the price estimation for 2010 and the years following, meaning that the prices for 2010 are based on data for the year 2009.

The costs are annualised in order to ensure that they are recovered over the economic lifetime of the asset. In previous versions, the Hybrid Model used a tilted annuity, which calculates the sum of depreciation and cost of capital. In version 2.5 of the Hybrid Model, users are able to select from a range of annualisation methods; however, the approach selected by NITA (and used as the default setting) is a still tilted annuities.

4.3 Calculation of economic depreciation

The annualisation method used in the Hybrid Model should be consistent with two principles:

> Each asset cost is fully recovered for over its own lifetime;

> An existing network operator is able to compete on an equal basis with a hypothetical new operator entering the market in a later year on equivalent terms.

In addition, annualisation methods should ideally reflect all of the following:

> An underlying price trend in the purchase price of the asset;

> An underlying output trend in the number of units of output produced per year;

> An underlying change in the reliability of the asset (and hence need for opex to maintain the asset).

Depending on different economic conditions, both tilted annuity and economic depreciation can meet these requirements and therefore the Hybrid Model can make use of both methods. The conditions identified by NITA as influencing the most appropriate method are:

- Whether output is constant, rising or falling;
- Whether asset costs are fixed or variable;
- Whether there is a price constraint, due to market conditions or regulation.

Different combinations of these conditions can warrant different methods of annualisation, as shown in the matrix below. Even when Economic Depreciation is selected as the default, in practice the default method used in the Hybrid Model is:

- Black boxes – Tilted annuity;
- Red boxes – Output adjusted tilted annuity (Economic depreciation).

			Asset purchase price	
			Fixed costs	**Variable costs**
Change in Output	**Increasing**	**No price constraint**	No advantage gained by later entrant as they still have to buy the same quantity of the asset over time since all costs are fixed (i.e. do not depend on output trends).	Change in output is not relevant as the extra assets purchased each year are fully utilised over their lifetime.
		Price constraint	If there are market and/or regulatory constraints on the product market price and output is increasing, then the depreciation charge should be increased over time to reflect the higher value of future cashflows generated by the asset. Another way of looking at this is that if the market price limits what can be charged for a product, then the company would tend to keep a static unit price over the years, which would equate to lower depreciation in the early years.	Change in output is not relevant as the extra assets purchased each year are fully utilised over their lifetime.
	Decreasing	**No price constraint**	No advantage gained by later entrant as they still have to buy the same quantity of the asset over time since all costs are fixed (i.e. do not depend on output trends).	Makes good business sense to accelerate depreciation as later entrant can price lower since does not need to buy as much asset (i.e. it is not constrained by previous decisions).
		Price constraint	If there are market and/or regulatory constraints on the product market price and output is falling, then the depreciation charge should be reduced over time to reflect the lower value of future cashflows generated by the asset. Another way of looking at this is that if the market price limits what can be charged, then the company would tend to keep a static unit price over the years, which would equate to higher depreciation in the early years.	Makes good business sense to accelerate depreciation as later entrant can price lower since does not need to buy as much asset (i.e. it is not constrained by previous decisions).

Economic depreciation may be modelled explicitly by forecasting capex, opex, asset prices and output year-on-year over the full economic lives of network assets, which for some assets (eg. trench, copper) may be 30 years or longer. Although a detailed 30-year forecast may look impressive, it relies heavily on assumptions relating to annual output volumes, price trends, asset replacement cycles and WACC rates, which become progressively more spurious the further into the future the model attempts to forecast. A simpler approach, which has been adopted in the Hybrid Model, is to adjust the tilted annuity formula so as to account for changes in output as follows:

$$\textbf{Annuity} = \frac{\textbf{Purchase\_Price * (WACC–Adjusted\_Price\_Trend)}}{\textbf{1 – ((1+Adjusted\_Price\_Trend)/(1+WACC))}^{\textbf{Lifetime}}}$$

where Adjusted Price_Trend = (1 + Output_Trend) * (1 + Price_Trend) - 1

Assuming constant price and output trends, this formula gives the same results as a detailed economic depreciation calculation. While the method is not able to model annual variations in output volumes, or asset prices that do not follow a single trend, such detailed and varied forecasts are unlikely to be accurate many years into the future and tend to add little value to the final result, particularly as applied to a one-year model. NITA therefore believes that the adjusted tilted annuity method can be used as a proxy for economic depreciation.

Operating Expenditure

The same output-adjusted tilted annuity formula can be applied to operating expenditure.As assets get older, they generally require more maintenance. As a result, the operating expenditure associated with network assets tends to increase over time. If we assume that a second operator enters the market with identical assets, and that these assets are annualised by tilted annuity or economic depreciation so that their depreciation charges equal those of an existing operator, then the second entrant would still be able to undercut the incumbent simply because it would benefit from newer assets and lower associated operating costs. This violates the modelling principle that both entrants should have the same efficient cost base, assuming identical assets.

To put both operators on an equal footing, the model makes the following assumption: Just as an operator would choose to depreciate its assets more heavily in the years before Operator 2 enters the market so that it has a lower cost base when competition arrives (the principle underlying tilted annuities), it might choose to bring forward some of the anticipated opex associated with ageing assets to guard against the threat of being undercut by a new entrant. If Operator 2 enters the market on the same basis, and smoothes its own opex to be prepared for future competition, then its cost base on entry will be the same as that of Operator 1.

This is modelled as follows:

> Assume that opex increases by a given percentage every year due to the underlying asset getting progressively less reliable;

> Find the NPV of the opex cashflows over the lifetime of the asset;

> Turn that NPV into a constant (ie non-tilted) annuity.

This results in equal annual opex charges over the lifetime of the asset. These theoretical cashflows can be then be modelled in the same way as capital expenditure and adjusted for output as appropriate.

4.4 The Cost of Capital

The cost of capital in the LRAIC Hybrid Model is based on the weighted average cost of capital (WACC) of an efficient Danish SMP provider.

A telecom company is financed both by equity and loan capital. Consequently, the total cost of capital is the average cost of utilising the two types of capital. The weighted average cost of capital comprises the company’s combined cost of equity and debt.

WACC before tax is calculated as:

$$WACC_{BEFORE\ TAXES} = R_E \bullet \frac{E}{E+D} + R_D \bullet \frac{D}{E+D}, \text{ where}$$

- E is equity
- D is loan capital (or debt)
- R_E is the return on equity
- R_D is the return on loan capital

The cost of capital used in version 2.5 of revised LRAIC Hybrid Model for both the core and access networks is 8.0%.

4.5 Asset lives

In the LRAIC Hybrid Model, the asset lives should reflect the economic asset life. This is the period in which the asset’s earnings exceed its costs. It is important to note that *the physical life* of the asset generally will be longer than the economic life. The column on the right hand side of Table 4.2 below depicts the asset lives used in the LRAIC Hybrid Model. As the estimates of the economic asset lifetimes are not integers, values have generally been rounded to the nearest number divisable by 5. This is, however, not the case for asset lives that are shorter than 10 years.

Table 4.2: Asset lives

Cost category	Hybrid Model
Access duct	40*
Access trench	40*
Copper cable	20
Access fibre	20
Cabinets, distribution points	15
NTPs	10
Line cards	5
Circuit boards, jointing	15
DSLAMs/MSANs	5
Layer 2 processors	5
Layer 3 processors	5
Peering routers	5
Media gateways	5
IMS controllers, servers	5
IN platform	5
MDF	15
International switch	10
DWDM transmission	5
Power supply unit, backup	15
Air conditioning unit	15
Security system	10
Security guard	0
Site preparation	10
Site maintenance	0
Core duct	40*
Core trench	40*
Core cable	20
Submarine cable	15
Technical house rack space	10
POI	10
Buildings, land	30
IT, cabling, and PCs	6

*Asset lives for trench and duct in soil is 20 years, as the cable is ploughed in the ground.

4.6 Price trends

Price trends used in the model should be forward-looking, indicating the expected future development in equipment prices as the trends have to be used to project the equipment prices in the model. Using the historic development in prices as a proxy may often be the best way to estimate future price changes. Such a methodology can only be used, however, if the past development is believed to continue in the future. In general, NITA believes that a historical period of no longer than five years is a good starting point for an assessment of the future price trends.

With regard to estimating the price trends which best reflect the expectations to the future price development, a combination of several sources has been used: The average price development of the contractors' list prices, price indices from Statistics Denmark, input from TDC and the LRAIC Working Group as well as international benchmarks, when relevant. In this respect, it has been a prerequisite that the development in list prices and documented sales prices, all other things being equal, is identical, whereby drops in prices or increases in prices have the same effect on both sets of prices.

It has been necessary in a few cases – when assessing price trends – to apply multiple cost drivers to the relevant price of equipment. In these instances, the price trend has been based on a weighted assessment of relevant and accessible cost drivers (e.g. hardware, software and wages).

The price trends used in the revised Hybrid Model, together with previous values for comparison where relevant, are shown in Table 4.3 below.

Table 4.3: Price trends

Cost category	Hybrid Model v2.5	Hybrid Model v2.4
Access duct	3%	3%
Access trench	3%	3%
Copper cable	6%	6%
Access fibre	-5%	-5%
Cabinets, distribution points	1%	1%
NTPs	0%	0%
Line cards	0%	-6%
Circuit boards, jointing	1%	1%-
DSLAMs/MSANs	0%	0%-
Layer 2 switches	0%	-7.5%
Layer 3 routers	0%	-
Peering routers	0%	-
Media gateways	0%	-
IMS controllers, servers	0%	-
IN platform	-8%	-8%
MDF	0%	0%
International switch	-6%	-6%
DWDM transmission	0%	-
Power supply unit	0%	0%
Backup power	-4%	-4%
Air conditioning unit	2%	2%
Security system	0%	0%
Security guard	0%	0%
Site preparation	0%	0%
Site maintenance	0%	0%
Core duct	3%	3%
Core trench	3%	3%
Core cable	-5%	-5%
Submarine cable	-8%	-8%
Technical house rack space	0%	0%
POI	0%	0%
Buildings	0%	0%
Land	4%	4%

4.6.1 Trench and duct in access and primary networks

Statistics Denmark regularly publishes an index concerning the regulation of tenders for earth and asphalt work. The view of NITA is that this index provides a good indicator for the price of digging trenches.

The official statistics for 2001-2005 show a positive price trend of between 3.1% and 3.6% for earth and asphalt work. Based on this, NITA used a price trend of 3% in the 2005 LRAIC hybrid model for trench in the access and primary network. This price trend was also used in the original version of the LRAIC Model and is supported by international benchmarks. For the 2009 version, updated statistics were obtained together with actual data from the LRAIC Working Group relating to digging costs, which have been taken into account in the revised Hybrid Model. On the basis of this analysis, NITA has updated the prices but kept the existing price trend of 3% for trench and for duct in both the primary and access networks.

4.6.2 Copper cables

The price of copper cables is to a large extent dependent on the price of raw copper. Table 4.4 shows the figures for the price development of copper from Statistics Denmark for the period 2001-2008. The information indicates that the price of copper has been fluctuating significantly in recent years.

Table 4.4: Changes in the Wholesale Index for Copper, Percent, Pro Annum

	Cobber and articles thereof	Imported raw cobber and semi-manufactured
2001	2.1%	6.3%
2002	-3.3%	-6.7%
2003	-3.1%	-5.2%
2004	4.9%	6.2%
2005	6.0%	8.9%
2006	20.0%	21.5%
2007	9.8%	8.3%
2008	-8.5%	-17.0%
Average 2005-2008	6.8%	5.4%
Average 2001-2008	3.5%	2.8%

Source: Statistics Denmark

Information from TDC indicates a price trend of approximately 2 to 15 percent. NITA has decided to leave the 6% price trend used in the previous model unchanged, as this reflects the average price development of copper from 2005-2008, although again the prices themselves have been updated.

In 2005, NITA commissioned a study into the pricing of raw copper, which supported NITA’s view that prices for raw copper should be based on forward-looking rather than historical costs. Forward-looking replacement costs will send correct signals about the real economic value of the network, ensuring stable pricing which is not dependent on the accounting principles chosen by the network owner. Correctly applied, forward-looking replacement costs, in the same way as historic costs, will also ensure full recovery of the original installation costs of the network, neither more nor less.

4.6.3 Storage and factory buildings and land

The price development for storage and factory buildings and land can be found in Table 4.5 below:

Table 4.5. Changes in the Index for Storage and Factory Buildings and Land, Per Annum

	Industrial buildings	Land
2001	3.6%	2.2%
2002	-4.4%	2.4%
2003	3.0%	1.4%
2004	-4.2%	6.6%
2005	7.4%	4.0%
2006	11.6%	9.7%
2007	15.1%	4.9%
2008 (Q1-Q3)	2.4%	6.4%
Average 2001-2008	4.3%	4.7%

Source: Statistics Denmark

The prices of storage and factory buildings have fluctuated considerably in the period of 2001 to 2008. The same development can be identified regarding the prices of land, albeit to a lesser extent.

Given the recent fall in property prices, which looks likely to continue for a number of years, NITA has decided to use a price trend of 0% for buildings. Land prices have been more stable, and therefore NITA has based its price trend on the average over the last 8 years, rounding down to 4%.

5. Additional Products Added in 2006

>

5.1 Introduction

In 2006 NITA extended the scope of the existing LRAIC model to facilitate the determination of interconnection prices for bitstream access (BSA), which is the description used within Denmark for the resale of xDSL connection via TDC's network. Certain aspects of the equipment and physical telecommunications network required for the production of BSA had already been modelled in the previous LRAIC model. This was primarily the case for raw copper and exchange buildings. However, certain equipment related specifically to the production of BSA needed to be added in.

Following discussions with NITA, it was initially agreed that three separate BSA products would be specifically modelled: BSA at the Street Cabinet, BSA at the Layer 2 Ethernet switch location, and BSA at the Layer 3 IP router location. It was not required for the model to include a cost estimate for BSA National Access, or indeed retail xDSL services, except in so far as it would be necessary to include them for the purposes of sharing of common network elements such as DSLAMs.

In addition to expanding the model to include BSA products, NITA required that the LRAIC model should also be upgraded to cover sub-loops of raw copper. Following discussions with NITA and the parties at the outset of the project, it was agreed that a sub-loop would be defined as the copper pair connection between the Primary Distribution Point (PDP) and the Network Termination Point (NTP).

5.2 Impact on access and core models

In version 2.3 of the model, the access network was essentially modelled in two ways: the trench and ducts were modelled on a national basis, whereas the cable was modelled on the basis of 20 sample areas. In both cases the emphasis was on calculating the total cost of connections between the ASM (local/remote concentrator) and the NTP (subscriber network termination point).

For version 2.4, the major change implemented with respect to the modelled access network was to analyse the required trench and duct also on the basis of the same 20 sample areas as used for the cable, in order to split the corresponding equipment requirements into two parts, the primary network (from the ASM/TH to the PDP) and the secondary network (from the PDP to the NTP). Care was taken to ensure that the resultant “national” totals were consistent with those previously calculated.

In the Core part of version 2.3 of the model, the network was analysed separately for nodes (switch locations), switching, and transmission (covering both the active transmission equipment and the core trench and duct network). The emphasis was very much placed on the costs of standard voice products and services. Data services, leased lines and other services were essentially only considered in sufficient depth to allow for a suitable allocation of common and shared costs (such as core trench and duct for example).

For version 2.4, the major change implemented with respect to the modelled core network was the addition of the data equipment required for BSA products and services up to, but not including, the Layer 3 (and above) rings. Thus specific equipment was added to the model (DSLAMs and Layer 2 Ethernet switches) and additional analysis sections added to cater for the transport network (i.e. trenches, ducts and cables) to interconnect this equipment.

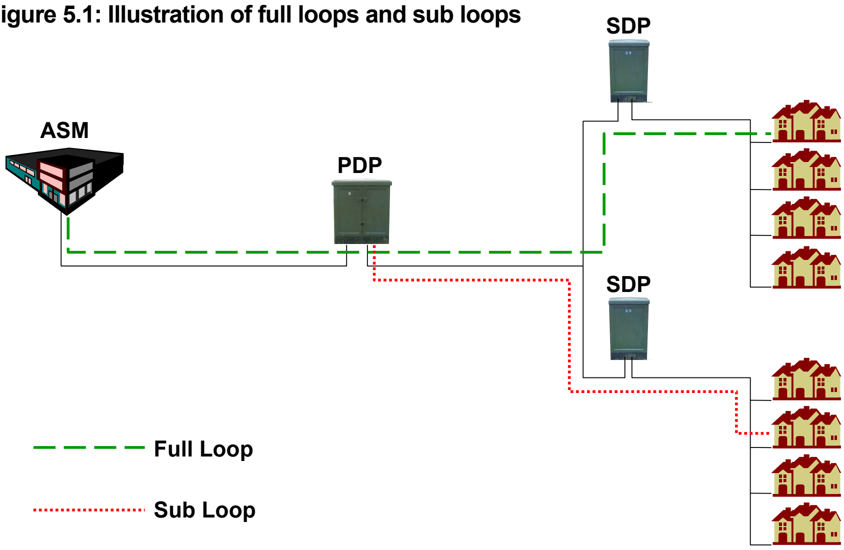
The following sections provide a more detailed overview of the model modifications relating to the introduction of sub-loops and BSA products and services.

5.3 Sub-loops

Sub-loop unbundling involves the interconnection of an alternative operator's (OAO's) network with the local loop infrastructure of TDC at a point somewhere between the ASM (Local/Remote Concentrator) and the end user's NTP (Network Termination Point).

The most likely reason that an OAO would wish to unbundle a sub-loop, rather than the full loops available at the ASM, is to significantly shorten the overall copper loop distance. This will then allow the OAO to offer much higher speed xDSL services to their subscribers than might otherwise be feasible over longer full loops. Indeed, this is also the reason that TDC is currently deploying DSLAMs in various Street Cabinets around the country, as they have a declared intention to be able to offer very high speed aDSL services to a large proportion of the country within the next few years.

Figure 5.1: Illustration of full loops and sub loops



In theory, the interconnection point could be at any junction point in the local loop cabling. However, in practice it is likely that the interconnection will take place at the larger street cabinets, since the smaller street cabinets are unlikely to provide sufficient numbers of subscribers to make the unbundling worthwhile to the OAO. Following discussions with NITA, it was agreed to consider that a sub-loop would run between the PDP (Primary Distribution Point) and the end user's NTP. In particular, it was also agreed that the definition of what constituted a PDP would be based on the existing LRAIC model, and furthermore that every PDP within the model would be considered a potential sub-loop unbundling point.

The latter agreement was deemed necessary to remove any reliance on TDC's own Street Cabinet DSLAM deployment programme, particularly as there was no available source within TDC of which street cabinets would be upgraded and, in any event, these locations would most likely not match those included within the LRAIC model since the latter took a Bottom Up approach to their location.

Version 2.3 of the LRAIC model modelled full local loops in two distinct parts: trench/duct and cabling. The trench and duct required was calculated on a national basis using a database of the Danish road system. The cabling requirements were calculated on the basis of an analysis of 20 sample areas; these were then aggregated to a national equivalent using a series of weights. The method of calculating the cabling made it relatively straight-forward to estimate the cabling costs of sub-loops since the analysis separately considered ASM-PDP links from PDP-SDP and SDP-NTP links.

For the trenching, it was concluded that it would be necessary to assess the amount of trenching required for each of the 20 sample areas contained within the existing model in order to then more easily distinguish between ASM-PDP trenching and PDP-NTP trenching. This involved adding a separate worksheet to the Access model that, instead of starting with an analysis of the road system by geotype, contained an analysis by sample area. A similar process was then followed to that contained within the existing *[C_Trench and Duct]* worksheet to arrive at tables detailing the required amount of trench and ducting, and in addition distinguishing between primary (ASM-PDP) and secondary network (PDP-NTP).

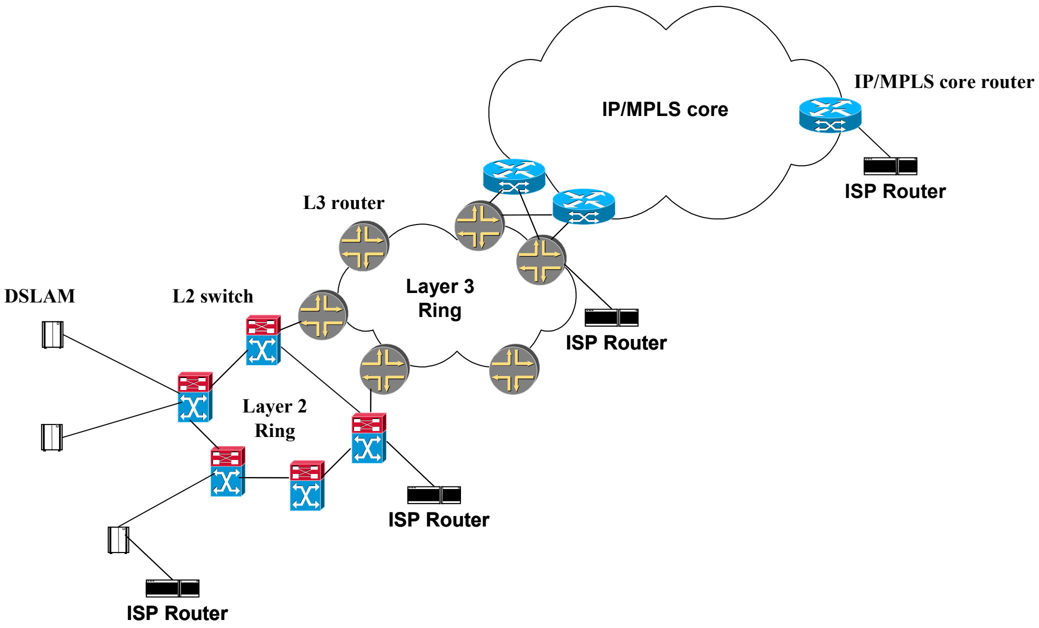
In recognition of the fact that the 20 sample areas were unlikely to yield the previously calculated national totals for trench and duct (the weights were originally designed to match a different set of national figures), the additional worksheet normalised the sample by sample analysis such that identical total amounts were calculated when the sample weights were applied.

5.4 Bitstream Access

Bitstream Access is the term used in Denmark to refer to the products purchased by OAOs that they can then use, in conjunction with their own network infrastructure, to provide retail xDSL services in competition with TDC. Various forms of BSA are possible, depending on the level of interconnection in TDC's network.

TDC's network originally used ATM-based DSLAMs with OAOs connecting either at a national level (utilising TDC's ATM network for backhaul from the DSLAMs to the single point of interconnect), or at a regional level (at the first ATM node). As of the end of 2005, less than 1 per cent of BSA-based end users were routed to the OAOs at the ATM node. In 2006 TDC embarked on a programme of deploying DSLAMs deeper into the access network than at the ASM level and announced plans to move around 1,500 DSLAMs into Street Cabinets within the next few years, although the actual number in place at the end of 2008 was much less than this. The DSLAMs used for this programme are modern, Ethernet-based ones and TDC also expects over time that the existing ATM-based ones will also be upgraded or replaced by this current technology, although the precise timeframe for this is known.

Figure 5.2: Schematic illustration of Ethernet-based xDSL network

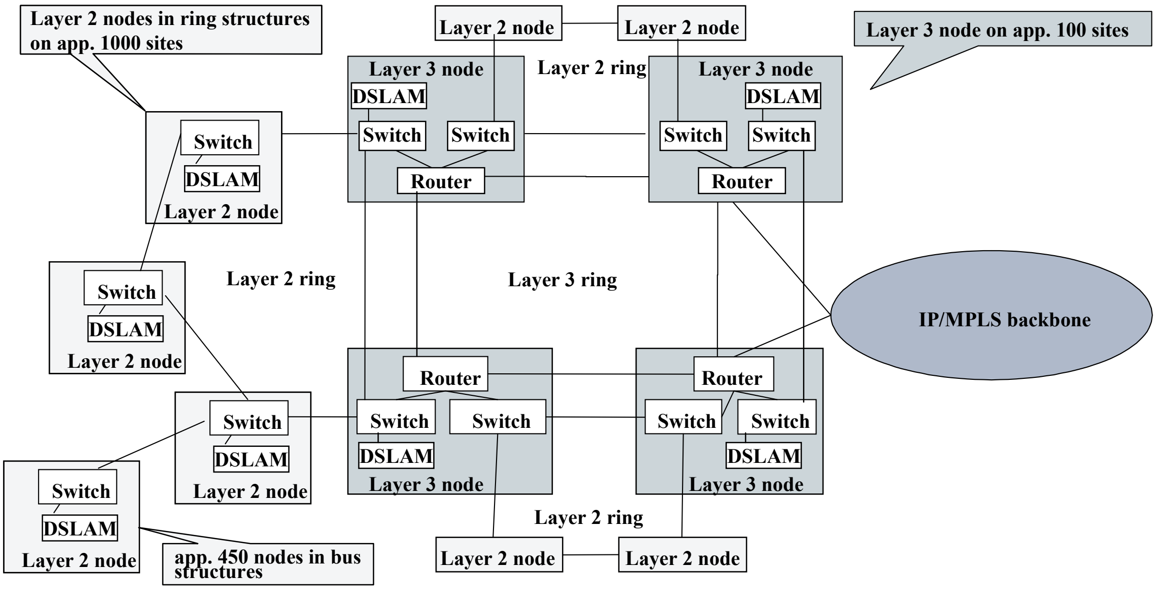


The network structure relevant to the Ethernet-based DSLAMs consists of a number of levels. At the lowest level, one or more DSLAMs are connected to Layer 2 Ethernet switches. These switches are capable of the vlan tagging necessary (a) to allow different data streams to have different priorities over the network, and (b) to allow multiple OAOs to gather traffic from their own end users connected to the DSLAMs covered by that switch.

At the next level, a number of Layer 2 Ethernet switches in a geographic area are connected in a ring to a Layer 3 IP router. If an OAO connects at the location of this Layer 3 router, then it would have access to all DSLAMs covered by that router. The routers are then connected together in higher level regional rings to IP/MPLS core routers. The highest level of the network consists of the interconnection of these MPLS routers.

OAOs are of the opinion that modern Ethernet-based DSLAMs could support direct connections from multiple operators. TDC has accepted that this might be the case in theory (although they contend that the maximum number would be limited), but believe that for overall operational reasons interconnection should be achieved via a Layer 2 switch.

Figure 5.3: Functional block overview of Ethernet-based xDSL network



In the 2006 model revision, it was assumed that OAOs would connect via a Layer 2 switch. Following discussions with NITA, it was agreed that three specific BSA products would be addressed, all of which would assume Ethernet-based backhaul:

> BSA at the Street Cabinet

> BSA at the Layer 2 Ethernet switch location (approximately 1000 sites on the Layer 2 rings, with around a further 450 sites feeding off on of those ring locations)

> BSA at the Layer 3 IP Router location (approximately 100 sites on the Layer 3 rings).

The network modelled is essentially that which would exist following the completion of the Street Cabinet upgrade programme. Additional inputs were thus added into the model to allow the user to define, among others:

> The proportion of xDSL lines fed by Street Cabinet-based DSLAMs

> The number of Street Cabinets having DSLAMs

> The number of ASM/Technical House locations on Layer 2 rings

> The number of Street Cabinets also populated with smaller Layer 2 Ethernet switches.

5.5 Ancillary products

In addition to the principal products (exclusive and shared sub-loops, and BSA), a number of ancillary products were also included in the 2006 model:

> Ancillary products relating to sub-loop installations (installation, request, new set-up, physical rearrangement, change of trunk number, technical assistance)

> Ancillary products relating to BSA (new installation unassisted and engineer assisted, reactivation unassisted and engineer assisted, additional fee for installation without co-production, conversion to BSA without co-production, new NTP for BSA)

> Products relating to co-location within a technical house (one-off and recurring fees for 1/5th rack space, installation and recurring fees for 48V power for same).

For BSA new installation and re-activation, NITA decided that the costs related to the DSLAM (including the line card) should not be allocated to installation but recovered via the recurring fee. Thus the costs included in these products are limited to end-user specific administrative tasks and to time charges for an engineer visit, where appropriate.

6. Product Changes in 2009

>

6.1 Introduction

The 2009 release of the Hybrid Model contains a lot of changes, most fundamental of which has been the decision to base the core network on an all-IP network structure. This in turn led to a need for the demand associated with additional products to flow through the model to the output sheets in the consolidation model. Since this greatly increased the number of products addressed, NITA decided to have two ”output” sheets. The first of these, O_Output, would contain data related to all products modelled, whereas the second, O_Results, would only contain data related to regulated products and services. The changes made are summarised in the following sections.

6.2 Main LRAIC service costs

O_Output

Core Services now covers all voice related products, including those connecting to traditional customers and those connecting to customers utilising TDC’s VoIP service.

Additional products have been added to Colocation Costs. These encompass additional power variants.

Access Services now covers all access related products. These also show prices broken down by geotype.

Bitstream Access has been extended to include BSA National Access and also to show prices broken down by geotype.

Additional sections have been added to cater for Bitstream Transport, IPTV and VoD and costs allocated to residual non-PSTN products.

O_Results

Core Services now only includes Local Interconnect, since higher level interconnect is no longer price regulated.

Additional products have been added to Colocation Costs. These encompass additional power variants.

6.3 Other LRAIC service costs

O_Output

Additional products have been added to Full Loops and Sub Loops to cater for a number of additional activities such as unproductive visits and fault handling.

Additional products have been added to BSA to cater for a number of additional activities such as conversions, migrations and changes of speed.

Additional products have been added to Other to cater for preselection related activities.

O_Results

Additional products have been added to Full Loops and Sub Loops to cater for a number of additional activities such as unproductive visits and fault handling.

Additional products have been added to BSA to cater for a number of additional activities such as conversions, migrations and changes of speed.

Additional products have been added to Other to cater for preselection related activities.

6.4 Co-location services

O_Output

Additional products have been added to to cater for a multiplexing and power products.

O_Results

Additional products have been added to to cater for a multiplexing and power products.

7. How to Use the Revised Hybrid Model

>

7.1 Introduction

The purpose of this chapter is to provide some guidelines on how to use the LRAIC Hybrid Model.

Before using the four Excel workbooks that make up the Hybrid Model, a user should understand the purpose of each workbook and should have at least a high level understanding of the structure and interdependencies of the different models. Note that a user need not have detailed Excel skills, but a basic knowledge is expected. If the intention is to modify the models or to investigate the algorithms used, then some advanced Excel skills may be required to understand the details of how data is processed.

7.1.1 Description of model package

The models have been developed using a standard software package, Microsoft® Excel. However, total functionality cannot be guaranteed for users with a version older than Microsoft® Excel 2003.

7.1.2 Quick start and how to find main results

All results are in the consolidation model. It is not necessary to have the other models open to *see* the results. When opening the consolidation model, Excel will offer the choice of updating links. If the model is opened for the first time, this is not necessary. Links should be updated, however, if changes have been made to the other models. If you update links from the consolidation model, then the other model files must be available in the same directory.

When the model is opened, a standard precautionary message may appear, containing a warning on the presence of macros in the model. If this is the case and if the file is from a trusted source, users should click on the button “Enable Macros”, otherwise the macros that support the model will be disabled and the model will not work properly.

Running the consolidation model opens a Control Sheet. This allows the user to select the model language – English or Danish – by clicking on the country flag. The settings will automatically feed through to all other models. It should be noted, however, that some recent additions to the Hybrid Model are available in English only.

In order to find service costs the user should click on the *Show Results* box. The *O_Results* sheet provides a quick overview of final unit costs for each regulated service, reproduced from the *O_Output* worksheet.

7.2 Overview of common model features

The models are Excel workbooks. Each Excel file has the following logical structure:

> Descriptive/ navigation sheets.

> Input worksheets

- Calculation sheets
- Output sheets

The name of each input, calculation, or output sheet is prefixed "I_", "C_", or "O_" respectively to indicate its primary status. They also use different coloured tabs – yellow for inputs, dark grey for calculations and blue for output (pink for “output to consolidation” sheets). Light grey tabs indicate descriptive or navigation sheets.

There are some overlaps between sheet functionality. These have been introduced to ease both use and development, since they help to avoid a proliferation of worksheets. Thus, some calculations may be done in input sheets and there may be some inputs in the calculations sheets. The separation of sheet types is therefore only a guiding principle. However, the overlaps between sheet functionality have been kept to a minimum.

This divisional approach to modelling promotes transparency in the calculations since any inputs are shown separately, avoiding any hard-coding of data within formulae.

Each model has a number of standard management sheets:

- *Workbook map* or *control sheet.* This is the normal starting point for users. Workbook maps contain a diagram showing the main sheets within the workbook and the main flows of information between the sheets. Clicking on any of the boxes in the diagram enables the user to move to the relevant sheet. This allows easy model navigation.
- *Version history.* This records the model versions and any changes carried out. Users are strongly recommended to use this and to introduce a version control procedure so that different versions are controlled.
- *Colour codes.* This contains the Excel styles and colour coding used throughout the model. It can also be used for descriptive information.
- *Changes.* This provides a summary of what changes have occurred between the various versions published by NITA. In addition, cells in column A of individual worksheets may be colour-coded to highlight recent changes.
- All sheets have a macro link (labelled "Model Overview") to link back to the model map or control sheet. This eases navigation. The normal Excel navigation tabs can still be used. A drop-down menu takes the user to individual tables within each worksheet.

The models all have the same Excel Styles and colour coding. This ensures that the cells are easily identified. The Styles used are shown in the diagram below.

Figure 7.1 Styles used in the models

Style	Can the user edit it?	Meaning	Looks like:
Option	Yes	Options that will affect results	**Bold Green text / pale green background**
Input data	Yes	Data that (generally) affects results	**Bold Green text / pale yellow background**
Input data	Yes	Input data that is a results of off line analysis or data where care must be taken when making changes	**Bold Green text / pale green/blue background**
User notes	Yes	Comments about the data. No direct impact on results.	Green text / lilac background
Header at start of table	no	Shows the structure of the calculations.	**Bold Blue text / pale grey background**
Sub-header of table	no	Shows the structure of the calculations.	**Bold Black text / clear background**
Header of sub-table	no	Shows the structure of the calculations.	*Italic black text / white background*
Calculations	no	Calculations, that (generally) affect results	Black text / clear background
Developer notes	no	Design / build issues.	**Bold Purple text / clear background**
Warnings / Error messages	no, just take note	Warnings and errors. 'Error' means it needs fixing.	**>>> Bold red text / clear background**
Cells that link to (ie use) External data	no	Calculation cells that refer to other workbooks.	**Bold Grey text / tan background**
Camouflaged data	Yes	Camouflaged for confidentiality reasons	**Bold White text / blue background**

These styles can be summarised as follows:

> *Input data.* Yellow boxes indicate an input. The user may enter a value or occasionally enter a hard coded formula to create the value required – this is not recommended, but it can be useful.

> *User notes.* Lilac shading indicates important notes or the source of the data. Changing these cells will have no effect on results. These cells generally describe neighbouring cells.

> *Input parameter.* Pale blue boxes indicate that the values could be changed but require thought before doing so. This is because changes will alter the meaning of other data, or because the values are key parameters that affect a considerable part of the model calculations. The inexperienced user should generally leave these unchanged, or at least check the consequences (e.g. using the Excel Audit tools) before making a change.

> *Header at start of table.* Each worksheet has areas ("tables") that relate to a type of calculation or processing of data. These areas are separated from each other by a header row – blue text on a pale grey background.

- *Calculations, Developer notes, Warnings/Error messages*. Unfilled (white) cells are used for working or for text comments that describe a neighbouring cell. These should not be altered unless you are developing the model.

- *Bold red text (or cells shaded pale red*) indicates warning messages; some data has not passed a sense check, or some calculations have given results that do not appear to be correct. The error message will indicate the nature of the problem, but it is left to the user to resolve the problem.

- *Cells that link to external data.* Tan coloured areas indicate linked data from another workbook.

- *Confidential input data*. Bright blue indicates a confidential input. The user may enter a value or occasionally enter a hard coded formula to create the value required – this is not recommended, but it can be useful. Values in these cells have been camouflaged for reasons of confidentiality.

- *Single cell array calculations*. These are often accompanied by a warning message. The inexperienced user should particularly avoid editing these cells, as single cell array calculations can get corrupted by being edited, even if the user does not change the formula. (These array calculations are used to perform larger calculations whilst keeping the size of the model manageable). Refer to the Excel on-line help for more information on array calculations.

Excel Comments and some floating text boxes have been used to expand on the user notes. Some are in colour simply to highlight the information more clearly. Comments fields also supply information about specific data or formulae used. The comments and explanations within the model are a vital part of the model, since they aid the user in understanding the model. Hence the model can only be fully understood by additional reference to the Excel Comments and by reading comments fields.

Use of the auditing toolbar functions is highly recommended to understand the model workings. Due to the complexity of the Hybrid Model, it is not possible to provide details of all functions in the documentation – there are far too many cells to consider.

Each sheet is divided into a series of Tables numbered 1, 2, 3, etc, one below the other. Some of these Tables are divided further into sub-tables e.g.: 3.1, 3.2, etc. This means that some worksheets can have many functions and many rows, but the functional areas are still clearly delineated. Generally, data will flow from left to right and top to bottom within a worksheet. Drop-down menus at the top of most worksheets enable the user to navigate easily through the different tables.

7.3 How the models are linked

The consolidation model has links from all of the other three models. The other three models also have links between them to enable data to flow automatically between the models. Each of the three source models (Access, Core and Co-location) has an interface sheet, *I_Interface*, showing inputs from other models in tan colour coding, together with a note indicating the original source of the input. This allows users to locate the original (yellow-coded) input cell, which can be modified if required.

Wherever practical, data that flows into these three source models from another model does so via the *I_Interface* worksheet.

7.3.1 Important actions

We strongly advise that all four model files should be kept in a single folder and that other files within that folder be kept to a minimum.

The user should track any changes to the model and utilise version control as appropriate. As a minimum it is recommended that the user keep a master copy of the original models so they are always available in case changes are made that cannot be corrected or if the files are accidentally deleted.

The user should make full use of the facilities within Excel for exploring the workings of the models. In particular, the Audit toolbar is helpful in tracking the logical flow of data and dependencies.

The user should avoid using “drag and drop” to move input data, since this corrupts the flow of data in the models.

Other than that, changing the input values has no damaging effect on the workings of the model. However, changes to the data can make the results misleading or incorrect. Entering inappropriate values, e.g. text in place of numbers, can also cause errors in the calculations, giving #VALUE! and #DIV/0! errors. Some traps have been built into formulae to cope with such events, but it is not practical to cover all eventualities.

Altering formulae is more serious and should only be done with care and after due study. We would also strongly recommend making a full backup of the models prior to changing the formulae, just in case. Particular care should be taken when changing array formulae (including single cell array formulae).

Adding new features or processing can be simple or complicated, depending on the scope. The developer must understand the model and the Excel formulae. Changing the names of named arrays, named cells or the name of a worksheet is highly likely to give errors, especially to data links between the models. Since the models include a number of macros written in Visual Basic for Applications, users should not change any sheet names, as this will cause the macros to malfunction. Many calculations use lookup formulae based on data labels and headings in another data sheet. These should only be amended, therefore, after careful investigation of the consequences.

Please note that if a file name is changed (which is allowed, and indeed this is recommended if there are changes as part of version control policy), then Excel links in another model must be updated (since the other model will still link to the previous version). If two models are open simultaneously, then saving one to a new file name will result in the links automatically moving to the saved file. It is recommended, therefore, that all models should be open while files are saved under a new name. In addition, all files should be individually saved prior to closing down Excel. This will ensure that any links between files refer the most recent model version.

8. The Access Model

This section sets out to describe the methodology and assumptions behind the access model and describes the changes that have been made in the revised Hybrid Model to reflect the increasing importance of sub-loops and DSLAMs at the street cabinet resulting from the transition to Next Generation Access (NGA).

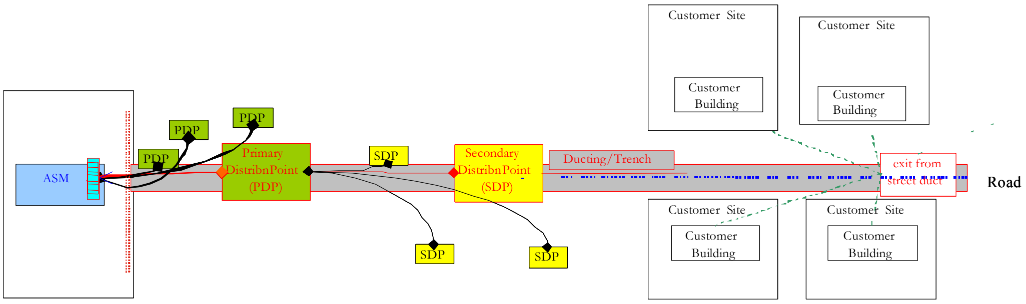
8.1 The Access Network in Denmark

The access network connects the end user with central equipment in the core network. Subsequently, the related costs primarily depend on the number of subscribers, and less so on the volume of traffic. Consistent with this, access can alternatively be defined as those services which allow the subscriber to send and receive traffic.

Both definitions suggest that the access network includes all costs for cable and trenching associated with subscriber lines between the customer premises and the concentrator. These definitions also suggest that the access network includes analogous costs for other lines, such as those for public call boxes between the customer premises and the concentrator. Furthermore, the definitions suggest that the access network includes the line card within the concentrator/DSLAM and potentially other subscriber related costs. This is consistent with the first definition, 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 definition since the line card is essential to sending and receiving traffic. However, for ease of modelling, line cards have been included in the core model rather than the access model. The costs associated with these items are then allocated to the relevant access products in the consolidation model. In this sense, it is important to realise that the access network is not the same as the access *increment*.

A schematic representation of TDC's access network is provided in Figure 8.1 below.

Figure 8.1: Schematic outline of Local Access Network



Assets within the access network include:

> the final drop wire to the customer's premises (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 concentrator/DSLAM;

> 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 concentrators/DSLAMs.

8.2 Overview of the Hybrid Access Model

8.2.1 General Approach

NITA's preferred approach to modelling access is described in the bottom-up MRP and has been used in the hybrid model. The preferred approach involves the following stages:

- selecting a sample of exchange areas from each geotype;
- setting the boundary for each of these exchange areas on the basis of the boundary in the SMP operator's own network;
- on the basis of detailed maps, determining the optimal layout of a network, given the known number of subscribers for that exchange area, the dwelling and street pattern;
- aggregating up to estimate costs for the geotype as a whole and in turn for Denmark (e.g. if the proportion of subscribers examined in a particular geotype is 10%, costs are multiplied by 10).

The hybrid model relies on geographical data provided by GIS databases. The model calculates the distance of the "primary access network", i.e. the part of the subscriber line that runs from the exchange to the primary distribution point (generally a street cabinet), and distance of the "secondary access network", i.e. the part of the subscriber line that runs from the primary distribution point to the final drop to the customer's premises.

Information is needed for each of these distances separately (a) to facilitate the costing of sub-loops, and (b) because the dimensioning rules for these different parts of the access network will differ. For example, the slow and erratic growth on the secondary access network makes it much more difficult to dimension than at the aggregated primary access network. For this reason, provision of secondary access network capacity will usually be more generous than the primary access network.

Finally, information is also provided on the length of the final drop to the subscriber premises.

8.2.2 Sub-Loops

In 2006, the Hybrid model was extended to include the modelling of sub-loops within the Access network, as described in Chapter 5 above. NITA is conscious that moves towards the incorporation of next generation access (NGA) technologies and techniques are likely to fuel demand for such sub-loops. One possible consequence of this might be that the currently defined point of access (a nationally averaged primary distribution point, or PDP) might not necessarily continue to be best representative of where alternate operators actually require access.

The impact of a move towards Next Generation Access on the existing model could occur in a number of ways, in particular:

> A potential need to geographically de-average the PDP locations fed by fibre

> A potential need to model access backhaul services such as lit/dark fibre or ducts from the PDP back to the exchange or technical house

> A potential need to model full fibre local loops.

The model now allows the user to specify the number of PDP locations fed by fibre (referred to in the model as Active Street Cabinets) for each of the four geotypes. This geotype disaggregation is fed all the way through to the output sheet of the consolidation model, producing cost-based prices for sub-loops by geotype in addition to the national weighted output.

NITA has taken note of the LRAIC Working Group's desire for regulated access to backhaul bandwidth and in particular for its inclusion within the next revision of the Hybrid model. NITA has initiated a formal analysis of the markets for both unbundled access and broadband connections in accordance with the EU Commission's new recommendations on Markets 4 and 5. The revised model therefore has been adapted to help anticipate potential regulated access backhaul products and add the necessary functionality to allow for the calculation of cost-based prices, should that prove necessary.

8.2.3 Key network elements

The main purpose of the access model is to calculate the cost of raw copper access, defined as access to the copper line stretching from the Main Distribution Frame (MDF) to the customer premises. The access model itself does not calculate access network costs (essentially customer facing line cards) at the DSLAM/MSAN site or the MDFs at those sites (these are calculated within the core model).

The main components of the access model are:

> Trench, Duct, and Poles used by the access network

> Copper cables

> Fibre cables

> Passive street cabinets and distribution points.

> Final-drop miniduct (duct to subscriber building from street), associated digging works, and Network Termination Points (NTPs).

> Active street cabinets (but not the equipment inside them)

> Backhaul trench, duct and cable (copper and fibre) from the active street cabinet sites to the "exchange" building.

After calculating the resources needed to build this part of the network, the model uses the results to calculate the capital cost of those resources, and the event-driven annual operating cost of such a network.

The methodology used to work out the equipment requirements is summarised in the table below and explained in further detail in the following sections.

Table 8.1: Summary of methodology used to estimate major network elements in access

Network element	Summary of methodology
Trench and duct	The main methodological assumption that has been adopted in the bottom-up model in order to model trench requirements in the access network is that trenches in Denmark have a direct relationship with road paths. The DAV database has been used to classify all roads in Denmark in the sixteen road categories created and in the four given geotypes. For each of the sixteen types of road, a factor (ranging from 0.4 to 1.8) has been assumed to convert road length into trench length. These are referred to as “conversion factors”.
Copper	The methodology adopted to work out copper requirements is quite complex and relies on the results of a dimensioning exercise performed on a sample of twenty MDF areas (hereafter called sample) selected by the LRAIC Forum among TDC’s 1,183 exchange areas in 2002. The copper requirements for the whole network are worked out through the means of the weights attributed to each zone. The 20 sample zones are used to calculate the total amount of copper cable necessary to connect all of the actual and prospective customer sites available. These totals are then adjusted downwards via scaling factors to take account of the actual number of customers connected.
Cabinets	The number and the size of modelled SDP and PDP cabinets depends on the number and the size of the modelled SDPs and PDPs for each of the twenty sample zones (again, the requirements for the whole network are worked out through the means of the weights attributed to each zone). The number of modelled SDPs per zone is worked out as the ratio between number of subscriber lines served in each zone and connected copper pairs per SDP, an input of the model. The number of modelled PDP per zone is an input of the model. The model now also includes the facility to model active street cabinets (located at PDP sites) by geotype. Note that where active street cabinets are assumed to occur, then care needs to be taken in deciding the average number of subscriber lines covered by each cabinet location, since too small a number will result in a location with insufficient subscribers to warrant an upgrade and too large a number will negate the improvements of shortening the copper loop length. In general, a suitable number of potential customers per active street cabinet is considered to be around 500.
Fibre	The modelled amount of fibre used to connect business customers has been derived by modifying the existing fibre requirements, using MEA-adjustments. Additional fibre is included to connect the exchange locations to the acive street cabinets. Subscribers connected through copper are assumed to continue to be supplied by copper unless the NGA Selector is switched on, in which case the model provides an illustration of the costs for a full fibre network.
NTPs	Network Termination Points have been modelled on the basis of the existing number of lines served in the network.
Line cards	Line cards have been modelled on the basis of the existing number of lines served in the network.

8.3 Main definitions and assumptions in Access

The Main Distribution Framework (MDF) areas in the access model, are allocated to one of four categories, called *geotypes*, according to their tele-density:

- City ("Storby") – more than 1000 lines per km2
- Urban ("By") – 100 to 1000 lines per km2
- Rural A ("Land A") – 10 to 100 lines per km2
- Rural B ("Land B") – less than 10 lines per km2.

The optimal design of the network, and the mix of costs incurred, will be quite different in each of these types of area. It will also vary, although to a lesser degree, within a geotype, since two zones of the same geotype can still have very different tele-densities.

Although the Hybrid Model currently calculates geographically averaged results, the revised model also shows geographically de-averaged costs for the four geotype categories. This facilitates analysis of geographical de-averaging in order to inform future pricing decisions.

The main assumptions in the access model are as follows:

- In general, subscribers are connected to the same ASM site as at present.
- Sharing of trench and/or duct is allowed: with the core network, with other TDC increments (such as its cable TV network) and with other cable TV networks and utilities.
- There is no sharing of copper cable with the core network, with other TDC increments or other utilities.

In addition, the access model includes technical houses, which are also found in TDC’s network. The purpose of these technical houses is to reduce the loop lengths for the relatively small number of subscribers connected to these houses. In that sense, they are similar in concept to the active street cabinets, although they are not modelled as such.

8.4 Modelling the access network

8.4.1 Trench and duct

The network of trenches and ducts is assumed to follow the road network. The primary input data is therefore a breakdown of the national road network. This is done by road type and by geotype.

The classification by road type refers to sixteen categories of road, which are defined according to the number of addresses found on each side of the road, per kilometer of road distance, as follows:

- A: More than 40 sites on one side of the road per km
- B: From 11 to 40 sites on one side of the road per km
- C: From 1 to 10 sites on one side of the road per km
- D: No sites on one side of the road.

In the hybrid model, 16 different types of roads are classified, as a combination of the density on both sides of the road (AA, AB etc.), i.e. according to the same classes of number of households per kilometer on either side of the road. When reclassifying road lengths, the number of households on either side of the entire road (rather than the number of households on each segment of the road) is weighted against the length of the entire road (rather than the length of each segment). In order to do this, NITA has used the databases from DAV and the totals have been updated, applying information from Statistics Denmark. The length of each road segment was estimated using the MapInfo software in 2002.

The following table shows the allocation of streets by the sixteen different categories (the classification by geotype is not shown here, for the sake of simplicity).

Table 8.2 Total number of road kilometres

Road type	Hybrid model
AA	3,193
AB/BA	5,013
AC/CA	468
AD/DA	366
BB	17,424
BC/CB	7,831
BD/DB	903
CC	63,755
CD/DC	5,553
DD	8,202
Total	**112,708**

8.4.1.1 Conversion factors

The hybrid model estimates most of the conversion factors through an analysis of TDC “INCA” maps. Through these maps, NITA looked at the amount of trench in place in TDC’s network for a sample of roads that would try to mirror the different road classes previously identified (i.e. AA, AB etc).

In many cases, the actual network was used to set the conversion factor. However, in some areas — particularly those with very few sites — an adjustment was made to reduce the amount of trench in the network where trench was considered to be excessive for the area served.

Moreover, when the analysis was carried out, it was not always possible to extract, from the available maps, a meaningful sample of roads for each of the 10 classes of road.[2] Regarding those classes for which it has been considered that the available information was not sufficient to estimate the conversion factors, an econometric analysis has been applied instead. This was undertaken by estimating the remaining conversion factors and the associated weights for the A, B, C and D segments. The conversion factor for the CD/CD segment consists thus of the weighted average of A and B with the value of 0 and C and D with the value 1. The estimated conversion factors are thus adjusted to the directly measured conversion factors.

Concerns were also raised, during the original reconciliation phase, with respect to the treatment of so-called *Ekstra vej* (extra roads). The conversion factor associated with these streets in the original model is very low, as if these roads had no sites at their sides. NITA has identified, through the use of the DAV database, the location of all *Ekstra vej* in Denmark in order to verify whether they were included in the INCA maps provided by TDC. Unfortunately, only two of these were part of the INCA maps provided and therefore it has not been possible to meaningfully estimate a separate conversion factor for these types of road. However, they are included in the overall database (along with squares, for a meaningful measurement of which concerns were also raised) and the conversion factors for most of the road length in Denmark have been estimated making reference to a meaningful sample of data.

The table below shows NITA's conversion factors as estimated through analysis of INCA maps and the econometric method.

Table 8.3: Overview of conversion factor estimates

Road type	The Hybrid model
AA	1.80
AB/BA	1.61
AC/CA	1.40
AD/DA	1.10
BB	1.63
BC/CB	1.18
BD/DB	0.89
CC	1.00
CD/DC	0.70
DD	0.40

Table 8.3 shows the conversion factors used in the hybrid model. The total length of trench is hereby estimated to 124,245 kilometres.

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[2] 10 instead of 16 classes like AB and BA would count as a single road class.

8.4.2 Mini-duct

The hybrid model estimates mini-duct in the following way:

> by measuring the number of subscriber sites in each of the 20 sample areas and over the whole network using the DAV database. The numbers from the DAV database are also corrected using information from Statistics Denmark about the number of inhabited residences.

> by conducting a stand-alone analysis of the average distance between sites and road side by geotype for a sample of streets.

Raster maps[3] as indicated in the following table were requested from TDC to assist the calculation of the distance from the exit to street duct (EFSD) to customer premises.

In order to ensure a reasonable degree of accuracy in the sample, six areas were selected within geotype “Storby”, 10 within geotype ”By”, 18 within geotype ”Land A” and six within geotype “Land B”. These numbers were chosen to reflect the relative diversity of geotypes in Denmark. Once the different zones had been selected, streets were chosen randomly within these zones.

For the selected streets in each geotype, 10 house numbers[4] were randomly chosen and two distances measured:

> The shortest distance (beeline) from the street duct to the house

> the actual trench distance from the street duct to the house. Under this approach, the number of houses sharing the trench was noted and the calculations adjusted to reflect this sharing. If, for example the exit from street duct was shared by two houses, the total trench length was measured and divided by 2.

The two approaches led to similar results (the former approach of not including trench sharing does not necessarily lead to a shorter average distance) and NITA decided to adopt the second approach, because it was more consistent with the constraints likely to be faced by an operator laying down mini-ducts in Denmark.

The average length of mini-duct (NTP to SDP) by geotype derived from this process is shown in the table below:

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[3] Raster maps are maps from TDC showing the existing, secondary access network. It is possible from these maps to measure the distance from the subscriber NTP to the road to the EFSD

[4] In some cases, it was not possible to select 10 houses.

Table 8.4: Average length of mini-duct (by Geotype) in the hybrid model

Geotype	Average length per site (m)
City (Storby)	5.1
Urban (By)	8.5
Rural A (Land A)	15.4
Rural B (Land B)	10.9

8.4.3 Copper and fibre equipment

This section describes the methodology used to estimate the amount of copper cables, fibre cables, street cabinets, and network termination points in the hybrid model.

8.4.3.1 Overview

For the access network, the model allows for a three-layer tree and branch structure: ASM – Primary distribution point (PDP); PDP – Secondary distribution point (SDP); and SDP – network termination point (NTP).

The primary input to these calculations is Geographical Information System (GIS) data for a sample of 20 MDF areas. This sample should be constructed to be representative of the whole country, covering all four geotypes and covering a representative range of zones within each geotype.

The most important data required for these zones is as follows:

> Location of zone centre (grid reference)

> Location of switch (grid reference)

> Area in km^2

> Weighting, i.e. the number of similar zones in the country. Different weightings can be given to each zone in the sample.

> Number of copper pairs.

> Parameters that define the dispersion of subscribers within the zone

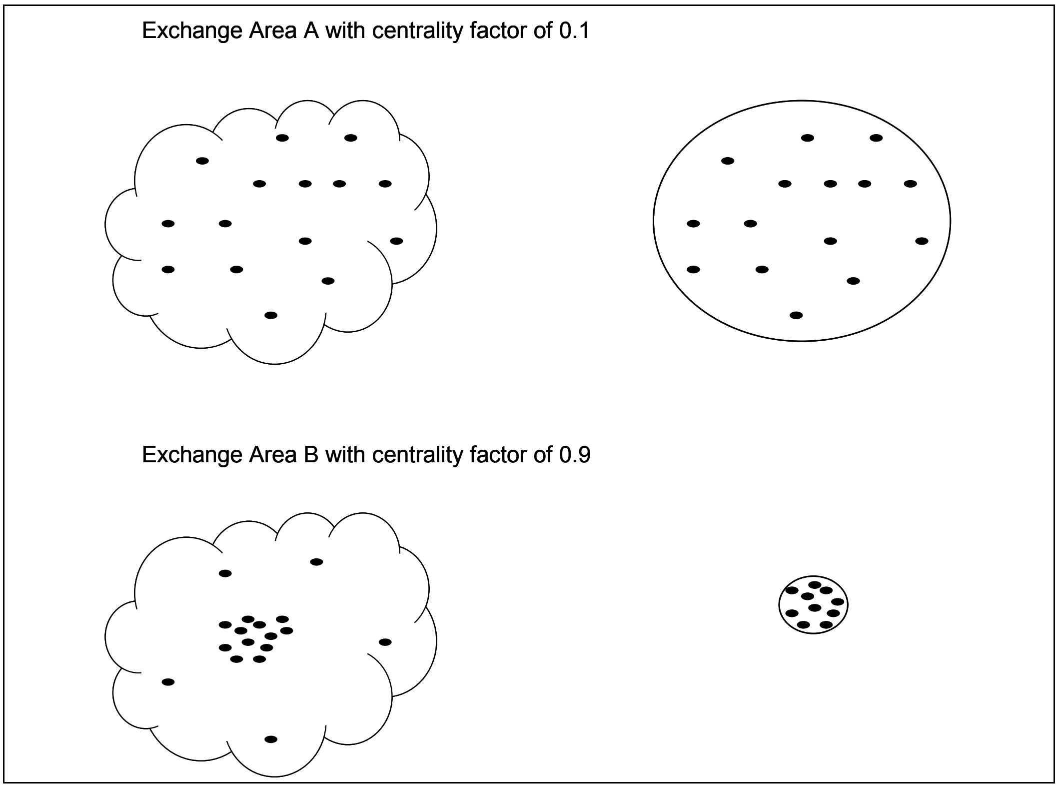
> Street-level attributes – the typical dimensions of a customer site such as its frontage, the distance from the street duct to the customer building, also whether customer sites tend to be on one side of the road or on both sides.

> Finally, the strategy to be adopted in designing the access network for the zone. This consists of four factors, two that control the number of primary and secondary distribution points (PDPs and SDPs), and two to control the strategy for locating them – near to the subscriber, near to the ASM, or somewhere in between.

Most of the calculations for the copper network are developed for each of the 20 zones individually. The purpose of these calculations is to determine the length of the local loop and then to equip it with cable.

In order to estimate these distances, an assumption is made about how dispersed subscribers are within each ASM zone. The main assumption is that each zone can be turned into a circle through the use of a centralization factor. This factor turns the exchange area into an Equivalent Homogenous Area (EHA) in which all subscribers are assumed to be evenly distributed. The closer the centralization factor is to zero, the closer the EHA is (in terms of area) to the original exchange area. This is illustrated in the box below.

Figure 8.2 Converting Exchange Areas into Equivalent homogenous areas



Exchange Area A with a centralization factor of 0.1

Exchange Area B with a centralization factor of 0.9

Once the size of the zone has been estimated, average beelines are calculated for different parts of the network, namely:

- ASM to PDP,
- PDP to SDP,
- SDP to NTP.

This is by far the most complicated part of the calculation algorithm and relies on the usage of a function that approximates the average distance between any point in the area and a particular point at a given distance from the centre of the area.

PDP areas are assumed to be circular and SDP areas are assumed to be rectangular, but a fallback approach is in place for SDP areas, so if the rectangular shape of the SDP area is not consistent with the circular shape of the PDP area, the SDP area is considered to be circular as well.

The next step in the model is to convert beelines to realistic distances on the ground.

Subsequently, the model then:

- Determines the number of copper pairs and the number of links on each connection
- Determines the number of NTPs, cabinets and joint boxes for each sample zone.
- Calculates and saves these results for each of the 20 sample zones in turn. This can be done automatically with the aid of a macro, or the user can copy and paste the values manually if preferred.
- Calculates the weighted sum of the results for the 20 sample zones to determine the resources needed for copper access network for the entire country in terms of length by size, broken down by geotype (pair-km), NTPs and cabinet equipment.
- For copper cable, it adjusts for spares for each connection and geotype and then distributes the entire length-by-size amount over the different sizes of cable through the distributional assumption.

- Adjusts the total for the number of pair kilometres now fed by fibre.

More details on how the model calculates each of these steps are provided below.

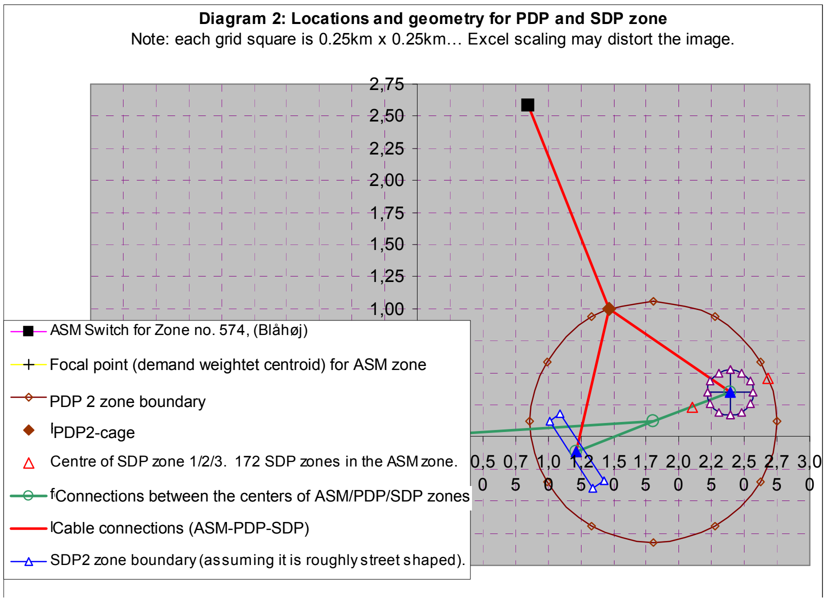
8.4.3.2 Average distances of different parts of the loop

This section shortly describes the method used to estimate the distance in the different parts of the access network.

- From ASM to PDP. This distance has been estimated as the difference between the ASM and the centroid of the PDP zone (the elliptic function has here been used after the original area has been converted into an EHA) and the distance between the centroid of the PDP zone and the PDP cabinet (the location strategy of the PDP cabinet plays an important role here, given that centroid of the zone and ASM are assumed to connected through a straight line).
- From PDP to SDP. This is worked out through trigonometric formulas (if the preferred approach is consistent with the other assumptions in the model) and the usage of the elliptic function (if the fall back approach assuming circular SDP areas are used instead). A direct examination of the formulas is the best way of understanding this part of the model, which is quite complicated.
- From SDP to EFSD. This distance, in the preferred approach, is worked out on the basis of street length and width, whereas in the fallback approach on the elliptic function calculations (the fallback approach allows for this methodology to be applied because the SDP area is assumed to be circular).
- From EFSD to NTP. This is worked out as the summation of two distances: from street duct to building, from building to NTP. The inputs used come directly from the data on buildings and street sizes for each of the 20 sample zones.

An input which exerts an influence on the location of PDPs and SDP (and the length of the different parts of the subscriber line) is the location strategy. This input is applied to assess the relative location of the PDPs and the SDPs between the ASM and a randomly selected subscriber in the area. The value of the parameter is between 0 and 1 and is an input in the model. An extract from the model for the MDF *Slangerup* is shown below.

Figure 8.3: Extract from the Hybrid model, showing the geometry for PDP and SDP zones



More specifically, the figure shows that:

- The PDP location strategy gives the freedom to locate the PDP either at the edge of the PDP area (the brown ring), if a value of 1 has been selected or closer to the subscriber, if a value lower than 1 has been selected
- The SDP location strategy allows an SDP to be located at the border of the SDP zone, nearest to the PDP, if a value of 1 is selected or reciprocally, closest to the subscriber, if a value of 0 is selected.

The figure also shows the prescribed shape of the PDP and SDP areas. By default, the PDP areas are circular and the SDP areas rectangular. However, the model undertakes two sanity checks, which may imply that the SDP is then estimated to be circular. A rectangular and a circular SDP area can be identified in the above listed figure.

The two sanity checks are:

- The length and width of the SDP zone is compared with the diameter of the EHA for the PDP in question. The length and width of the SDP zone should be smaller than the diameter of the EHA for the PDP in question.
- The average distance between the subscriber and the SDP cage is compared with the average distance between the subscriber and the PDP cage. The average distance between the subscriber and the SDP cage should be smaller than the average distance between the subscriber and the PDP cage.

If neither of these conditions is met, the SDP zone is determined to be circular rather than rectangular.

8.4.3.3 Beeline adjustment factor

The beelines are converted to "actual" distances by multiplying each distance by an adjustment factor. These factors are model inputs and vary according to the different parts of the network and the geotype.

8.4.4 Street cabinets

NITA decided that the average number of lines per SDP to be assumed should be in accordance with the experience from other EU countries. NITA has thereby obtained access to information on the average number of PDP and SDP cabinets per MDF area and in the total network as well. In addition, information has also been received regarding the average number of subscriber lines in use per PDP and SDP.

NITA also conducted a simple cross check of its methodology by reviewing maps and considering other relevant data. NITA has reviewed the DAV database of roads which showed that there are about 600,000 road segments corresponding to 100,000 roads in Denmark.

Finally, NITA has taken into account that for active street cabinets (which are assumed to be sighted alongside the PDPs) a compromise needs to be reached between the desire to shorten the length of the copper loop and the need to keep a suitable number of potential customers at each PDP location.

NITA has therefore chosen to apply the following the number of cabinets in the hybrid mode, being sufficiently flexible for an access network provider. The numbers shown in the following table are derived from GIS pilot data.

Table 8.5: Number of SDPs and PDPs in the access network	
Total number of PDPs in the network	13,800
Total number of SDPs in the network	431,551
Average number of connected lines per PDP	173
Average number of working lines per SDP	5.7

The consequences of this assumption are shown below:

Table 8.6: Average number of PDPs per MDF area	
Geotype 1	62.5
Geotype 2	18.4
Geotype 3	9.2
Geotype 4	7.1
Whole network	**11.7**
Total number of PDPs in the network	**13,800**

Table 8.7: Average number of SDPs per MDF area	
Geotype 1	1,731
Geotype 2	873
Geotype 3	255
Geotype 4	126
Whole network	365
Total number of SDPs in the network	**431,551**

Table 8.8: Average number of connected copper pairs per PDP	
Geotype 1	477
Geotype 2	475
Geotype 3	123
Geotype 4	52
Total network	**173**

Table 8.9: Average number of connected copper pairs **per SDP**	
Geotype 1	17
Geotype 2	9
Geotype 3	5
Geotype 4	3
Total network	**5.7**

Different assumptions regarding the number of cabinets have an impact on the loop lengths. The more cabinets in the access network, the shorter the total loop length will be. This is because the presence of more cabinets reduces doubling back (with lots of SDPs you take subscribers directly to their homes; with few you will often go further and then double back).

On the other hand, more cabinets should increase the length between the MDF and the SDP (increasing the number of SDPs takes you closer to the subscriber) and decrease the distance between the SDP and the NTP.

The method used by the model when calculating distances between the connection points in the access network considers assumptions on the number of cabinets.

8.4.4.1 Active Street Cabinets

Version 2.4 of the model (released in 2006) introduced the concept of Active Street Cabinets (essentially street cabinets housing small DSLAMs and intended to reduce the effective length of the local loop – and hence the maximum speeds achievable with xDSL). It was agreed at that stage that such cabinets should be assumed to be located at the modelled Primary Distribution Points (PDPs). The number of PDPs in the modelled network was left unchanged, and the resultant costs were based on a national average.

In 2006 it was anticipated that TDC would be rolling out in the region of 1500 such cabinets over the course of around a two year period. The reality has been that TDC has only to date introduced a very limited number of such cabinets, although they do still intend to implement a more aggressive rollout programme over the coming years.

On the basis of past events, and probable future rollouts, the modelling in the revised Hybrid Model has been adapted in two specific ways:

- Incorporate a facility to “target” specified geotype(s) for the Active Street Cabinets
- Adapt the assumption on PDP numbers for the sample areas such that, where active street cabinets are to be deployed, the number of customers fed from a PDP is around 500, at least in the more urban geotypes.

The model also now has the ability to include specific node equipment for the Active Street Cabinets. This is on the assumption that the existing (passive) PDP would still exist with an Active Street Cabinet located adjacent to it. The costs of the active cabinets have been based on information provided by the operators.

8.4.4.2 Backhaul from Active Street Cabinet sites

Specific backhaul products are now included in the revised model to cater for a number of options for active street cabinet backhaul. These are products that could be utilised by OAOs should they decide to “unbundle” such a street cabinet location. For the sake of completeness and modelling integrity, a third backhaul “product” was introduced to cater for TDC’s own xDSL (and Bitstream) customers.

The full list of street cabinet backhaul products introduced is:

- Street Cabinet backhaul – duct
- Street Cabinet backhaul – dark fibre
- Street Cabinet backhaul – xDSL

Since the last of the above bullets represents costs more normally associated with the core network, the relevant costs are identified within the model and are then allocated back to core-based products.

8.4.4.3 Cable size

The hybrid model assumes a 2 pair copper cable connecting each NTP to the relevant SDP. This implies a utilisation rate of 50 per cent with no route sharing for this part of the network.

On the other hand, the hybrid model does allow for “route sharing” in the distribution part of the access network (from the SDP to the ASM). This means that the links connecting SDPs with PDPs and PDPs with the ASM share routes and, as a consequence, they travel on thicker cables, and at lower unit costs, than they would do otherwise if route sharing was not taken into account.

The approach used in the hybrid model to dimension distribution cable consists of the following steps.

> For each sample area and for each part of the distribution network, cable requirements in terms of "length by size" is obtained by multiplying "total connection length"[5] by "connection size"[6] ("connection size" excludes the adjustment for growth, at this stage).

> "Length by size" cable requirements by geotypes are worked out by multiplying "length by size" requirements for each sample area by the weight given to the area in question.

> Allowances for spares are taken into account through inputs that are specific to each part of the network and each geotype. This would increase "length by size" cable requirements.

> "Length by size" cable requirements by geotypes are then allocated to different cable size categories through specific distribution assumptions. The distribution assumptions are derived from the top-down model.

It is NITA's view that this method offers the following advantages.

> It makes use of intermediate outputs produced by the bottom-up model and, in particular, of the distances between cabinets (worked out in the original model in a very detailed way).

> As the original reconciliation exercise has shown, working on the variable "length by size" allows separation of the issues of connection lengths, connection number and their sizes. It therefore enables the problem of cable distribution by size to be dealt with as the last step of the dimensioning process.

> All the necessary information is available.

On the other hand, a key issue is whether it is appropriate to use the top down assumptions on cable distribution in a world where other elements of the top-down approach are violated. NITA has identified two important factors:

> Different utilisation rates may have an impact on distributional assumptions with higher utilisation rates implying thinner cables. In order to correct for this difference between the hybrid and the top-down model, the cable distribution assumed for the hybrid model should be shifted to the left.

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[5] "Total connection length", for each part of the distribution network (i.e. SDP to PDP and PDP to RCU), is calculated as the product of the average length of each connection (i.e. the distance between SDP and PDP and PDP and RCU) and the number of connections (this depends on the number of SDPs and PDPs assumed in the area).

[6] "Connection size", for each part of the network, is calculated as the number of subscriber lines indirectly linked to the point of connection closer to the RCU in the network hierarchy.

- Differences in number of PDPs and SDPs may have an impact on distributional assumptions, but this also depends on the number of joint boxes that do not enter the model explicitly. A smaller number of cabinets would generally imply a higher degree of route sharing and therefore thicker cables.

While it is not possible to verify and assess the significance of the second factor (as splicing boxes are not directly estimated in the model), it is possible to estimate the impact of the first factor. This has been done in the following manner.

- The cable lengths for the different cable sizes have been calculated from the utilisation rates in the earlier top-down model
- The distribution of cable sizes is equal to the distribution in the top-down model.
- The distribution is skewed slightly to the left (thinner cables replacing thicker cables) until the cable lengths, ranked after size, for each geotype corresponds to the higher utilisation rates, applied in the hybrid model.

8.4.5 Fibre access network

For business subscribers having fibre feeds, the model works from an existing set of TDC data on the number of relevant subscribers and the amount of fibre in the access network required connecting them. The steps are:

- Define a Calibration Scenario using historical data - a known number of connections and a known quantity and mix of installed fibre;
- Convert the mix of fibre into Modern Equivalent Assets (MEA)
- Define the number of connections in the Actual scenario
- Define the Cost-volume Relationships (CVR), for fibre in rings and fibre on spurs;
- Calculate the fibre required to fulfil the actual scenario, by starting from the calibration scenario and using the cost-volume relationships to adjust for the differences.

Additional fibre is included within the modelling to account for the need to connect the Active Street Cabinets back to the historical exchange sites. This is calculated in worksheet C_Trench_by_zone using the assumed number of Active Street Cabinets (allocated across the 20 sample zones) together with a number of other input assumptions that are used to allocate the shared trench and duct systems.

Under normal running conditions, the model does not adopt fibre in the access network to serve existing copper connections – thus existing copper-supplied subscribers (PSTN etc) are assumed to be supplied via a copper network. The exception to this is where the NGA Selector is switched on. In such a case, the copper access network is assumed to no longer exist and all customers are fed by a fibre cable. In this scenario, every PDP site is assumed to contain an Active Street Cabinet, and from these locations there is assumed to be a direct point-to-point fibre feed to the home. The model does not, therefore, currently consider a Passive Optic Network, or PON, architecture.

8.5 Treatment of shared costs in the Access Model

Most of the cost categories modelled in the access network are shared between different services. The costs of all these elements are apportioned to the services that share the infrastructure through the Access Routing table.

The main inputs to estimate the allocation keys for the different services using the access network are the average number of copper pairs used as means of transport by the individual services. The list of services using the access network, therefore, includes a category called "Others" that includes all those services whose costs are not specifically estimated by the model (this would require the inclusion of a set of service specific costs) on the basis of the total number of copper pairs these use and then assume that this fictional service requires one copper pair.

Moreover, some components of the core network equipment are used by the access related products. These costs are calculated in the core model and the costs that are relevant to the access products are transferred across in the Consolidation model. These costs include line cards, the MDF and some building costs – the access part of the core equipment takes some building costs due to the area occupied and also some shared common building costs (such as site security and power systems, etc.).

Finally, some shared, common business costs are allocated using an uplift technique (equal mark-up approach).

8.6 Next Generation Access

The model has been modified to allow for an exploring of the potential cost impact of moving to a full fibre access network (a Next Generation Access, or NGA scenario). The intention at this stage is that the model will be able to produce indicative results, but not at this stage results for use in any regulatory decisions.

The broad design guidelines currently adopted for the NGA scenario are:

> All PDP locations will be re-sized in accordance with the Active Street Cabinet assumptions (that is, a design guideline of around 500 customers per PDP, particularly in urban locations).

> Active Street Cabinets will be introduced at all PDP locations and will be fed with high fibre count cable (though not sufficient fibres for a full fibre to the home scenario) from the existing DSLAM/MSAN sites.

> A full fibre to the home rollout will be assumed from the Active Street Cabinet. This is in contrast to assuming a Passive Optic Network (PON) architecture.

The rationale for assuming a non-PON architecture from the PDP site is twofold:

> From a bottom-up perspective it will allow a greater degree of future proofing than a PON architecture.

> It will facilitate fibre loop unbundling, albeit at the street cabinet level.

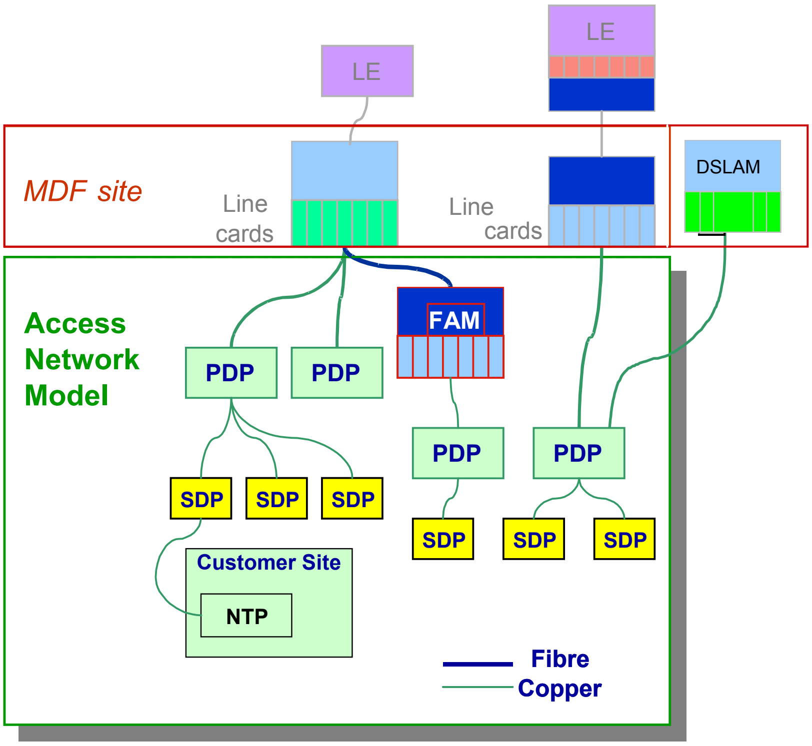
8.7 How to use the Access Model

8.7.1 Model scope

The purpose of the access model is to calculate the resources required to build that part of the network that is below the existing MDF site (housing also a Local Exchange, DSLAM or MSAN), as far as the Network Termination Point (NTP) at the customer premises.

The model does not calculate access network costs at the exchange site itself – as the following diagram illustrates:

Figure 8.4 Scope of Access Model



Any parts of the access network that are at or above the existing MDF site are dimensioned and costed, along with operations and maintenance costs, in the core model, and results (costs and resources used) are passed to the consolidation model.

The main components of the access model are:

> Trench and duct used by the access network

> Copper cables and distribution points, including Active Street Cabinets

> Final drop miniduct, associated digging works, and Network Termination Points (NTPs)

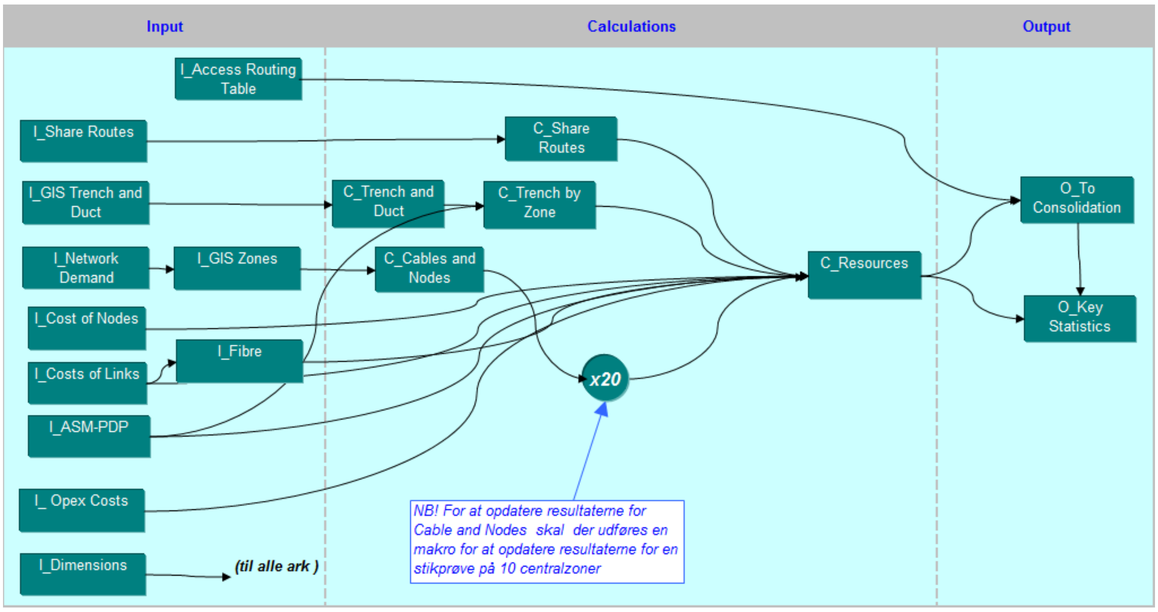
- > Fibre in the access network
- > Backhaul from Active Street Cabinets

After calculating the resources needed to build this part of the network, the model uses the results to calculate the capital cost of those resources, and the annual operating cost of such a network.

8.7.2 Model structure

For ease of navigation, the access model includes a map of all major information flows between them. This is reproduced in the diagram below.

Figure 8.5: Access Model – Navigation Map



NB! For at opdatere resultaterne for Cable and Nodes skal der udføres en makro for at opdatere resultaterne for en stikprøve på 10 centralzoner

The user can click on any of the buttons on the map to jump straight to the relevant worksheet. Each subsidiary worksheet has a "Model Overview" button, which the user can click on to return to the navigation map. Most sheets also have a drop-down menu below the Model Overview button to take the user to different tables contained in each worksheet. Note that it is still possible to navigate the model using the sheet tabs.

The arrows show the major flow of information between the different sheets to give an illustration of the logic of the access model.

8.7.3 Start-up

There are two ways to open the Access model. The first method, which is recommended, is to first open the Consolidation model and then select the "Open Linked Sheets" option, which will open all the individual worksheets of the Hybrid Model. This ensures that linked information is updated automatically and links are preserved when the model is saved under a different filename. The user should also be aware that the Excel auditing tools will trace precedent and dependent cells only for workbooks that are currently open.

Alternatively, the user may open the Access model directly from the file directory. “Enable macros” when asked, unless the file is from an uncertain (untrusted) source. There may be a message asking whether to update links. Such updates are performed automatically on recalculation if other parts of the model are open, otherwise links should be updated if other models have been changed and are located in the same directory. There is an introductory message that warns the user that older versions of Excel may not provide full functionality.

8.7.4 Understanding the model

The recommended approach to gaining an understanding of the model is to work through each sheet in turn, starting with inputs, moving to calculations and then outputs. One way to improve understanding is to edit the input data, recalculate and investigate the effect of the changes on the results. These can be easily checked in the sensitivity analysis sheet in the Consolidation model.

The Access model is considerably larger and hence more complicated to navigate and understand than the other models. Therefore a large part of the user guide has been included in the model itself. This guidance has not been duplicated in this document.

The final costs for all modelled access products are shown in the output and results sheets of the Consolidation model.

A sheet-by-sheet description of the Access model is provided in Appendix C of this document.

9. The Core Model

>

This section describes the methodology and assumptions behind the core model. This includes a description of the modelled network, dimensioning of the network and the approach taken towards allocation of costs.

The analysis has been based on the “scorced node approach” as described in Section 2.2.1 above. The Scorched node approach implies that:

> At least one switch or router is placed at each exchange;

> All transmission and switching equipment is co-located on the site. No sites in addition to the existing sites are required;

> No sites are removed: all existing sites remain in the network including technical houses; and

> The size of the building required to contain the equipment is determined in the model.

The trenches (and cables) connecting the sites are routed optimally. It is assumed that these trenches and facilities can be shared with other utilities and also with the access network.

9.1 Overview of the Core Model

9.1.1 Network structure

As has already been mentioned, NITA is concerned that the Hybrid Model should continue to reflect an efficient operator utilising an optimally configured network based on latest, proven technology. Therefore, NITA believes that from version 2.5 onwards, the underlying technology on which the model is based should no longer be based on circuit-switching but instead packet-switching, and in particular an all-IP core. This core network would have all services running across it, from traditional telephony to more advanced “triple play” services utilising, for example, multicast and multichannel functionality.

The basic concept of an all-IP core network is relatively straightforward and indeed was addressed during the 2006 version 2.4 revision of the NITA model. The hierarchical nature of the core network remains, but the type of equipment located at each level of the hierarchy differs. In principle, the hierarchy will consist of (from top downwards):

> Core Layer 3 IP Routers

> Edge Layer 3 IP Routers

> Layer 2 managed Ethernet traffic aggregation switches

> DSLAMs/MSANs containing a mix of xDSL and POTS line cards.

In addition to the above, in order to provide a voice telephony service, there will be a need to “overlay” certain other equipment including:

- Softswitches, and associated servers, to control voice telephony call routing and call data record management
- Media Gateways to provide a TDM-based level of interconnection whilst the alternative operators themselves still maintain and operate circuit switched networks.

IP-based equipment tends to be cheaper than TDM-based equipment, when comparing similar levels of throughput. This means that a greater proportion of asset-related costs will now be due to the trenching, ducting and fibre optic cables. However, it is still necessary to assess the configurations of the equipment upon which the model is based, and to what degree the necessary investment ought to vary with service demand. Thus the model still needs to incorporate the ability to alter the configuration inputs for each major type of equipment in order that the level of investment within the core network can adequately flex with traffic demand.

9.1.2 Scope of the core model

The core model is a bottom-up model of the equipment and systems required to carry the services defined in the MRP with the required level of service quality. It therefore calculates the cost of both wholesale (interconnect) and retail PSTN and IP Network products.

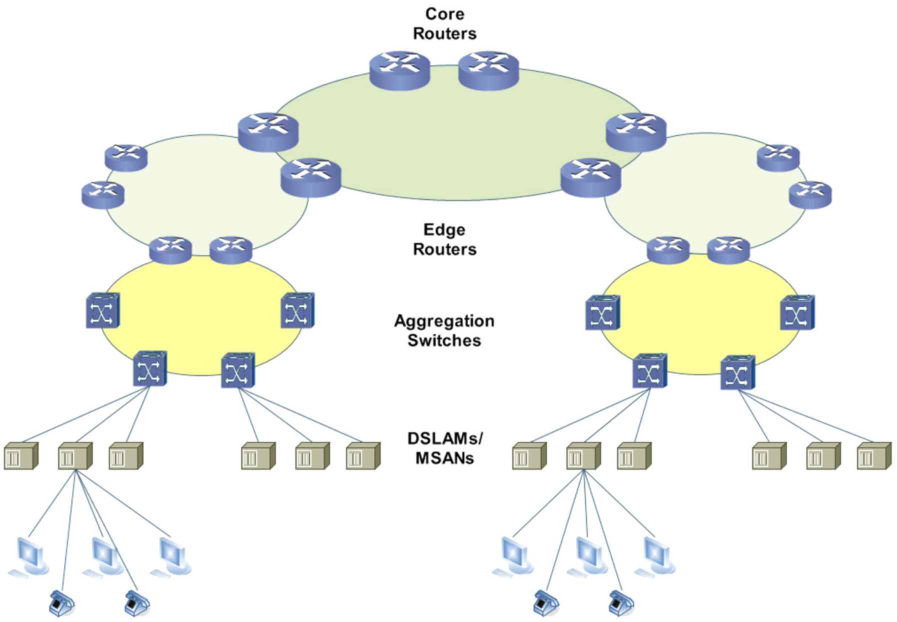
The core network model is defined to include all systems and equipment contained in scorched nodes, including links between the nodes. It does not include links from the node to the customer (these links are in the access model). Whilst the core network *increment* does not include line cards and the MDF, these are still included within the core model for ease of modelling. The costs associated with these items are then allocated to the relevant access products in the consolidation model.

The core model includes additional costs required to give the extra capacity needed to support other services than those defined in the MRP. These other services include IPTV, leased lines and (non-broadband/Bitstream) datacom services. The costs of servicing and supply of dedicated equipment for these increments are not included. However, the capacity effect on the PSTN/IP Network increment is taken into account. Due to the effect of cost-volume relationships, this increased capacity reduces the average cost per unit of products and services using that capacity.

9.2 IP network design

The basic design of an IP network is a hierarchical one, as depicted in Figure 9.1 below.

Figure 9.1: Basic IP Network Design

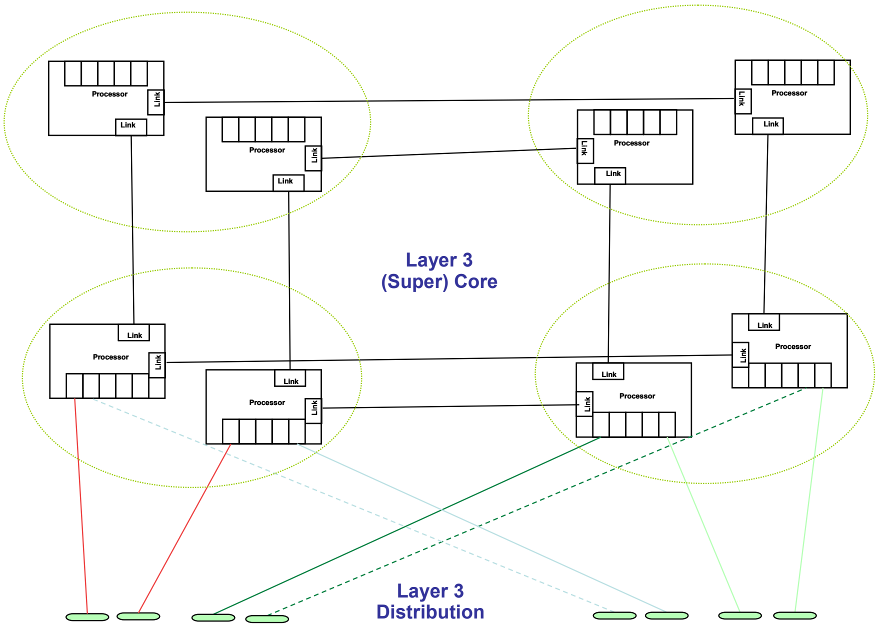


The existing IP network deployed by TDC is a slightly modified version of the above in that the Core routing layer comprises two sub-layers: (Super) Core routers and Distribution routers. The Distribution routers collect traffic from a number of Edge router rings. Where it is necessary for one Distribution router to exchange traffic with another one, it does so via one or more (Super) Core routers.

Each (Super) Core router site actually comprises two distinct routers for resilience reasons, with the routers interconnected in a “square” arrangement. Each Distribution router connects to two of the (Super) Core routers.

This is illustrated in Figure 9.2.

Figure 9.2: TDC's IP Network Structure



Each Distribution router site also comprises two distinct routers to provide resilience. There are no direct connections between Distribution routers. Instead, all relevant traffic passes up to the (Super) Core level.

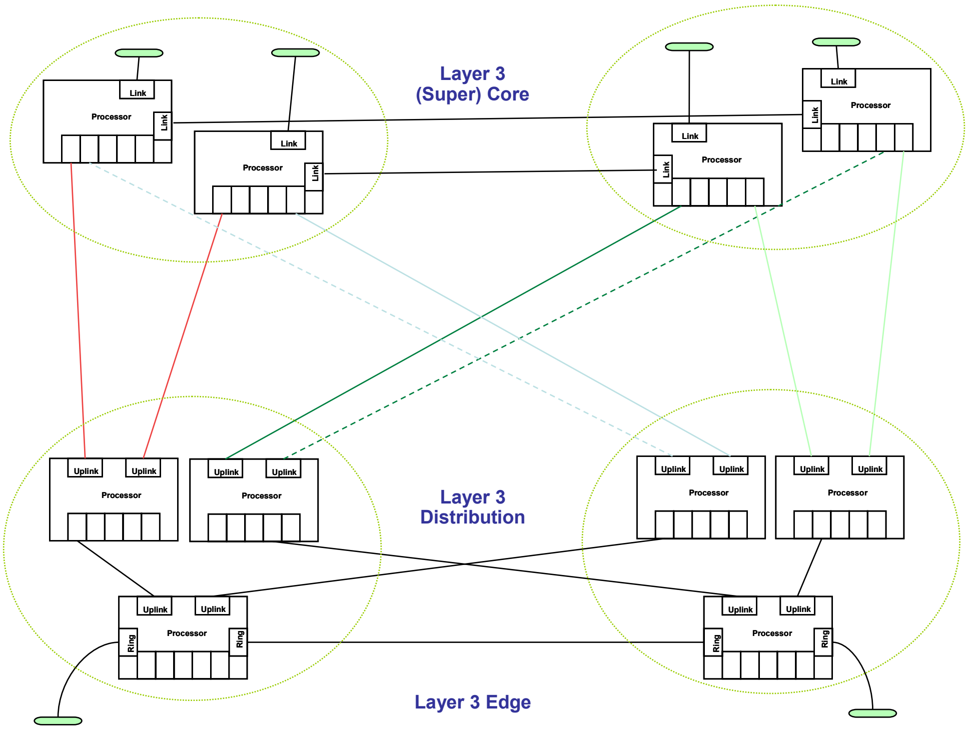
Each Distribution router site will also contain one or more Edge routers that "head" logical Edge router rings. Every "head" Edge router will connect to two Distribution routers, one at the same physical site and the other at a remote site, again for reasons of resilience. This is illustrated in Figure 9.3.

In version 2.5 of the model, the ASM sites have been replaced with DSLAM/MSAN sites (an MSAN, or "Multi Service Access Node", essentially comprising a DSLAM with POTS and/or ISDN line cards). Although, in theory, an operator could combine xDSL customers with POTS/ISDN telephony customers in the same DSLAM/MSAN, the model keeps the two services separate for modelling convenience reasons as much as anything.

The advantage of this from a modelling point of view is that it improves clarity in the cost allocation process. From a technical point of view, it might be argued that it also eases segregation of real-time voice telephony traffic from non-real-time xDSL traffic, though the existence of a significant number of VoIP subscribers in today's TDC network would tend to reduce the strength of this argument.

For medium to large sites the adopted approach is not likely to have any real impact on the overall level of investment, whereas for the smallest sites it will tend to overstate the number of DSLAM/MSAN chassis. Overall though, the impact will be minor.

Figure 9.3: TDC's IP Network including Edge Routers



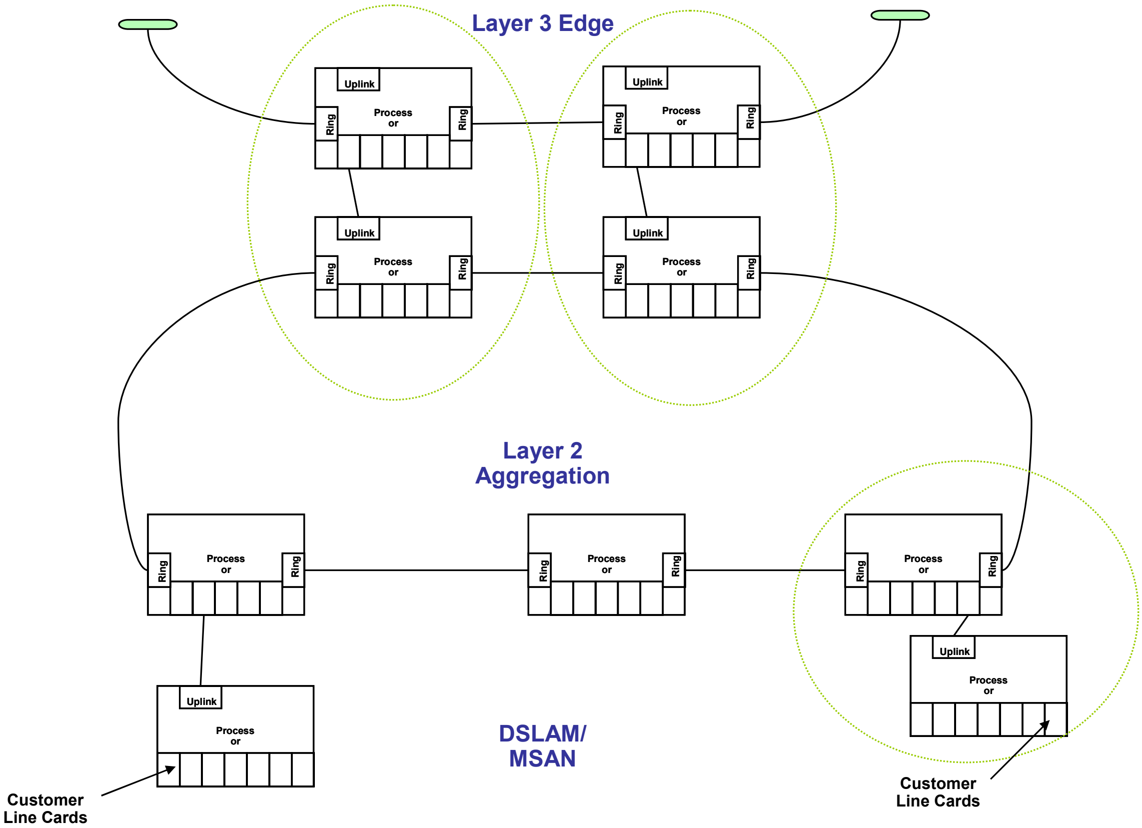
In the Hybrid Model it is assumed that each DSLAM/MSAN site will also contain a Layer 2 Aggregation switch. This will allow grooming of the traffic from multiple DSLAMs to a single uplink stream, and also facilitate direct connection to customers and/or OAOs that require this.

The Layer 2 Aggregation switches are connected together into logical rings, with each ring having two "heads" (Layer 3 Edge router sites).

This is illustrated in Figure 9.4.

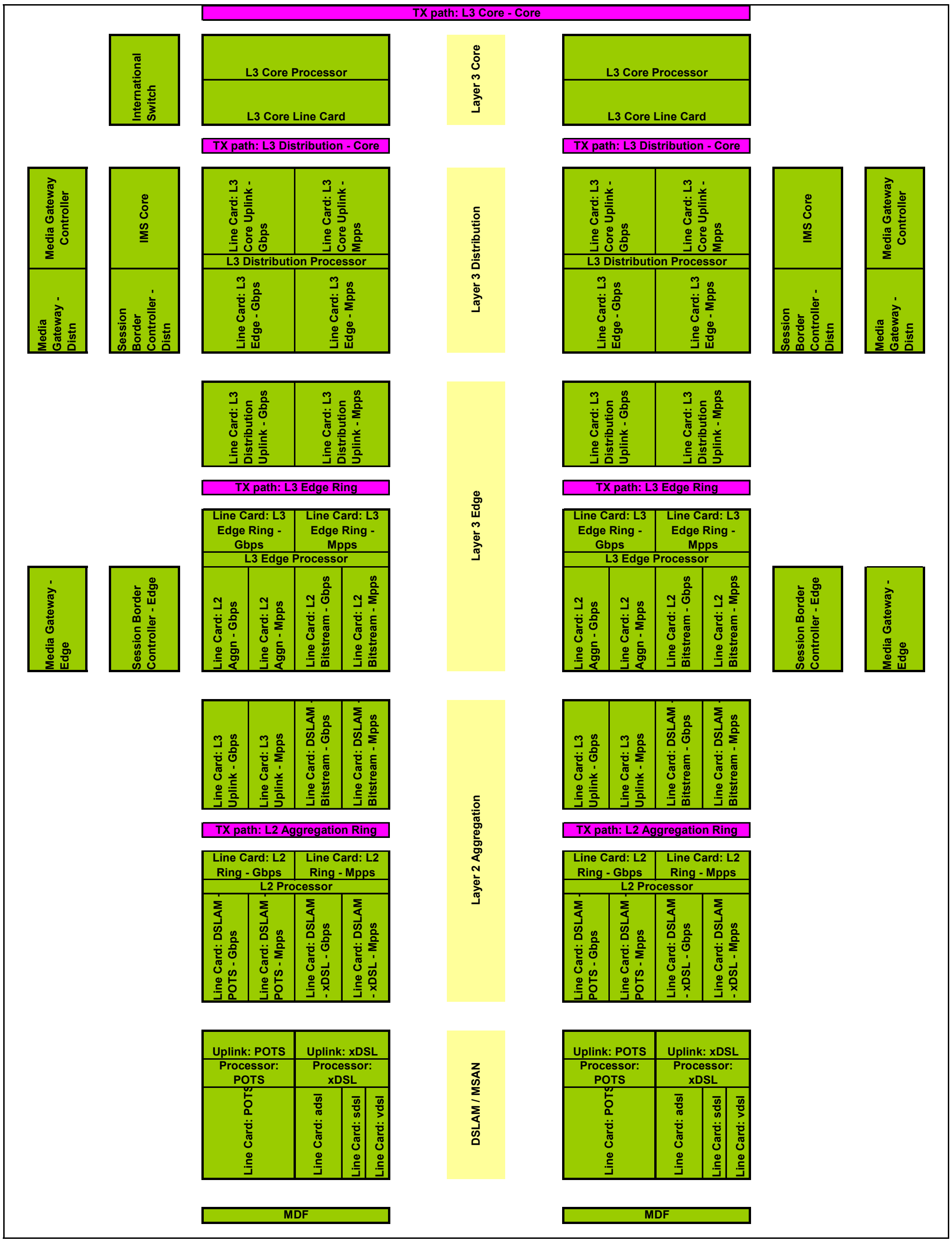
>

Figure 9.4: IP Network Structure – Edge to DSLAM



The model also contains a simple graphical representation of the network structure that was added to aid routing factor analysis. This is shown below in Figure 9.5.

Figure 9.5: Network Structure – Route Chart



9.3 Network dimensioning

9.3.1 Basic assumptions

The main source of information on the current level of demand for the hybrid model is TDC. The model includes all the current traffic, including:

- Voice, data and video traffic;
- leased lines; and
- any other services, including those offered by other operators to end-users via the SMP operator's network.

An assumed rate of growth over the assumed planning period is added to the current volume of traffic in order to attain end-user demand. The decision of which growth rate to use is based on an assessment of the time factor involved in building the network. The planned expansion should thus take into account the expected time used for the individual activities preceding the date when new – major or minor – parts of the core network are put into use. This particularly concerns activities such as obtaining local planning permits, construction, acquisition/ installation/ testing/ operationalisation of equipment for expansion or new installation (exchanges, transmission equipment, infrastructure, etc.).

It should be noted that the model contains a number of negative growth rates. If the network was dimensioned in order to carry only the future lower traffic demand, it would be under-dimensioned to carry current traffic.

Instead, the network should be dimensioned to be capable of carrying the largest amount of traffic within the planning period. Therefore, a correction mechanism has been built into the model, which ensures that under-dimensioning does not occur.

By using the routing factor method (see Section 9.3.2) below, the network is subsequently adjusted to the "dimensioned demand" which the network has to carry. The adjustments concern:

- the application of routing factors;
- the adjustments for grade of service;
- allowance for resilience;
- consideration of the "burstiness" of the service; and
- application of the "busy hour" estimate.

9.3.1.1 Routing factors

The routing factors show the way in which the different network elements are used in the process of establishing a call. In an IP network, this potentially involves many more network elements than in a traditional PSTN. The following example may help to illustrate this. A legacy local call can be routed through a remote subscriber stage and then on to a local exchange, from which it is directed to another remote subscriber stage. In this case, the call setup uses:

> 2 ASM or remote subscriber stages

> 1 local MSG exchange

> 2 transmission connections between the remote subscriber stage and the local MSG exchange.

In an IP network, by contrast, packets may travel through many more “switching” points (Layer 2 switches and Layer 3 routers in the case of an IP network) than would typically be the case for a legacy PSTN network.

As shown in Figure 9.6, a “local call” made over an IP network might take a complex route involving, for example, the following Network Elements:

> Multi-Service Access Node processor at the originating end of the call

> MSAN facing line card in a Layer 2 Ethernet Switch

> Processor in the Layer 2 Ethernet Switch

> Ring facing line card in the Layer 2 Ethernet Switch

> Layer 2 ring transmission link

> Layer 3 Edge Router facing line card in the Layer 2 Ethernet Switch

> Layer 2 Ethernet Switch facing line card in the Layer 3 Edge Router

> Processor in the Layer 3 Edge Router

> Ring facing line card in the Layer 3 Edge Router

> Layer 3 Edge ring transmission link

> Layer 3 Distribution Router facing line card in the Layer 3 Edge Router

> Layer 3 Edge Router facing line card in the Layer 3 Distribution Router

> Processor in the Layer 3 Distribution Router

> Session Border Controller at the Layer 3 Distribution Router site

> IMS Core at the Layer 3 Distribution Router site (onmly used for call set up)

> A second instance of the Layer 3 Edge Router facing line card in the Layer 3 Distribution Router

> A second instance of the Layer 3 Distribution Router facing line card in the Layer 3 Edge Router

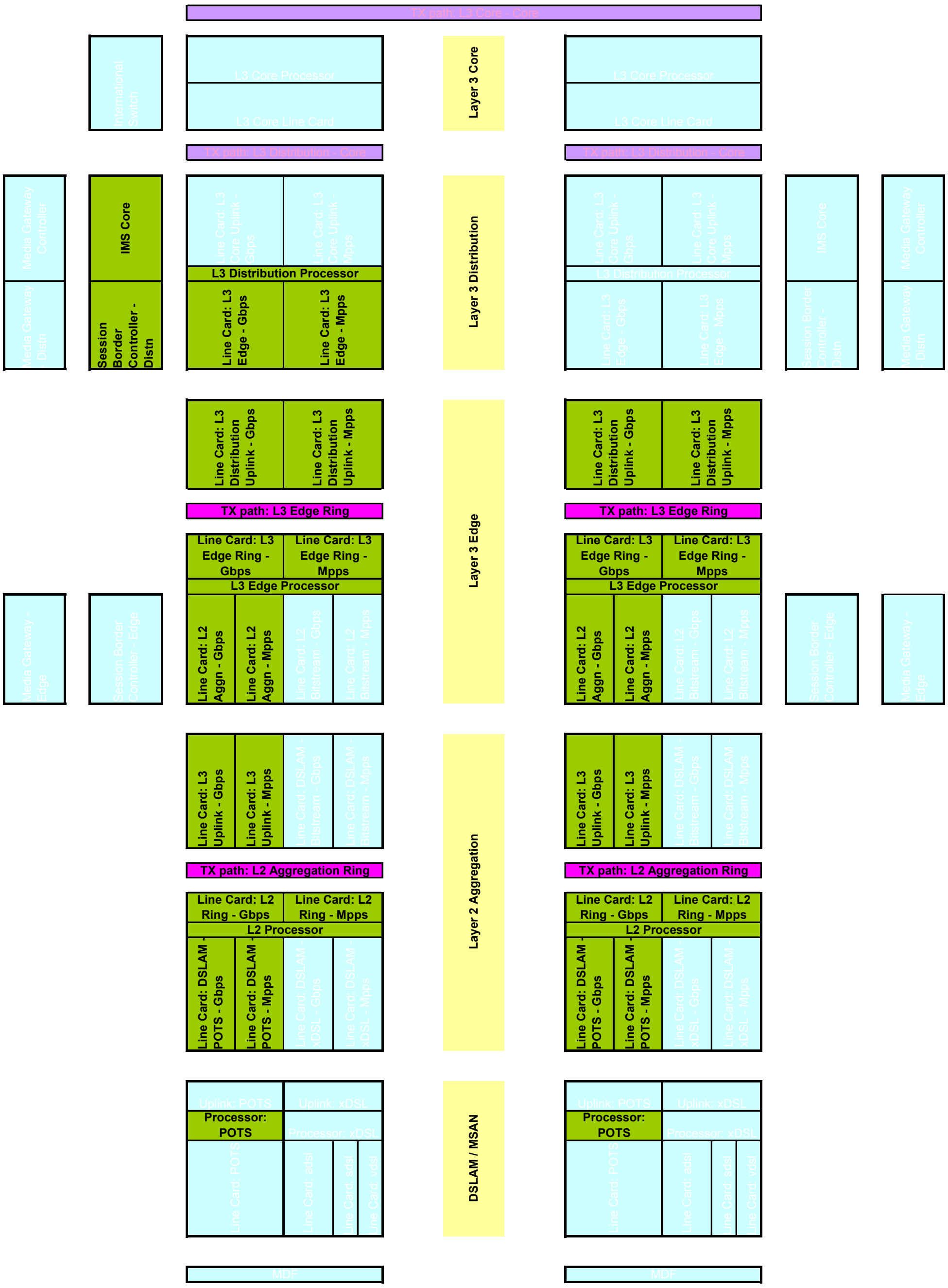
> A second instance of the Layer 3 Edge ring transmission link

> A second instance of the Ring facing line card in the Layer 3 Edge Router

- A second instance of the Processor in the Layer 3 Edge Router
- A second instance of the Layer 2 Ethernet Switch facing line card in the Layer 3 Edge Router
- A second instance of the Layer 3 Edge Router facing line card in the Layer 2 Ethernet Switch
- A second instance of the Layer 2 ring transmission link
- A second instance of the Ring facing line card in the Layer 2 Ethernet Switch
- A second instance of the Processor in the Layer 2 Ethernet Switch
- A second instance of the MSAN facing line card in a Layer 2 Ethernet Switch
- Multi-Service Access Node processor at the terminating end of the call

In the hybrid model, the routing factors together with the traffic volumes are used for dimensioning the number of exchanges and transmission capacity (it should be noted that demand for transmission capacity is also driven by leased lines and other services).

Figure 9.6 Routing factors – an example



9.3.2 Method for network dimensioning

The dimensioning of equipment is based on the routing factor method, whereby traffic data for the individual routing factors are applied to the dimensioning rules of the relevant equipment. The model converts call minutes into Busy Hour Erlangs (BHE) in the sheet ‘I_Product_Demand’ and data traffic into Busy Hour Gigabits per Second (BH Gbps). In the next step, a routing factor is applied to define the extent to which the different network elements are used by the different services.

Each product modelled within the core network contains entries in the routing factor input table, worksheet I_Route_Table. A product can have up to three separate routes defined, with percentag likelihoods attached to each one. The weighted averages of these separate routes are collated together in a table at the bottom of that worksheet. The routing factors are combined with the product demand in worksheet C_Route_Table and it is this worksheet that aggregates the demand for each network element. This aggregate network element demand is then overlaid onto the network structure in worksheets I_Trenching_Transit, I_Trenching_Local and I_Node_Equipment in order to dimension the equipment at each layer of the network hierarchy (taking into account the aggregate demand on that network element together with the number of instances of the element in the network and the relevant dimensioning rules defined in worksheet I_Technical).

When the results for the individual services are summed (in the Consolidation Model), it is visible how much the different parts of the network are utilised to deliver fixed network services.

9.3.2.1 Busy Hour conversion

The values for Erlang busy hour are an important element of network dimensioning. The model uses the conversion factor BHE = [yearly number of minutes]/52/[busy days per week]/[busy hours per day]/60 to convert the yearly number of minutes to Erlang in busy hour.

The yearly traffic load is first split by a factor of 52 for the number of weeks per year. In the next step, traffic is split by the number of busy days per week, a user input. This is further divided by the number of busy hours per day, also a user input. In the previous model, these parameters were hard-wired into the conversion algorithm. The introduction of user inputs allows the model to adapt to evolving trends, such as increasing broadband usage per day, or the fact that traffic loads are no longer determined predominantly by office hours or peak/off-peak tariffs. Finally, a factor of 60 is applied to convert the number of minutes to hours. The parameter default settings are guided by information provided by TDC.

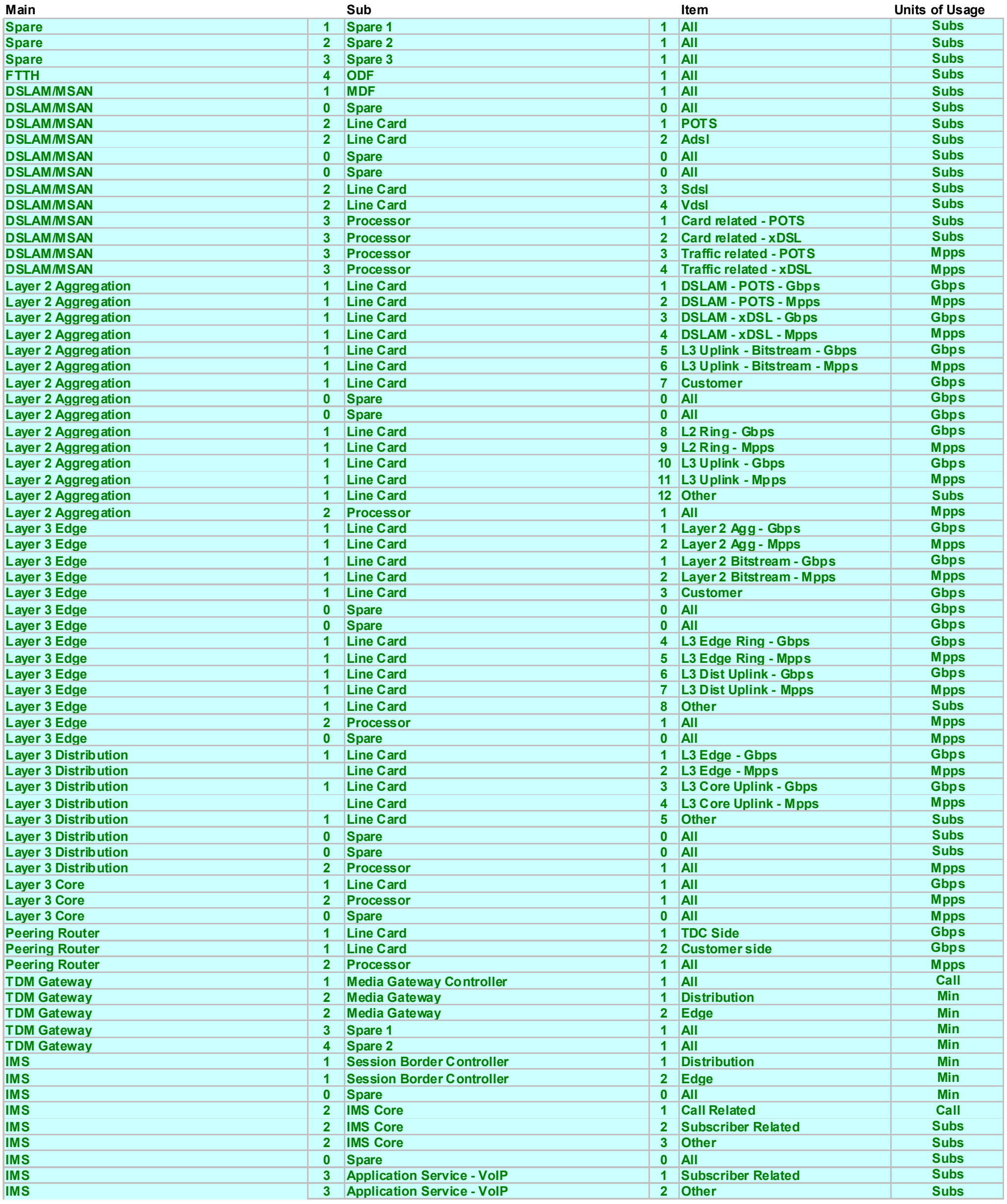
9.4 Key Network Elements

The list of Network Elements used within the core model has been, by necessity, completely revised to adapt to the new IP network structure. In arriving at the definitions of the Network Elements a balance was sought between the need to:

- Keep the number of Network Elements to a manageable total
- Allow for allocation of costs in as cost-causal a manner as practical
- Maintain a single "unit of use" for each Network Element.

The selection of Network Elements also had to reflect the level of available detail in the modelled equipment configurations, there being little point in having Network Elements at a greater level of detail than that in which the equipment could be usefully defined within the model. The revised list of available Network Elements, together with their respective units of usage, is defined in worksheet I_Network_Elements and is illustrated in Figure 9.7.

Figure 9.7: Network Elements in the Core Model



Main		Sub		Item	Units of Usage
Spare	1	Spare 1	1	All	Subs
Spare	2	Spare 2	1	All	Subs
Spare	3	Spare 3	1	All	Subs
FTTH	4	ODF	1	All	Subs
DSLAM/MSAN	1	MDF	1	All	Subs
DSLAM/MSAN	0	Spare	0	All	Subs
DSLAM/MSAN	2	Line Card	1	POTS	Subs
DSLAM/MSAN	2	Line Card	2	Adsl	Subs
DSLAM/MSAN	0	Spare	0	All	Subs
DSLAM/MSAN	0	Spare	0	All	Subs
DSLAM/MSAN	2	Line Card	3	Sdsl	Subs
DSLAM/MSAN	2	Line Card	4	Vdsl	Subs
DSLAM/MSAN	3	Processor	1	Card related - POTS	Subs
DSLAM/MSAN	3	Processor	2	Card related - xDSL	Subs
DSLAM/MSAN	3	Processor	3	Traffic related - POTS	Mpps
DSLAM/MSAN	3	Processor	4	Traffic related - xDSL	Mpps
Layer 2 Aggregation	1	Line Card	1	DSLAM - POTS - Gbps	Gbps
Layer 2 Aggregation	1	Line Card	2	DSLAM - POTS - Mpps	Mpps
Layer 2 Aggregation	1	Line Card	3	DSLAM - xDSL - Gbps	Gbps
Layer 2 Aggregation	1	Line Card	4	DSLAM - xDSL - Mpps	Mpps
Layer 2 Aggregation	1	Line Card	5	L3 Uplink - Bitstream - Gbps	Gbps
Layer 2 Aggregation	1	Line Card	6	L3 Uplink - Bitstream - Mpps	Mpps
Layer 2 Aggregation	1	Line Card	7	Customer	Gbps
Layer 2 Aggregation	0	Spare	0	All	Gbps
Layer 2 Aggregation	0	Spare	0	All	Gbps
Layer 2 Aggregation	1	Line Card	8	L2 Ring - Gbps	Gbps
Layer 2 Aggregation	1	Line Card	9	L2 Ring - Mpps	Mpps
Layer 2 Aggregation	1	Line Card	10	L3 Uplink - Gbps	Gbps
Layer 2 Aggregation	1	Line Card	11	L3 Uplink - Mpps	Mpps
Layer 2 Aggregation	1	Line Card	12	Other	Subs
Layer 2 Aggregation	2	Processor	1	All	Mpps
Layer 3 Edge	1	Line Card	1	Layer 2 Agg - Gbps	Gbps
Layer 3 Edge	1	Line Card	2	Layer 2 Agg - Mpps	Mpps
Layer 3 Edge	1	Line Card	1	Layer 2 Bitstream - Gbps	Gbps
Layer 3 Edge	1	Line Card	2	Layer 2 Bitstream - Mpps	Mpps
Layer 3 Edge	1	Line Card	3	Customer	Gbps
Layer 3 Edge	0	Spare	0	All	Gbps
Layer 3 Edge	0	Spare	0	All	Gbps
Layer 3 Edge	1	Line Card	4	L3 Edge Ring - Gbps	Gbps
Layer 3 Edge	1	Line Card	5	L3 Edge Ring - Mpps	Mpps
Layer 3 Edge	1	Line Card	6	L3 Dist Uplink - Gbps	Gbps
Layer 3 Edge	1	Line Card	7	L3 Dist Uplink - Mpps	Mpps
Layer 3 Edge	1	Line Card	8	Other	Subs
Layer 3 Edge	2	Processor	1	All	Mpps
Layer 3 Edge	0	Spare	0	All	Mpps
Layer 3 Distribution	1	Line Card	1	L3 Edge - Gbps	Gbps
Layer 3 Distribution		Line Card	2	L3 Edge - Mpps	Mpps
Layer 3 Distribution	1	Line Card	3	L3 Core Uplink - Gbps	Gbps
Layer 3 Distribution		Line Card	4	L3 Core Uplink - Mpps	Mpps
Layer 3 Distribution	1	Line Card	5	Other	Subs
Layer 3 Distribution	0	Spare	0	All	Subs
Layer 3 Distribution	0	Spare	0	All	Subs
Layer 3 Distribution	2	Processor	1	All	Mpps
Layer 3 Core	1	Line Card	1	All	Gbps
Layer 3 Core	2	Processor	1	All	Mpps
Layer 3 Core	0	Spare	0	All	Mpps
Peering Router	1	Line Card	1	TDC Side	Gbps
Peering Router	1	Line Card	2	Customer side	Gbps
Peering Router	2	Processor	1	All	Mpps
TDM Gateway	1	Media Gateway Controller	1	All	Call
TDM Gateway	2	Media Gateway	1	Distribution	Min
TDM Gateway	2	Media Gateway	2	Edge	Min
TDM Gateway	3	Spare 1	1	All	Min
TDM Gateway	4	Spare 2	1	All	Min
IMS	1	Session Border Controller	1	Distribution	Min
IMS	1	Session Border Controller	2	Edge	Min
IMS	0	Spare	0	All	Min
IMS	2	IMS Core	1	Call Related	Call
IMS	2	IMS Core	2	Subscriber Related	Subs
IMS	2	IMS Core	3	Other	Subs
IMS	0	Spare	0	All	Subs
IMS	3	Application Service - VoIP	1	Subscriber Related	Subs
IMS	3	Application Service - VoIP	2	Other	Subs

9.5 Core trenching

Due to the increasing importance of the cost of trenching/duct/fibre on the resultant product costs, the model now adopts a radical new method of assessing the requirement for core trench km. A study was conducted of the core trench routes required to interconnect the various core sites within TDC's network in Denmark. The study was based around a dataset of the node locations provided by TDC and utilised Microsoft Autoroute software.

The analysis was conducted in two separate stages – one considering the trench km necessary to connect all of the higher level nodes (from Layer 3 Edge routers upwards) together, and the second to connect all of the DSLAM/MSAN sites to the Edge router sites. In both cases, the analysis covered the complete set of sites and also included additional trench km to provide for a reasonable amount of trench "rings" so as to provide physically resilient routing possibilities.

For the higher level nodes, each route segment (connection between two node sites) was separately assessed and measured with Autoroute. The resultant trench network is illustrated in Figure 9.8 below. The blue routes are those necessary to interconnect the higher level sites (Distribution router and above) and the red routes the additional routes to include the Edge router sites. The purple routes are those that need to travel underwater.

Figure 9.8: Core Trench Mapping in Autoroute

Undersea cable routes were included where necessary to interconnect islands, though bridges were used in preference where available.

For the lower level nodes (ie connections between the DSLAM/MSAN sites and the Edge routers), each Edge router area was separately assessed and measured with Autoroute, though the individual route segments were not separately recorded within the model due to the large number involved. Instead, only aggregate distances were included.

Once the core trench routes had been established, the necessary logical routes could be overlaid onto them. This was done for each level in the network hierarchy following the broad principles adopted by TDC in its own IP network design. This consists of:

> 4 core node sites, each containing two routers, interconnected in a "square" arrangement.

> 13 distribution node sites (4 shared with the core node sites), each containing two routers, with each site having direct connections to two core node sites but not having connections to each other.

> 108 edge node sites (13 shared with the distribution node sites). These are connected together in logical rings with each ring having two distribution node site "heads" and a total of between 5 and 7 sites on each logical ring. Accepting that a logical ring might pass through physical locations not included on that ring, the model allows the user to specify where such locations are used (with the fibre assumed to "pass through" that location but not requiring any active equipment at the location).

> 1,838 DSLAM/MSAN node sites (108 shared with the edge node sites). These are again connected together in logical rings, although due to the number of sites involved this is not carried out ring-by-ring within the model. Instead, a design maximum number of Layer 2 sites on each logical ring is specified in the model and used to calculate the required number of such rings to connect each edge node site with its relevant DSLAM/MSAN node sites.

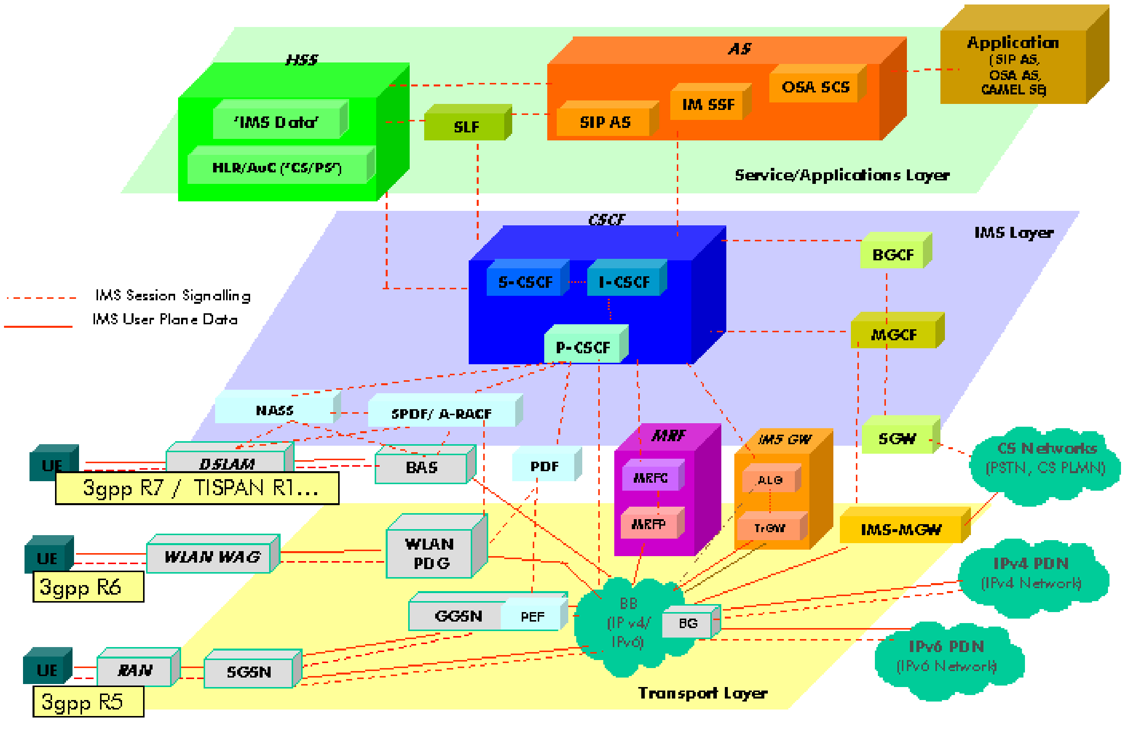
Once this overlay is complete, it is then possible for the model to overlay the traffic onto these logical rings, which in turn allows the model to determine fibre counts and necessary IP equipment configurations. The model contains a complete set of physical route segments and all logical route segments, allowing modification of the overall design according to differing principles, should this prove necessary in the future.

9.6 Modelling the core network

9.6.1 Voice telephony overlay

TDC currently has a significant number of customers using its existing VoIP service. This in turn means that TDC already has in place a network structure capable of handling such traffic and of interconnecting such traffic with a legacy TDM-based network. The conceptual design adopted for the revised model follows the same broad principles as that currently used by TDC.

Figure 9.9: Conceptual Design of TDC's VoIP Network



It follows the broad IMS structural guidelines, as illustrated in Figure 9.9 above. A number of CSCF (Call Session Control Function) "softswitch" servers are located across the network. One such server facility has been assumed at each of the 13 Distribution router sites, though clearly other configurations would be equally viable. All voice telephony traffic is fed through a Session Border Controller for reasons of seeking to maximise the overall integrity of the service. A Session Border Controller is located again at each of the Distribution node sites.

Interconnection with TDM-based networks is via IP-TDM Media Gateways, themselves controlled by Media Gateway Controllers. These have been assumed to be located at each of the Distribution node sites and also at each of the Edge Router node sites.

9.6.2 DWDM

Dense Wavelength Division Multiplexing (DWDM) equipment is currently used within TDC's network for one of three principal reasons:

> To address the need to achieve point-to-point connections over long distances.

> To facilitate the provision of very high bandwidth circuits that have no intrinsic need to utilise equipment within the IP network.

- To provide resilient fibre routings in the event of cable failure.

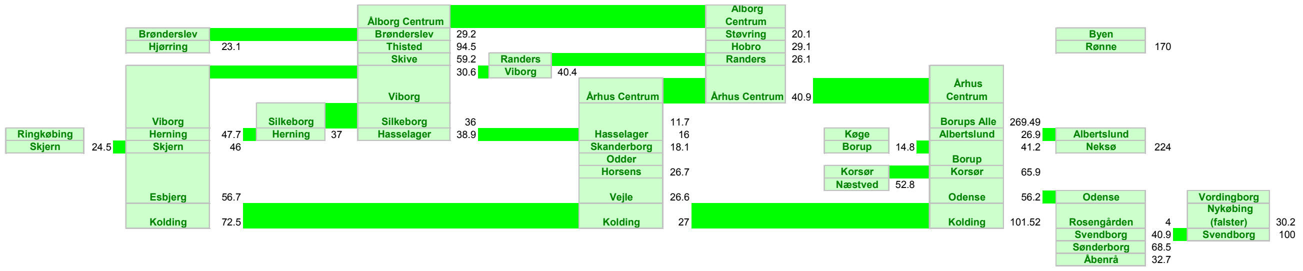
Whilst no specific information was available regarding the second of the above bullets, there is still merit in including DWDM equipment within the revised model in order to address the first bullet. This would in turn better reflect the type of network architecture currently being deployed.

The current distance limit for fibre modules in Layer 2 switches and Layer 3 routers tends to be around 80km, beyond which there is a need to "repeat" or "regenerate" the signal. DWDM equipment typically provides modules that can communicate over greater distances (100km unamplified is assumed in the revised model), but more importantly allows for simple (and cheaper) amplification of all wavelengths carried by a fibre whenever that is necessary without having to turn the optical signal back into an electronic/electrical one first (as would be the case with a conventional repeater/regenerator).

An analysis of all links greater than the 80km limit was conducted and a conceptual network of DWDM links that would cover those routes developed. This is illustrated in the diagram below, which is also included as a worksheet within the core model.

Figure 9.10: DWDM Link Structure

This graphic has been manually created.
The intention is to show a potential DWDM network
All of the sites, links and distances have been manually entered in the graphic, based on the information in I_Trenching_Transit and also the Autoroute mapping



The individual routes were then assessed both in isolation and in aggregate to arrive at a compromise network with DWDM links that addressed the 80km limit whilst seeking to minimise the overall level of investment in DWDM equipment. In this respect, not all of the complete distance for a link greater than 80km was deemed to run over the DWDM network. Instead, the tails of the link were allowed to remain non-DWDM as long as the length of the tails remained within limits.

9.6.3 Equipment configuration

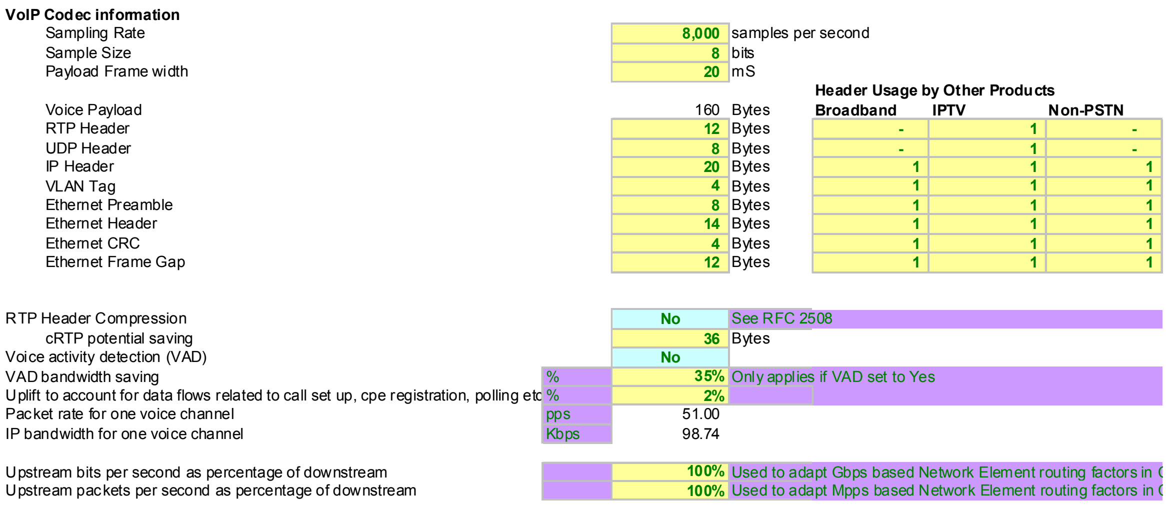
For practical modelling reasons a balance needs to be sought when determining the level of detail to which different types of equipment can be defined and configured within the model. This view is strengthened by the fact that different equipment suppliers can adopt different concepts in the modularity of the equipment. Thus if the level of detail is too great, then the model will tend to only be capable of reflecting a single manufacturer (or indeed a single range from a manufacturer) for each type of equipment modelled.

Diagrams illustrating the level of configuration detail currently contained within the revised model have been included in Appendix B of this report.

9.7 Network demand parameters

As mentioned previously, there is a need to maintain clarity over a number of parameters which are applied to the product demand, along with the routing assumptions, in order to calculate the aggregate and relative levels of traffic flowing across the network. The first issue relates to the conversion of TDM-based voice traffic minutes into IP-based packets, and the parameters included within the model are illustrated below.

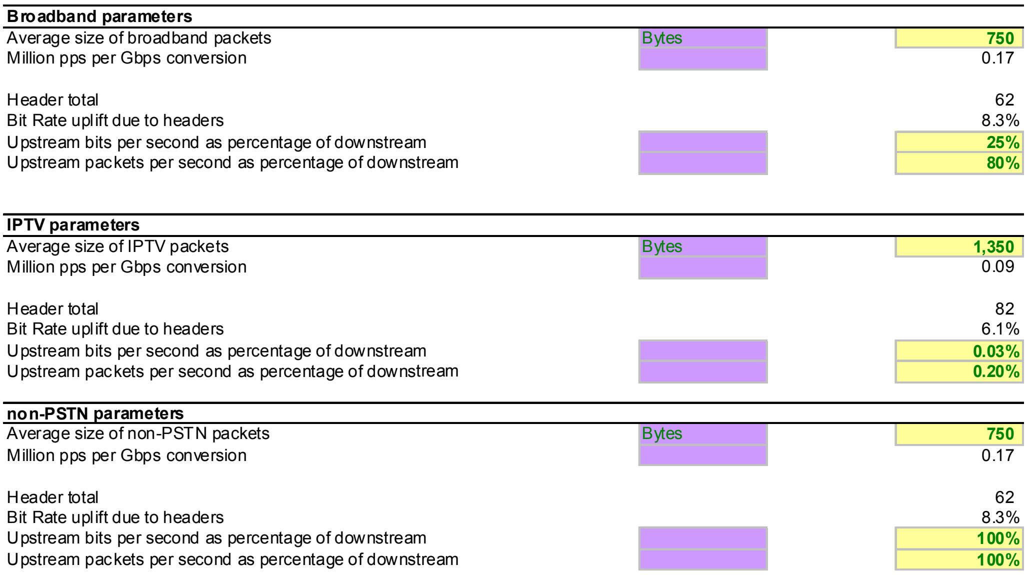
Figure 9.11: Network Parameters – VoIP



VoIP Codec information						
Sampling Rate		8,000	samples per second			
Sample Size		8	bits			
Payload Frame width		20	mS			
				Header Usage by Other Products		
Voice Payload		160	Bytes	**Broadband**	**IPTV**	**Non-PSTN**
RTP Header		12	Bytes	-	1	-
UDP Header		8	Bytes	-	1	-
IP Header		20	Bytes	1	1	1
VLAN Tag		4	Bytes	1	1	1
Ethernet Preamble		8	Bytes	1	1	1
Ethernet Header		14	Bytes	1	1	1
Ethernet CRC		4	Bytes	1	1	1
Ethernet Frame Gap		12	Bytes	1	1	1
RTP Header Compression		No	See RFC 2508			
cRTP potential saving		36	Bytes			
Voice activity detection (VAD)		No				
VAD bandwidth saving	%	35%	Only applies if VAD set to Yes			
Uplift to account for data flows related to call set up, cpe registration, polling etc	%	2%				
Packet rate for one voice channel	pps	51.00				
IP bandwidth for one voice channel	Kbps	98.74				
Upstream bits per second as percentage of downstream		100%	Used to adapt Gbps based Network Element routing factors in			
Upstream packets per second as percentage of downstream		100%	Used to adapt Mpps based Network Element routing factors in			

The second issue relates to the average size (in terms of bytes) of IP packets for one service compared to another. The reasoning behind this is that much of the IP related equipment will process (for example, route) the data on the basis of complete packets rather than individual bytes. The model therefore needs to incorporate a number of "bits per second" to "packets per second" conversion factors such that the costs of relevant equipment can be allocated correctly. The conversion factors included are illustrated below (with the exception of voice telephony, which was shown in Figure 9.11).

Figure 9.12: IP Packets Conversion Factors



Broadband parameters		
Average size of broadband packets	Bytes	750
Million pps per Gbps conversion		0.17
Header total		62
Bit Rate uplift due to headers		8.3%
Upstream bits per second as percentage of downstream		25%
Upstream packets per second as percentage of downstream		80%
IPTV parameters		
Average size of IPTV packets	Bytes	1,350
Million pps per Gbps conversion		0.09
Header total		82
Bit Rate uplift due to headers		6.1%
Upstream bits per second as percentage of downstream		0.03%
Upstream packets per second as percentage of downstream		0.20%
non-PSTN parameters		
Average size of non-PSTN packets	Bytes	750
Million pps per Gbps conversion		0.17
Header total		62
Bit Rate uplift due to headers		8.3%
Upstream bits per second as percentage of downstream		100%
Upstream packets per second as percentage of downstream		100%

Flexibility with regard to the technical parameters of new services is important to enable the model to calculate the network demand resulting from the predicted levels of usage of the various products and services. A good example of this would be for VoIP, where not only can different codecs be used (G.711, G.729 etc) but also IP header packets can be compressed and periods of silence removed from the packet flows. The selected combination of these parameters can have a significant effect on the resultant demand placed on the network.

A case in point is the effect of the relative average size of IP packets on cost allocations based on packets per second rather than bits per second. This can result in differences in the amount of cost allocated to voice telephony services by a factor of between four and five. This highlights the importance of having clear parameters built into the model that the various industry participants can relate to, and therefore comment on, during the various consultation processes.

9.8 Detailed description of cost calculations

9.8.1 Overview

Gross Replacement Costs for exchange equipment are calculated by multiplying the equipment prices in the sheet ‘I_Costs’ with the amount of equipment required. This takes place in worksheet C_Equipment for the active equipment and C_Trenching_Transit and C_Trenching_Local for the trench, duct and fibre infrastructure. Some of these costs are classified as call related, while others are volume or subscriber related.

The necessary transmission capacity in the network covers the demand for voice and data services, leased lines and other services, such as IPTV. The actual demand for each product or service is fed from I_Product_Demand into worksheet C_Route_Table, which converts the demand for products into demand for network elements required to provide these products.

To allocate costs to core services the model gives users the option to select from five different units of usage:

> busy hour calls (BHC)

> busy hour minutes, measured in Erlangs (BHE)

> busy hour Gigabits per second (BH Gbps)

> busy hour Mega packets per second (BH Mpps)

> number of subscribers (Subs).

Using “busy hour minutes” as the allocation key, the product’s average use of a network element is divided by the total volume in minutes through the element. For “busy hour Gigabits per second” (and busy hour Mega packets per second), the model uses each product’s share of total Gigabits per second (or Mega packets per second) traffic in the busy hour as the allocation key, and so on. As described in Section 9.7 above, the model uses conversion factors which allow Mega packets per second to be calculated from Gigabits per second, with the exception of VoIP traffic, where the packets per second is an input parameter dependent on the selected Codec.

The amount of equipment required is further determined by the number of nodes in the TDC network (based on the scorched node assumption) and the distances between them. The distances between nodes have been determined by the Autoroute trenching analysis, as described in Section 9.5 above. The results are captured in the trenching input sheets in the core model, which feed into C_Trenching_Transit and C_Trenching_Local where the cost of trenching and cabling are computed. The cost of other network elements, such as routers and switches, is calculated in C_Equipment. The results from the equipment and transmission cost sheets are summed up in ‘O_Consolidation’, which feeds into the Consolidation model.

9.8.2 Cost input

Costs for different sizes of network elements are estimated in order to increase model accuracy, flexibility and to allow creditable cost-volume relationships. Equipment cost inputs are broken down into different component size categories as far as practical. Furthermore, costs for special products, such as IN services, are included (though for IN services, these are included within worksheet I_FA_Costs in the consolidation model).

Indirect costs for security, air conditioning, power supply, etc. are defined as common exchange costs. The following allocation keys have been applied in order to attribute common costs:

> Power supply unit – average power consumption is used as an allocation key, because the cost category has a distinct cost driver in power consumption. Thus, the dimensioning of the power supply unit depends on the total power

consumption for the modelled equipment in an exchange (average kW per type of exchange).

- Air conditioning – the dimensioning of the heat development in the exchange. This is partially dependent on the size of the room in which the equipment is placed and partially the heat developed by the equipment (measured as amount of kWh). Therefore, power consumption per square meter has been used as allocation key (average kW/m^2 per type of exchange).
- Security, security systems, site preparation and maintenance – with regards to site preparation and maintenance it is fair to assume that these are dependent on the demand for space. By contrast, it is not fair to assume that there is a distinct cost driver for allocation of cost to security guards and security systems. In order to increase model transparency and avoid unnecessary complexity, these cost categories are allocated according to spacing requirements (m^2). Security guard, security system, site preparation and site maintenance are thereby allocated in the same fashion as in the previous version of the hybrid model.

Costs that relate to trenching, ducting, fibre and IP network equipment are specified with a wide range of types. This enables the costs to be determined based on a realistic profile of the different elements required. For example trenching costs vary by the surface type – therefore, different unit costs are specified for each surface. Also, there is a profile determining the likely amount of each type of trenching required.

9.8.3 Cost allocation methods

9.8.3.1 Cost allocation between Core and Access

The allocation of costs from the core network model to access products takes place in one of two ways.

For active equipment and the MDFs, the costs are allocated to access-related network elements and then the cost of these elements is allocated to the relevant access products in the consolidation model.

For trench, duct and fibre, trench sharing parameters defined in worksheet I_Technical are applied to the costs at the bottom of worksheets C_Trenching_Transit and C_Trenching_Local in order to exclude from the core model costs not related to core products. The total amounts for shared trenching also feed through to the access model so that they can be taken into account there also.

9.8.3.2 Allocation of shared costs for other services

The IP network is dimensioned to carry a certain amount of traffic which is not modelled explicitly, such as leased lines, mobile or cable TV. This has been grouped together under the category of “non-PSTN traffic” and should carry a reasonable share of the cost of using the transmission network. This issue has been addressed in the core model by modelling one or more “aggregated” non-PSTN products.

The key to allocation of transmission costs driven by the network is based on the total traffic, including a possible positive growth rate. In practice this means that costs equivalent to the traffic in the costing year (i.e. the maximum traffic, because growth is negative) are allocated to modelled products.

With regards to other transmission and infrastructure costs, these are allocated on the basis of the actual traffic in the costing year. Infrastructure costs are driven primarily by cable length and the number of nodes and not directly by traffic. Therefore, these are roughly fixed in the long run. For these cost categories, cost is allocated between modelled products and non-PSTN services based on the actual volumes in the costing year (and not volumes incl. growth).

9.8.3.3 Allocation of shared infrastructure costs

The amount of core trench shared with the access network is calculated in order to determine the shared costs. Allocation is based on the percentage of shared length of trench and a percentage of cost sharing (for the shared length of trench), which is an input in the I_Technical sheet. Costs for land-based access transmission is calculated directly in the access model. As a consequence, these costs have been removed in the core model in order to avoid double counting.

9.8.3.4 Allocation of shared co-location costs

There is an element of sharing of site costs with other operators when sites are co-located. Therefore, these shared site costs, including sharing of space and air conditioning, are allocated to co-location.

9.8.4 Calculation of service costs

Service costs are calculated in the consolidation model. The use of network elements has been determined for a given service by multiplying the utilisation of each network element with the traffic volume in busy hour. A summation of the utilisation for all services results in the total utilisation of the network element in busy hour. This represents the minimum network capacity (and is used for network dimensioning, as described above).

Each service’s share of minutes in busy hour of minutes for all services have been applied as allocation key for allocating costs to each services. Due to the fact that the “busy hour” conversion is the same for all services, this allocation key corresponds to using the service’s average usage of the network element divided by the total volume in minutes using the element.

However, costs have been annualised in order to allocate costs to services. This is done in the consolidation model, where annualised GRCs and installation costs are added to operating costs (where the FA correction has been applied) in order to derive the annual cost. Cost of capital, asset lifetime and the price development are combined in this calculation. As a final step, the costs of services are “uplifted” with one or more mark-ups for overhead and costs related to working capital.

9.9 How to use the Core Model

9.9.1 Model scope

The purpose of the core model is to calculate the resources required to build a switching and transmission network for an operator of the size and scope of TDC. As discussed previously, this is based on an all IP network structure rather than the existing mix of platforms in the TDC network. The main components of this are:

> Cost of IP switching and routing equipment

> Cost of sites

> Cost of trenching

> Cost of transmission infrastructure

> Certain types of access network costs.

In relation to the last of these components, the core model calculates the costs of that part of the access network located at exchange sites, primarily line cards and MDF equipment.

The core model incorporates a large number of nodes (physical sites), interconnected by transmission paths. The majority of these nodes are considered to form part of the core network, under the scorched node principle. However, where DSLAMs or MSANs have been moved from the local exchange to street cabinets under a next generation access scenario, these are included in the access network (classified as Active Street Cabinets).

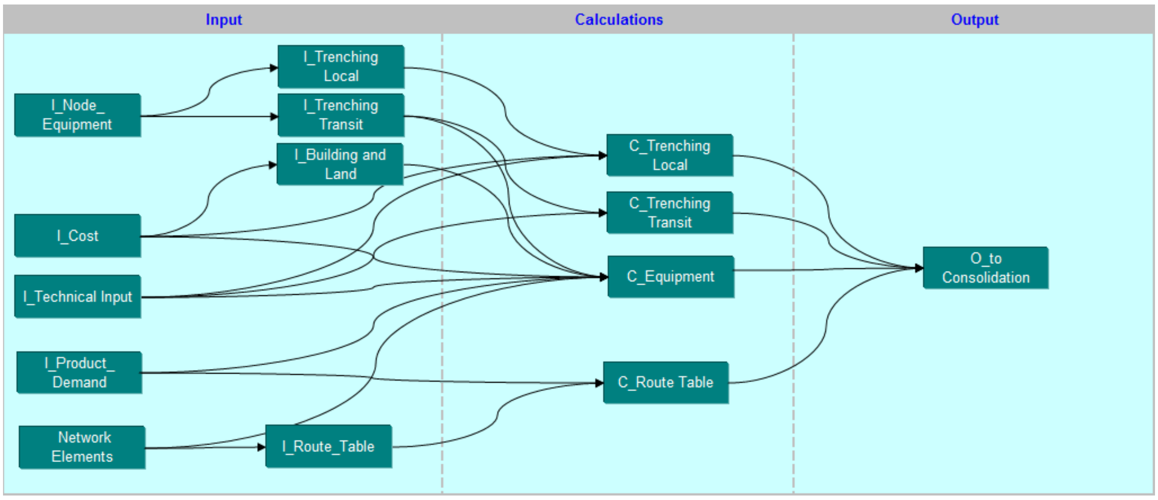
After calculating the resources needed to build this network, the model uses the results to calculate the capital equipment cost of those resources, and the annual operating cost of such a network. The model also removes (from the main calculation flow) the costs that are attributable to non-relevant services and calculates the costs of some elements of the access network (MDF, line-cards and other subscriber related costs).

The core model does not calculate the actual product costs. Instead, outputs in the core model are linked to the consolidation model, where these calculations are carried out.

9.9.2 Model structure

For ease of navigation, the core model includes a map of all major information flows between them. This is reproduced in the diagram below.

Figure 9.13: Core Model – Navigation Map



The user can click on any of the buttons on the map to jump straight to the relevant worksheet. Each subsidiary worksheet has a "Model Overview" button, which the user can click on to return to the navigation map. Most sheets also have a drop-down menu below the Model Overview button to take the user to different tables contained in each worksheet. Note that it is still possible to navigate the model using the sheet tabs.

9.9.3 Start-up

There are two ways to open the Core model. The first method, which is recommended, is to first open the Consolidation model and then select the "Open Linked Sheets" option, which will open all the individual worksheets of the Hybrid Model. This ensures that linked information is updated automatically and links are preserved when the model is saved under a different filename. The user should also be aware that the Excel auditing tools will trace precedent and dependent cells only for workbooks that are currently open.

Alternatively, the user may open the Core model directly from the file directory. “Enable macros” when asked, unless the file is from an uncertain (untrusted) source. There may be a message asking whether to update links. Such updates are performed automatically on recalculation if other parts of the model are open, otherwise links should be updated if other models have been changed and are located in the same directory. There is an introductory message that warns the user that older versions of Excel may not provide full functionality.

9.9.4 Understanding the model

The recommended approach to gaining an understanding of the model is to work through each sheet in turn, starting with inputs, moving to calculations and then outputs. One way to improve understanding is to edit the input data, recalculate and investigate the effect of the changes on the results. These can be easily checked in the sensitivity analysis sheet in the Consolidation model.

The final costs for all modelled core products are shown in the output and results sheets of the Consolidation model.

A sheet-by-sheet description of the Core model is provided in Appendix C of this document.

10. The Co-location Model, incl. Other Services

>

This chapter sets out to describe the general characteristics of the co-location model and the modelling of other services in the hybrid model.

Other services cover the services regulated by LRAIC, which do not directly use the access or core network or which are related to specific work processes.

10.1 Co-location services

10.1.1 Definition

The Executive Order Number 930 (Section 1(1)) refers to co-location as the "sharing of facilities such as buildings, exchange equipment, etc." and includes co-location as an interconnection product linked to the three other interconnection products, namely 1) exchange of traffic; 2) lease of infrastructure capacity; and 3) service provider access.

Section 1(7) of the Executive Order defines "sharing of facilities such as buildings, exchange equipment, etc." as:

> 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 hybrid model does not estimate the costs of all of the different types of co-location. LRAIC-based costs for co-location are limited to costs associated with sharing facilities such as buildings and exchange equipment, in accordance with section 6(1) and 7(2) regarding:

> agreements on exchange of traffic; and

> the lease of non-equipped infrastructure sections in the subscriber network.

The responsibilities and obligations with regard to co-location are described in detail in *Agreement on Co-location between TDC Totalløsninger A/S and Company X.*

10.1.1.1 Co-location for the exchange of traffic

For co-location related to exchange of traffic, the "access seeker" rents space on the "access provider's" premises to interconnect with that operator. In the process, the access seeker installs its own exchange, if needed, and its own interconnection equipment.

The access to a core network for the purpose of exchanging traffic is usually considered under three headings:

> Physical co-location, where the access seeker chooses, supplies, installs and operates the equipment needed on the premises of the access provider, and therefore, access has to be provided for the staff of the access seeker.

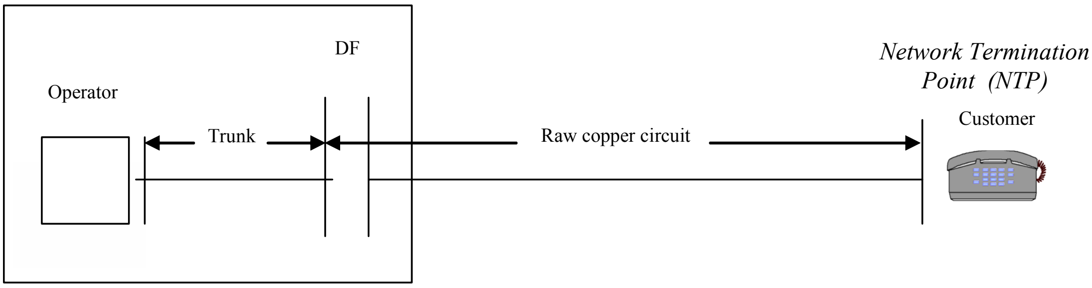
> Managed co-location (sometimes referred to as virtual co-location), where the access seeker chooses and supplies the equipment, but installation, operation and maintenance is carried out by the access provider.

> Direct connection, where no additional equipment is needed.

10.1.1.2 Co-location for raw copper

With regard to co-location in connection with raw copper, the access seeker will rent space on the access provider's premises in order to install and operate its own equipment, usually xDSL, to be used in connection with the local loop. This is illustrated in Figure 10.1.

Figure 10.1: Co-location



Typically, there are two different options:

> *Physical co-location*. The operator can physically locate its equipment at a site belonging to the SMP operator containing an MDF. An internal "tie-cable", supplied by the SMP operator, connects the chosen subscriber lines in the MDF with the operator's equipment – typically a Digital Subscriber Line Access Multiplexer (DSLAM). For security reasons, it is necessary to keep the location of the two Distribution Frames separated.[7].

> *Virtual co-location.* In cases where it is not possible for the SMP operator to physically locate equipment at a certain site, the SMP operator is obliged to provide the necessary transmission capacity free of charge from the Operator's premises and to the building of the co-location.

10.1.2 Modelling Co-location

The primary purpose of the co-location model is to cost existing co-location services used for access to the unbundled loop. Therefore the model considers costs that would be borne by the SMP operator in the event of offering co-location services at appropriate sites in the network.

Unlike services in the core and access network, co-location services consist of relatively few cost categories. These can be divided into costs that are specific to a particular service and into costs that are shared with other services.

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[7] Examples of demarcations include solid walls, lockable cabinets or wire meshes.

Services in the core and access network are costed by combining costs from a pool of cost categories using a routing style allocation table technique. This is not the case with co-location products. These are mostly standalone “sub-products” that may be combined by the operator who demands co-location. Therefore, although the co-location model is simpler in structure compared to both the core and access models, special care must be taken with the co-location model in order to model and capture costs at a sufficiently granular level.

One of the most important differences between the co-location model and the access and core models is that the co-location model does not model direct network related costs. Instead, the model estimates a range of “indirect” network costs and bundles them to form different co-location products and services.

The modelled co-location services are:

> Co-location space (indoor m² and outdoor m²)

> Rack space

> Power supply (48 VDC 16 A , 48 VDC 30 A, 48 VDC 60 A and 230 VAC 10 A)

> Cables (8, 24, 100 and 300 pairs, and in-span).

10.1.2.1 Types of co-location services and costs

The most important co-location services for all “access seekers” are indoor co-location space and rack space. Power supply and cables can be seen as additional services. For power supply there are different choices and combinations of 48 VDC and 230 VDC connected to the power supply of the available buildings. It is also possible for “access seekers” to order their own power supply and meters from the utility companies. Similarly for cabling, the choices are between different possibilities depending on the “access seeker’s” demand for capacity and on whether the co-location is used for interconnection or raw copper.

Another difference between the two main co-location services and the additional services is that a lot of the cost related to the main services (e.g. space) is calculated in coherence with similar demands in other parts of the hybrid model.

Conversely, the additional services have very few cost categories and, moreover, these are solely related to the specific co-location service. The cost categories typically consist of material and/or time spent on installation and order processing.

10.1.2.2 Demand

Demand data has been estimated by NITA on the basis of data provided by TDC. The data is updated on a yearly basis.

The demand volumes for all services are used to calculate the total costs for each service, as totals are used as output for the consolidation model. Hence, the co-location model includes specific input cells for demand volumes for each service.

10.1.3 Cost categories

10.1.3.1 Building and land

The costs for indoor and outdoor co-location space are calculated in the core model and split into two subcategories, internal and external. The main reason for this is that land and buildings have different asset lives and price trends. Another reason is the need for modelling outdoor co-location space.

Building costs are based on public valuations of TDC's buildings, adjusted to reflect current market trends. The methodology for evaluating building costs is described in detail in Section 3.5.

The estimated costs per m^2 for building and land for indoor and outdoor co-location are shown in the table below:

Table 10.1: Indoor and Outdoor Co-location Space excl. Mark-up

Geotype	Annual cost per indoor m^2	Annual cost per outdoor m^2
City	DKK 765	DKK 210
Urban	DKK 463	DKK 33
Rural A	DKK 361	DKK 12
Rural B	DKK 375	DKK 6

10.1.3.2 Common site cost

Common site costs are calculated in the core model and allocated to co-location in the consolidation model. Therefore, these costs are not shown in the actual co-location model.

Common site costs include the following cost categories related to exchange sites:

- Power supply
- Air conditioning
- Security system
- Site preparation
- Site maintenance
- Security guard

Each cost category contains the calculated annual capital expenses (depreciation and cost of capital) for equipment, materials and installation plus the annual operating expenses for maintenance, buildings and power consumption. As an example, the cost of air conditioning, including annual power consumption, related to co-location space is included in the site cost category of "air conditioning unit".

For the allocation of common site costs, the following allocation keys are used:

- Power supply unit – average power requirement (kWh)
- Air conditioning unit – average power requirement per m^2 (kWh/m^2 per exchange type)
- Security guard, security system, site preparation and site maintenance – space requirement (m^2)

Please note that costs of power supply are not allocated to the common site costs for co-location. The costs for power supply are modelled separately in the co-location model.

10.1.3.3 Rack space

The price of rack space covers the cost of preparing indoor co-location space for racks and cables. Rack space includes two cost categories:

- Room fit-out, including costs for floor, lighting, fire alarm and planning.
- Cable trenches, including costs for the actual trenches, cabling and planning.

The costs for the two categories are shown per rack space. In previous versions of the model, rack space was based on a standard size of 1.5 m^2. However, in practice in technical houses there is not sufficient space for an additional rack. TDC has, however, indicated that there will possibly be space in TDC's racks that the other operators will be able to use. Therefore, a new product "rack space in a technical house" has been added. This product is defined as 1/5 of a standard half depth ETSI rack (600x300x2200 mm).

Two charges have been included:

- A one-off charge covering (1/5 of) room fitting + cable trenching (as in the existing normal co-location product installation of co-location).
- A recurring charge covering (1/5 of) space for co-location (assuming that a rack (600x600x2200 mm) covers 1,5 m2, a rack of half the size (600x300x2200 mm) is assumed to cover 0,75 m2) + (1/5 of) an ETSI standard rack (600x300x2200 mm).

For room fit-out, the cost of lighting is included in the common site costs. The ongoing operating expenses for air conditioning are also included in the common site costs. Finally, the cost of fire alarms is modelled separately (but as part of room fit-out) with a cost of materials of DKK 64 per rack and installation costs of 1/3 hour for a technician per rack space.

On the basis of the above inputs, NITA has estimated the costs for room fit-out (excl. lighting and fire alarms) at DKK 2,500 and for cable trenches at DKK 7,000 per rack space.

10.1.4 Power supply

NITA has individually modelled the different costs related to installation and the annual consumption for four power supply services.

For each of these, the following parameters are defined:

- Materials
- Number of hours for technicians (physical installation)
- Annual consumption in kWh.

A separate category calculates the cost of order processing, exchange work and transport time to exchange.

For all power supply services the cost per kWh is applied.

Given the cost of materials and hourly salary costs for administrative and technical staff, the total installation cost for each power supply service can be calculated. In addition, given the cost per kWh and an assumption of an average power consumption, it is possible to calculate the ongoing annual cost.

The results for power supply in the hybrid model are split between a one-off cost and an annual cost for the power supplies Power 48 VDC 16 A, Power 48 VDC 30 A , Power 48 VDC 60 A, Power 230 VAC 10 A and Power 230 VAC service socket.

In response to an industry consultation in 2008, the service “shift to another power-product” have been incorporated into the revised Hybrid Model.

10.1.4.1 Cables

NITA has separately modelled the costs related to materials and installation of the different cabling services (100 and 300 pair copper, 8 and 24 pair coax plus in-span fibre). For each of the cabling services, the following parameters are defined:

- Cable increment (to allow for wastage during installation)
- Cable price (DKK/m)
- Digging (DKK/m), if any at all
- Administration (order handling, etc.) (hours)
- Technician (physical installation) (hours)
- Other installation costs, e.g. LSA

With the assumed cost per hour for administrative and technical staff, it is possible to estimate the total installation costs for cables and the cost of the cables. It is assumed that the installation cost is independent of the length of the cable, whereas the cost of the actual cable is dependent upon the length (in 10m increments). In addition, it is assumed that there are no annual costs.

Where possible, the prices of cables and digging from the access model are used as cost inputs (e.g. this is not possible for coax 8 and 24 pair cables). Thus, the model contains links to information in the access model (via the I_Interface sheet).

The co-location model computes the following outputs for cable costs: the cost per 10m cable, and a one-off cost, for the cable types 8 pair coax, 24 pair coax, 100 pair copper, 300 pair copper and in-span 48 fibre.

10.1.4.2 Overhead

Besides the directly modelled costs, NITA has applied a mark-up to all co-location services to take into account the relevant overhead costs not modelled explicitly. The mark-up is not part of the co-location model, but is added to the cost of each service in the consolidation model. Overhead costs are described in Chapter 3 of this report.

For co-location it is assumed that the net cost of working capital is zero. This is due to the fact that the price for co-location per m2 is paid in advance, whereas consumption is paid in arrears. As for the one-off costs and costs of establishment caused by co-location, TDC can ask for payment up-front. It is assumed that in total these items balance each other out.

10.2 Other services in the Hybrid Model

As mentioned previously, some of the services under LRAIC regulation are not modelled in the hybrid access or core models. This is because the services make use of neither the access nor the core network and/or they are services related to very specific work processes.

This section describes how NITA has estimated the costs of these services from a pure bottom-up perspective with focus on the specific activities relevant for the different services.

The services include:

Raw copper and shared raw copper (full loop and sub-loop)

- New installation – Unassisted
- New installation – Engineer assisted
- Reactivated installation – Unassisted
- Reactivated installation – Engineer assisted
- Request
- New setup
- Physical rearrangement
- Change of trunk number
- Technical assistance
- Cancellation fee II
- Calculation of attenuation on the line
- Unproductive fault handling
- Migration to full/shared loop

Bitstream access (BSA)

- New installation – Unassisted
- New installation – Engineer assisted
- Reactivated installation – Unassisted
- Reactivated installation – Engineer assisted
- Additional work for new installation for BSA without co-production
- Conversion from BSA on line to BSA without co-production
- Conversion from ATM BSA to eBSA
- Installation of Multichannel
- Change of speed BSA
- Migration to the different BSA-products (from BSA without telephony, from raw copper full loop, from shared raw copper full loop)

Exchange of traffic

- Establishment of pre-selection
- Establishment and operation of local points of interconnect
- Establishment and operation of (2Mbit/s) interconnection capacity

Supervised access

Most of these services mainly consist of the operating costs and NITA has decided to estimate the costs of the services separately. The calculations are based on the activities connected to the delivery of these services. The description of the tasks is based on information from the LRAIC Working Group and TDC plus NITA's reading of TDC's standard offers.

In response to an industry consultation in 2008 and SMP-decision on market 4, a number of ancillary products have been incorporated into the revised Hybrid Model. These are:

> Ancillary products relating to installation of LLU (unproductive visit by technician, cancellation fee, calculation of attenuation on the line, unproductive fault handling and migration to full loop)

> Ancillary products relating to BSA (conversion from ATM BSA to eBSA, installation of Multichannel, change of speed of BSA, migration to the different BSA-products)

> Multiplexing of terminating segments of leased lines

> Installation of street cabinet backhaul - access to duct

> Installation of street cabinet backhaul – dark fiber

> Installation of bitstream transport

- Installation of Multicast
- Products relating to carrier pre-selection.

In line with NITA’s decision on the transit market (Market 10), regional POI are no longer price-regulated in accordance with LRAIC and have therefore been removed from the co-location model.

Because of the lack of detail and documentation of the available information, NITA has to some extent made an assessment of a number of inputs.

10.2.1 General assumptions about hourly rate and overhead cost

When estimating the costs of individual services, NITA has generally differentiated between two groups of activities – those related to order processing and those related to carrying out the order.

Furthermore, when modelling the cost of each service, a distinction is made between the time spent by administrative personnel, academic (professional) personnel, and technicians.

To calculate the cost of delivering the service, the estimated time spent is multiplied by the hourly rate outlined in the LRAIC model. The hourly rates for administrative personnel, academic personnel, and technicians are shown in Chapter 3. For co-location, NITA uses the same hourly rate as in the access model.

As for other co-location services, NITA has applied a mark-up to ancillary products to take account of relevant overheads. This is added in the consolidation model.

10.2.2 Handling double-counting of order processing and transport

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

The following principles have been applied:

- If a task in relation to service B is always carried out as an extension of a task related to service A, and service A is a technical pre-requisite for service B, then service B should only contain the incremental cost derived from the extra work process undertaken in relation to service B. This implies that no party can be brought 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.

In the actual model, the allocations are made by applying a weighting factor. This is shown in column G of the I_Resource sheet.

10.2.3 Raw copper and shared raw copper

10.2.3.1 General assumptions

Order processing is assumed to be automated to a substantial extent. Receipt of orders happens automatically and no time is spent on receiving the order via, e.g. phone, other than in exceptional cases (system breakdown, etc.).

Tasks at the exchanges are assumed to be coordinated by the supplier with the tasks at the end-user premises. This implies that the supplier makes use of large-scale operation advantages that naturally come from the delivery of different services to both their own and other customers.

Transport is divided into time spent on transport following the trench to the end-user and the time spent on transport to the exchange, etc. The purpose is to avoid double-counting when the same time for transport is shared between several orders. This could be the installation of raw copper/shared raw copper and installation of NTP when installation of NTP is included in an order.

Installation of raw copper/shared raw copper and installation of NTPs are independent of each other in the sense that installation of NTPs does not require installation of raw copper/shared raw copper. Thus, installation of NTPs is billed separately at the price determined by LRAIC and not at the incremental cost of simultaneous installation.

10.2.3.2 New Installation – Unassisted/Engineer assisted

Related to the installation of raw copper and shared raw copper, for both full loops and sub-loops, the following cost driving activities should be considered:

> Processing of order – consists of cost of ordering before and after the physical coupling in the exchange, e.g. reception, confirmation, and putting the order into the system, and is considered an automatic process.

> Physical coupling in exchange – includes re-arrangement of cross thread plus establishment of connection from the wiring board via the MDF.

> Transport time to exchange – covers the time spent on transportation to and from the exchange (when the exchanges are un-manned)

> Visit at end user – contains the examinations of the connection at the end-user and potential changes (e.g. internal cross connections in the MDF) that are undertaken from the exchange to the end-user. This activity is only undertaken when installation is assisted by engineer.

> Transport time to end-user – covers the time spent on transport between the exchange and the end-user

As mentioned earlier, the revised Hybrid Model now also includes costs for activities that are ultimately unproductive, such as an unsuccessful visit by a technician or unsuccessful fault handling.

It should be noticed that costs related to examination and reservation of available trenches are included in the annual price of raw copper.

Because shared raw copper by definition is always installed on a copper pair which is already in use, the estimated cost only allows a limited amount of time in connection with a visit at the end-user. Raw copper, on the other hand, is typically installed on unused capacity and, therefore, transport to the end-user is included. In addition, transport to unmanned exchanges is included.

10.2.3.3 Inquiry

Inquiries are billed on an hourly basis and the rate is the LRAIC price for technicians. Inquiry concerning raw copper and shared raw copper is the hourly rate for a technician plus overhead, which is added in the consolidation model.

10.2.3.4 New setup

New setup of raw copper and shared raw copper is seen as services that are carried out in extension of installation of raw copper and shared raw copper. In this respect, NITA has included the following cost driving activities:

- Processing of order – is estimated to be covered by the ordering of the raw copper or shared raw copper and, thus, it only contains the extra time spent in connection with the new setup.

- Physical coupling in exchange – includes coupling in the access network in connection with the installation of raw copper and shared raw copper and transport, e.g. when a wire has to be moved from a multiplexer to raw copper or be pieced together via several stretches.

- Time for transport covers the transport to and from the exchange, but because new setup is a service that is carried out in connection with the installation, the transport is already covered by this service. Transportation is widely covered by the installation.

Additionally, it is understood that the technicians are based locally, which also reduces the need for transport. Therefore, a correction for double-counting of time for transport (the share covered by new setup) is made in relation to the services installation of raw copper/shared raw copper and other conditions reducing the need for transportation.

10.2.3.5 Physical rearrangement

Physical rearrangement of raw copper is regarded as a service that is carried out as an extension of installation of raw copper. In that light, NITA has found the following cost driving activities:

- Processing of order – is estimated to be covered by the ordering of the raw copper or shared raw copper and, thus, it only contains the extra time spent in connection with the physical rearrangement.

- Physical coupling in exchange – covers the actual physical rearrangement from one pair to another connected to the installation of raw copper.

> Time for transport covers the transport to and from the exchange, but as physical re-arrangement is a service that is carried out in connection with the installation, the transport is already covered by this service. Transportation is widely covered by the installation.

Additionally, it is understood that the technicians are based locally which also reduces the need for transport. Therefore, a correction for double counting of time for transport (the share covered by physical rearrangement) is done in relation to the services installation of raw copper/shared raw copper and other conditions that reduce the need for transportation.

10.2.3.6 Change of trunk number

The cost of change of trunk number is modelled from the following categories:

1) *Processing of order* – consists of cost of ordering before and after the physical coupling in the exchange, e.g. reception, putting the order into the system, and re-registration of trench.
2) *Physical coupling in exchange* – covers actually carrying out the order on the exchange, including connection the cross thread, coupling to trunk and securing that there is connection to the operator's co-location.
3) *Transportation* – includes the transport to and from the exchange. Time for transport includes transport to the un-manned exchanges. It can be reduced when the technician can carry out orders at one exchange at the same time.

10.2.3.7 Visit by technician, unproductive visit by technician

When a visit by a technician is billed by the hour and is carried out within normal working hours, the hourly rate for technicians (incl. overhead) calculated in the LRAIC model is used.

Generally, the LRAIC calculated hourly rate for technicians is the standard offer for raw copper and shared raw copper.

10.2.3.8 Cancellation fee II

According to TDC's standard offer for raw copper and shared raw copper, a cancellation fee II will be paid if an operator cancels an order after receipt of order confirmation with the date of TDC customer service until no later than midday 12:00 the working day before the date of delivery.

10.2.3.9 Calculation of attenuation on the line

An attenuation calculation, which is theoretical calculation of the wire pair attenuation on the basis of TDC's cable, can be ordered either when carrying out an installation of raw copper or an already established raw copper connection.

10.2.3.10 Migration to raw copper/shared copper

When sought a conversion from shared raw copper to administrative raw copper there is a administrative charge paid. The following migration services to LLU is calculated.

1. Migration to raw copper, full loop
- from BSA (visit and transport to the end customer is not necessary).
- from shared raw copper (only order processing necessary)

2. Migration to shared raw copper, full loop
- from BSA with PSTN (visit and transport to the end customer is not necessary).

3. Migration to raw copper, sub loop
- from BSA (identical to new installation – unassisted)
- from raw copper, full loop (identical to new installation – unassisted)
- from shared raw copper, full loop (identical to new installation – unassisted)
- from shared raw copper sub loop (visit and transport to the end customer is not necessary).

4. Migration to shared raw copper, sub loop
- from BSA (same as new installation – unassisted)
- from raw copper section (same as new installation – unassisted)

10.2.3.11 Unproductive fault handling

In case of fault handling and when the technician can not get access to the installation, for instance when the end customer are not at home, a charge is applied.

10.2.4 BSA installation

The costs of BSA installation are broken down into the following individual products or services:

> New Installation- Unassisted

> New Installation- Engineer assisted

> Reactivated installation- Unassisted

> Reactivated installation- Engineer assisted

> Additional work for a new installation of "BSA without co-production

> Conversion from BSA on line to BSA without co-production

> Conversion from ATM BSA to eBSA

> Installation of Multichannel

> Change of speed BSA

> Migration to the different BSA products (from BSA without telephony, from raw copper full loop, from shared raw copper full loop)

For BSA new installation and re-activation, NITA decided that the costs related to the DSLAM (including the line card) should not be allocated to installation but recovered via the recurring fee. Thus the costs included in these products are limited to end-customer specific administrative tasks and to time charges for an engineer visit, where appropriate.

10.2.5 Pre-selection

NITA has identified the following relevant tasks connected to establishing pre-selection for a new customer:

> Processing of order – includes all costs attached to pre-selection, including processing of order, confirmation, and registration of order. It also covers the costs related to the implementation of pre-selection. The process is assumed to be fully automatic.

> Customer service – covers the cost arising from customers calling 147 (fault complaints).

A mark-up is added to these costs to cover overhead (e.g. IT systems).

10.2.6 Implementation of prefix for pre-selection

When implementing or changing a operator prefix for pre-selection a charge per exchange is applied. The following tasks is relevant for implementing prefix.

> Processing of order – includes all costs attached to operator prefix, including processing of order, confirmation, and registration of order.

> Technician – covers the cost related to the implementation of operator prefix.

10.2.7 Interconnection

The hybrid model draws on the main activities linked to the different types of cost of points of interconnect. Furthermore, the hybrid model shows both the costs of installing points of interconnect and their operating costs.

Local points of interconnect include the estimated cost of the service interconnection bundles that is included as an individual element in TDC's standard offers. An interconnection bundle is defined as group of lines or 30-groups connecting the same pair of exchanges with similar technical environment such as signalling and direction. However, because TDC previously informed NITA that normally only one interconnection bundle per point of interconnect is installed, NITA has not found it reasonable to investigate this issue further.

10.2.7.1 Local Point of Interconnect (incl. interconnection bundles)

Installation

The cost of installing a local point of interconnect covers the following activities:

> *Processing of order* – includes receiving forms for traffic orders and orders for interconnect and transmission, putting orders in Columbus and processing the confirmation.

> *Changes in the network* – includes drawing up the signalling parameters, operation and maintenance (e.g. surveillance), functionality and traffic data, including programming. This is assumed as tasks for technicians.

Annual cost

The annual cost of a local point of interconnection covers the following activities:

> Administration – including both administrative personnel (e.g. billing, secretaries) and academic personnel (case processing).

> Network planning – contains operating and maintenance tasks such as individual repairs and "common" goods such as development of the network.

> Furthermore, a non-pay operating cost is modelled for the necessary expansion of the NMC system. This is calculated as a direct annual costs equal to the licence fee for the NMC system.

10.2.7.2 Interconnection capacity

Interconnection capacity is a 2 Mbit/s port ("30-group") in the co-location exchange.

Installation

The cost drivers for installation of interconnection capacity are:

> Processing of order – includes tasks for administrative staff, e.g. processing of order, confirmation, registration of order, and ordering hardware.

> Mounting of hardware, also including the physical coupling done by a technician.

Annual Cost

The annual cost of interconnection capacity consists of two types of costs:

> An annualised cost of ETC hardware (trunk port).

> Maintenance costs.

The price of ETC hardware is included in the model via a link to the core model where the price of trunk cards is included as an input. The annual cost of ETC hardware is annualised based on an asset life of 10 years, with the same price trend as for ports.

The maintenance costs are linked to calculations in the core mode, where they are calculated with the annual cost.

10.2.8 Supervised access (with notice)

Supervised access with the participation of a technician is charged by the hour, using the hourly rate for technicians including overhead from the LRAIC model. The service is only modelled as the standard service within normal working hours and is thus calculated on the basis of salary costs for normal working hours.

The hybrid model also includes costs for supervised access for co-location. The cost is the hourly rate for a technician plus a mark-up for common cost.

10.3 How to use the Co-location Model

10.3.1 Model scope

The co-location model calculates the resources required to offer co-location services in the fixed network at exchanges or technical houses. The main components of this are:

- Site costs
- Cabling costs
- Power, cooling and ventilation.

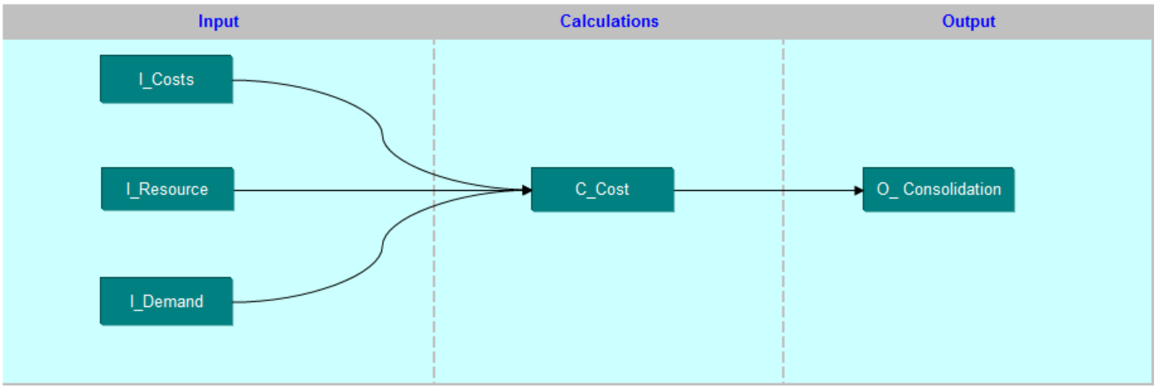
After calculating the resources needed to offer these services, the model uses the results to calculate the capital cost of those resources, and the annual operating costs of such services.

The Co-location model further contains a range of products which do not lend themselves to the modelling approach used in the Core and Access models. These include services related to installation of end-user equipment, order processing and the provision of raw or shared copper, whose costs derive largely from the use of manpower. These "other services" are discussed in detail in Section 10.2 above.

10.3.2 Model structure

For ease of navigation, the Co-location model includes a map of all major information flows between them. This is reproduced in the diagram below.

Figure 10.2: Co-location Model – Navigation Map



The user can click on any of the buttons on the map to jump straight to the relevant worksheet. Each subsidiary worksheet has a "Model Overview" button, which the user can click on to return to the navigation map. Most sheets also have a drop-down menu below the Model Overview button to take the user to different tables contained in each worksheet. Note that it is still possible to navigate the model using the sheet tabs.

10.3.3 Start-up

There are two ways to open the Co-location model. The first method, which is recommended, is to first open the Consolidation model and then select the "Open Linked Sheets" option, which will open all the individual worksheets of the Hybrid Model. This ensures that linked information is updated automatically and links are preserved when the model is saved under a different filename. The user should also be aware that the Excel auditing tools will trace precedent and dependent cells only for workbooks that are currently open.

Alternatively, the user may open the Co-location model directly from the file directory. “Enable macros” when asked, unless the file is from an uncertain (untrusted) source. There may be a message asking whether to update links. Such updates are performed automatically on recalculation if other parts of the model are open, otherwise links should be updated if other models have been changed and are located in the same directory. There is an introductory message that warns the user that older versions of Excel may not provide full functionality.

10.3.4 Understanding the model

The recommended approach to gaining an understanding of the model is to work through each sheet in turn, starting with inputs, moving to calculations and then outputs. One way to improve understanding is to edit the input data, recalculate and investigate the effect of the changes on the results. These can be easily checked in the sensitivity analysis sheet in the Consolidation model.

The final costs for all modelled co-location and other products are shown in the output and results sheets of the Consolidation model.

A sheet-by-sheet description of the Co-location model is provided in Appendix C of this document.

11. The Consolidation Model

>

This section sets out to describe the methodology and assumptions behind the consolidation model and describes the approach taken to the modelling of operating costs and also the production of the final cost based prices.

11.1 Overview of the Consolidation Model

The consolidation model uses the costs relating to core, access and co-location that are produced by each of the separate models. The costs are brought together in the consolidation model.

The consolidation model produces the final cost of each service. It also undertakes some checks for consistency between the other three models. In contrast to previous versions, the version 2.5 of the revised Hybrid Model shows geographically disaggregated costs of access products and services through to the Output sheet. Costs are now allocated to products for each geotype individually and these are then aggregated to calculate the total national costs.

The consolidation model performs a number of additional functions, such as annualisation of capital expenditure and the calculation of Functional Area costs. These have been described in detail in Chapters 3 and 4 of this report.

As an alternative to annualisation, any investment cost may be expensed, where the cost is recovered as a one-off payment. Some cost items that are relevant to access or co-location services are typically treated in this way. Core PSTN or IP network costs would not normally be expensed. The model therefore calculates service costs as a mixture of one-off and annualised costs.

Finally, the consolidation model includes a sensitivity analysis which allows users to test the sensitivity of any model changes on final outputs. Further details of the functions performed by the Consolidation model are provided in the following sections.

11.2 Operating costs – The Functional Area approach

The overall rationale behind the functional area approach was dealt with in Section 3.4. Thus this section concentrates on describing the actual calculation steps themselves.

There are two specific worksheets that deal with the functional area costs: I_FA_Costs and C_FA_Costs.

The first worksheet of these, I_FA_Costs contains five basic sections:

1. Functional area inputs
2. Staff costs
3. Calculation of pay costs
4. Calculation of total costs
5. Overheads

11.2.1 Functional Area inputs

The functional area inputs consist of six sub-sections. The first of these provides a set of operating cost drivers that are combined with the second sub-section to derive the numbers of FTE per functional area. These operating cost drivers include such measures as the number of core nodes, the number of km of core trench and the number of DSLAM lines. The measures essentially extract relevant data from elsewhere in the model and, as such, could relatively easily be expanded as and when necessary.

The second sub-section consists of a set of input parameters related to ongoing and one-off staffing requirements for each functional area. Each functional area has four inputs associated with it:

- A minimum number of FTE for that area
- An additional number of FTE that are required as the relevant driver increases in size
- The increase in size of the driver that relates to the additional number of FTE
- The actual driver itself (such as "# km Core Trench")

This sub-section also allows the user to input a different set of staffing assumptions that can override the calculations based on the parameters, and also to include an efficiency improvement that will be applied to either the calculated numbers or the alternate set of numbers.

The next two sub-sections cover ongoing network costs and one-off network costs respectively and allocate the calculated numbers of FTE between Academic, Technical and Administrative persons, according to the percentages in Table 2.2 of the worksheet. The two sub-sections also contain inputs for the user to specify the amount of equipment and materials consumed each year by that functional area.

The final two sub-sections cover non-network costs and IC specific & commercial costs respectively and follow the same format as the previous two sub-sections, although here the data comprises actual inputs rather than calculations.

11.2.2 Staff costs

The staff costs section simply contains inputs relating to the full annual cost (including social costs etc) associated with each of the three staff types: Academic, Technical, and Administrative. Also contained in this section, as mentioned previously, are the percentage allocations used to allocate the calculated FTE totals for each functional area to the three staff types.

11.2.3 Calculation of pay costs

This section comprises of four sub-sections covering: ongoing network costs; one-off network costs; non-network costs; and IC specific & commercial costgs. Within each sub-section the model calculates, for each functional area, the pay costs associated with each staff type and then the total for all four staff types.

11.2.4 Calculation of total costs

This section combines the staffing costs from the previous section with the non-pay costs from the third section to calculate the total costs for each functional area. It also (in table 4.3 of the worksheet) groups together the network related operating costs into one of a number of broad areas, including for completeness a number of other operating costs, these being:

- Supplier annual support costs
- Annualised accommodation costs
- Power costs
- Air-conditioning costs

Table 4.3 of the worksheet thus provides a useful summary of the aggregate operating costs of the overall network.

11.2.5 Overheads

This section calculates a number of mark-ups used in worksheet C_Services. The mark-ups comprise three types:

- General mark-ups for common business costs
- Specific interconnect and commercial costs
- NP/IN costs

The general mark-ups are calculated as a blend of an overall mark-up for common business costs with specific mark-ups for working capital. The former is based on the total non-network costs from Table 4.4 in the worksheet divided by the total cost base calculated by the model (mainly from worksheet C_Costs, but including some adjustments from worksheet C_Services). The working capital mark-ups are specific to access and core and are based on a number of inputs contained within this sub-section.

The mark-ups for specific interconnect and commercial costs are based on the costs calculated in Table 4.5 in the worksheet, spread across a number of business areas using inputs contained within this sub-section.

The NP/IN mark-up is based solely on inputs in this sub-section related to the costs of an IN platform. It is likely that in future revisions to the model this section will be replaced with specific costs calculated within the core model itself.

11.3 Calculation of service costs

The final calculation of the costs of the modelled products and services takes place in worksheet C_Services. This worksheet comprises three major sections:

1. Annualised costs by Network Element
2. Basic product costs

3. Final product costs (including mark-ups)

11.3.1 Annualised costs by Network Element

This section comprises two parts:

- Core (and co-location) network elements
- Access network elements

Each part collates the cost data from worksheet C_Costs and presents it in aggregated form by network element. The core network element part also handles the allocation of common site costs across the core and co-location network elements. These allocations utilise input tables in this worksheet to determine which network elements should take a portion of which common site costs.

These inputs should only be altered if the user fully understands the relevance of these allocations. However, should additional network elements be added to the model (and this part of worksheet C_Services be updated as a result) then it is very likely that these inputs will also need to be re-visited – if only to ensure that they remain relevant for the network elements for which they were intended.

11.3.2 Basic product costs

This section comprises seven parts. The first of these allocates the core network element costs between the various products addressed in the core model. Note that for any particular product, the costs will include costs related to Gbps, Mpps, calls, minutes and subscribers.

The remainder of this section contains six parts related to the access network elements. The first of these calculates the total usage of each network element by each product. This is calculated for each geotype individually and for the country as a whole. The other five serve to allocate the network element costs on the basis of this usage, with one part addressing the country as a whole and the following four parts addressing each of the four geotypes in turn.

11.3.3 Final product costs (including mark-ups)

This section collates the results of the previous sections, applies relevant mark-ups and calculates per unit costs as appropriate. It comprises three parts dealing with core products, access products and co-location products in turn.

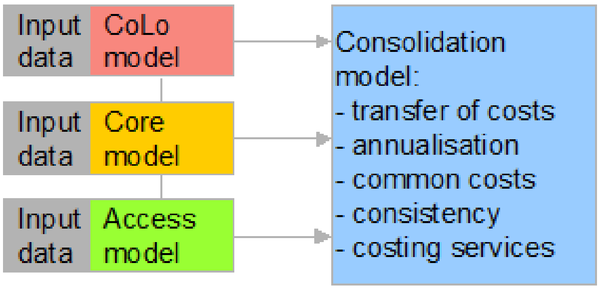
11.4 How to use the Consolidation Model

11.4.1 Model scope

The purpose of the consolidation model is to carry out the final steps in the costing process and allocate costs to the final services. The consolidation model therefore contains information from the other three models, which is retrieved through links.

The overall model architecture is illustrated below.

Figure 11.1 Model Architecture



The Consolidation model calculates the annualised costs of each cost category identified in the three main models.

The main components of this are:

- Calculation of operational and indirect costs;
- Calculation of the annualised cost of the capital equipment expense; and
- Calculation of the annualised cost of installation costs.

After calculating the annualised cost of each cost category, the model then attributes each of the cost categories to a network element. Next, by using a routing / allocation table for access and core services the model calculates the individual service costs.

Some costs may be expensed (not annualised, but are assumed to be paid for with a one-off payment). These expensed items are also processed, as the access and co-location service costs may be a mixture of annualised and one-off costs.

Further, the consolidation model carries out:

- Calculation of working capital
- Allocation of overhead costs.

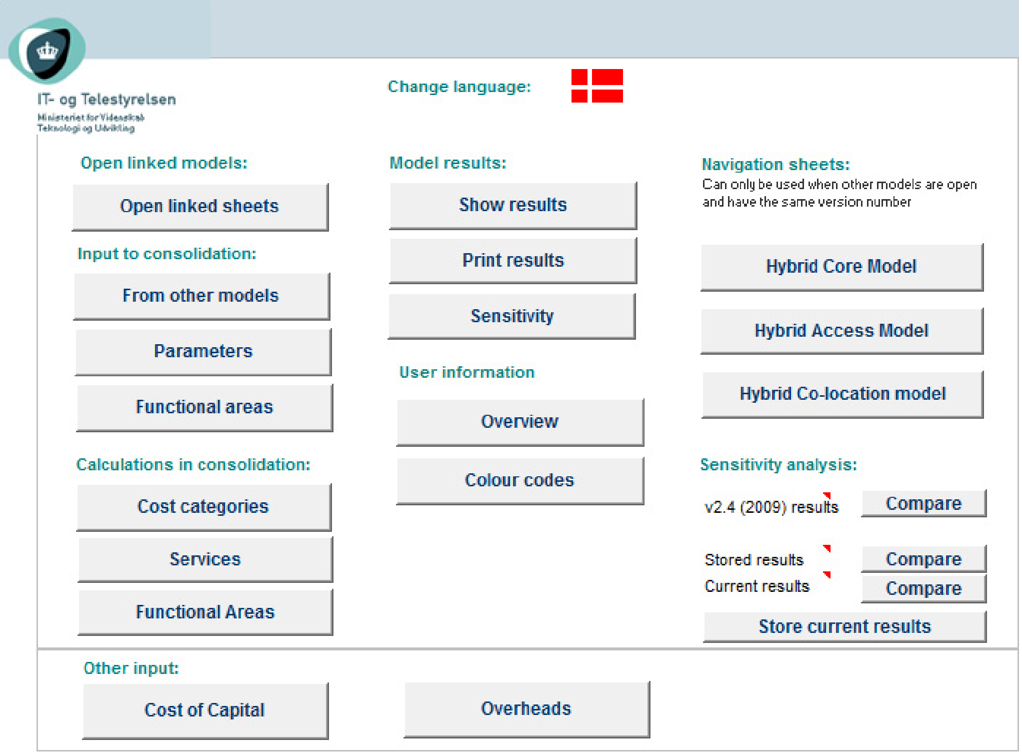
11.4.2 Model structure

The model includes a control sheet which provides shortcuts to important parts of the model, such as Results. It also allows the user to change the model language, print results and open other models.

The UK version of the control sheet is reproduced in Figure 11.2.

This user interface enables the user to navigate the Consolidation model. The user can click on any of the shortcut buttons on the map to jump straight to the relevant worksheet or table. Each subsidiary worksheet has a "Model Overview" button, which the user can click on to return to the navigation map. Most sheets also have a drop-down menu below the Model Overview button to take the user to different tables contained in each worksheet. Note that it is still possible to navigate the model using the sheet tabs.

Figure 11.2 Consolidation model – Control Sheet



Can only be used when other models are open and have the same version number

11.4.3 Start-up

The user should open the Consolidation model directly from the file directory. “Enable macros” when asked, unless the file is from an uncertain (untrusted) source. There may be a message asking whether to update links. Such updates are performed automatically on recalculation if other parts of the model are open, otherwise links should be updated if other models have been changed and are located in the same directory. There is an introductory message that warns the user that older versions of Excel may not provide full functionality.

11.4.4 Understanding the model

The main inputs in the Consolidation model are not normally altered – these are linked to the individual source models. However, the model contains original inputs relating to functional area costs and staffing options, as well as parameters for annualisation and general model setting such as language, base year and costing year. It also contains the inputs for cost of capital and the NGA selector.

The recommended approach to gaining an understanding of the model is to work through each sheet in turn, starting with inputs, moving to calculations and then outputs. One way to improve understanding is to edit the input data, recalculate and investigate the effect of the changes on the results. These can be easily checked in the sensitivity analysis sheet.

The final costs for all Access, Core and Co-location products are shown in the output and results sheets of the Consolidation model.

A sheet-by-sheet description of the Consolidation model is provided in Appendix C of this document.

12. Appendix A: Abbreviations

>

ADM	Add Drop Multiplexer
ADSL	Asymmetrical Digital Subscriber Line
ASM	Remote Concentrator (site)
ATM	Asynchronous Transfer Mode
BH	Busy Hour
BHCA	Busy Hour Call Attempt
BSA	Bitstream Access
Codec	Coder – Decoder
CSCF	Call Session Control Function
DSLAM	Digital Subscriber Line Access Multiplexer
DWDM	Dense Wavelength Division Multiplexing
eBSA	Ethernet Bitstream Access
EU	European Union
FTE	Full Time Equivalent (employee)
FTTB	Fibre to the Building
FTTH	Fibre to the Home
GBIC	Gigabit interface card
Gbps	Gigabits per second
GW	Gateway
IMS	Integrated Multimedia Subsystem
IP	Internet Protocol
IPTV	IP Television
ISDN	Integrated Services Digital Network
Kbps	Kilo bits per second
LLU	Local Loop Unbundling

LRAIC	Long Run Average Incremental Cost
L2	Layer 2 (as in 7 layer ISO model)
L3	Layer 3 (as in 7 layer ISO model)
MDF	Main Distribution Frame
Min	Minute
Mpps	Million packets per second
MRP	Model Reference Paper
MSAN	Multi-Service Access Node
NGA	Next Generation Access
NGN	Next Generation Network
NPV	Net Present Value
NTP	Network Termination Point
OAO	Other Authorised Operator
Opex	Operating costs
PDP	Primary Distribution Point
POI	Point of Interconnect
PON	Passive Optical Network
POTS	Plain Old Telephony Service
PPS	Packets per second
PSTN	Public Switched Telecommunications Network
RTP	Real Time Protocol
RTU	Right to Use (licence)
SBC	Session border controller
SDH	Synchronous Digital Hierarchy
SDP	Secondary Distribution Point

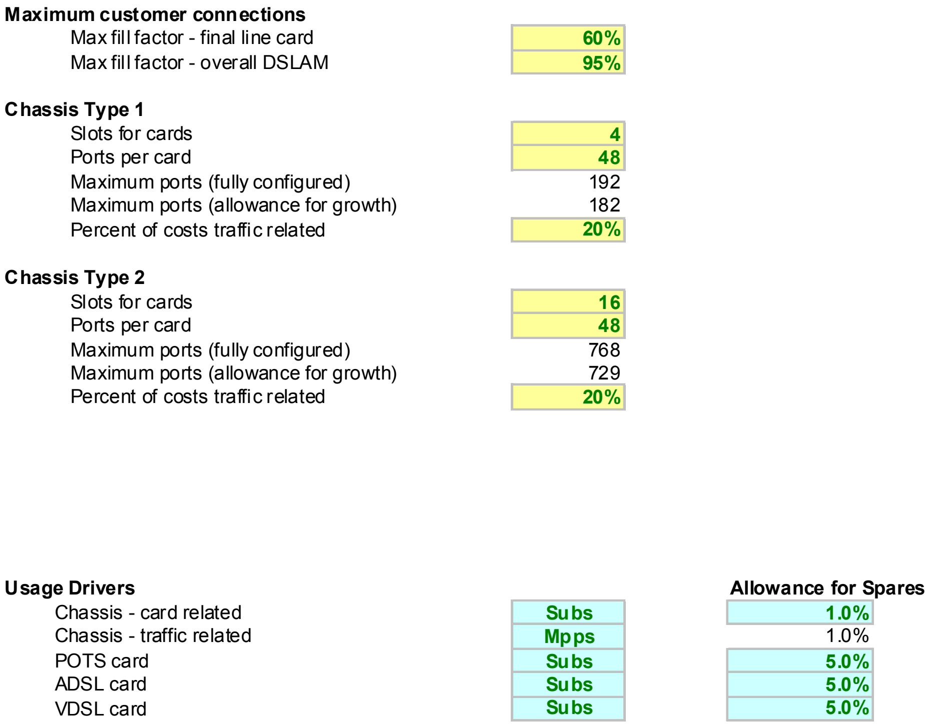
SDSL	Symmetrical Digital Subscriber Line
SMP	Significant Market Power (stærk markedsposition)
Subs	Subscribers
TDM	Time Division Multiplexing
TX	Transmission
VAD	Voice Activity Detection
VDSL	Very High Bit-Rate Digital Subscriber Line
VoIP	Voice over IP
xDSL	x Digital Subscriber Loop (includes such technologies as ADSL)
1GE	1 Gigabit Ethernet
10GE	10 Gigabit Ethernet

13. Appendix B: Core Model Inputs

>

The following diagrams illustrate the level of configuration detail contained within the revised model v3.1 for each of the major equipment categories.

DSLAM/MSANs



Maximum customer connections	
Max fill factor - final line card	60%
Max fill factor - overall DSLAM	95%
Chassis Type 1	
Slots for cards	4
Ports per card	48
Maximum ports (fully configured)	192
Maximum ports (allowance for growth)	182
Percent of costs traffic related	20%
Chassis Type 2	
Slots for cards	16
Ports per card	48
Maximum ports (fully configured)	768
Maximum ports (allowance for growth)	729
Percent of costs traffic related	20%

Usage Drivers		**Allowance for Spares**
Chassis - card related	Subs	1.0%
Chassis - traffic related	Mpps	1.0%
POTS card	Subs	5.0%
ADSL card	Subs	5.0%
VDSL card	Subs	5.0%

Layer 2 Aggregation Switches

Configuration Rules

Maximum number of sites per Layer 2 ring	8	
10GE ports per chassis for L2 ring	2	
10GE uplinks per chassis at L3 site	2	
Maximum number of L3 routers fed by Bitstream uplir	2	
Maximum utilisation of a L2 ring	7	Gbps
Maximum number of GBIC modules per chassis	5	

Chassis selection

Maximum xDSL customers for lower spec Type 1 cha	1000

Processor selection

Maximum ring traffic for lower spec Processor Type 1	2	Gbps
Maximum xDSL customers before Redundant Proces	1500	

Processor Type 1

Number of 10GE ports	2
Number of GBIC ports	4

Processor Type 2

Number of 10GE ports	2
Number of GBIC ports	0

10GE Module

Number of 10GE ports	6

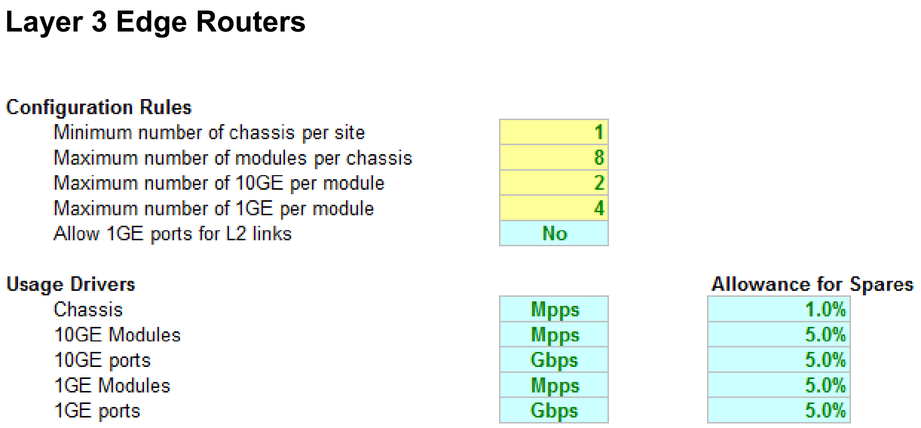
GBIC Module Type 1

Number of GBIC ports	6
Maximum number of DSLAMs per module	2

GBIC Module Type 2

Number of GBIC ports	48

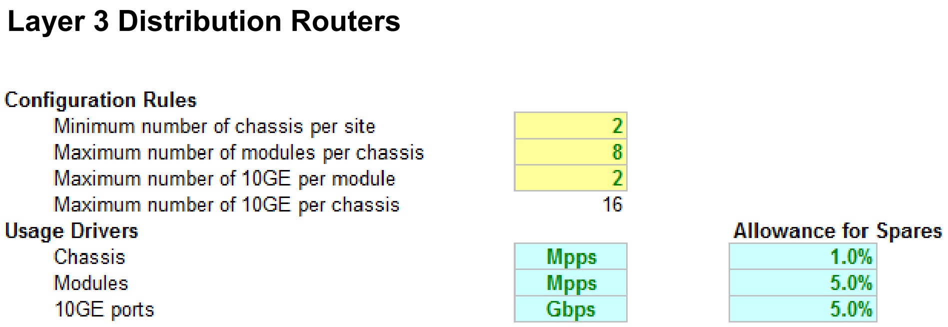
Usage Drivers		**Allowance for Spares**
Chassis Type 1	Mpps	1.0%
Chassis Type 2	Mpps	1.0%
Processor Type 1	Mpps	1.0%
Processor Type 2	Mpps	1.0%
10GE Module	Mpps	5.0%
GBIC Module Type 1	Mpps	5.0%
GBIC Module Type 2	Mpps	5.0%
10GE Adaptor	Gbps	5.0%
GBIC Adaptor	Gbps	5.0%



Layer 3 Edge Routers

Configuration Rules	
Minimum number of chassis per site	1
Maximum number of modules per chassis	8
Maximum number of 10GE per module	2
Maximum number of 1GE per module	4
Allow 1GE ports for L2 links	No

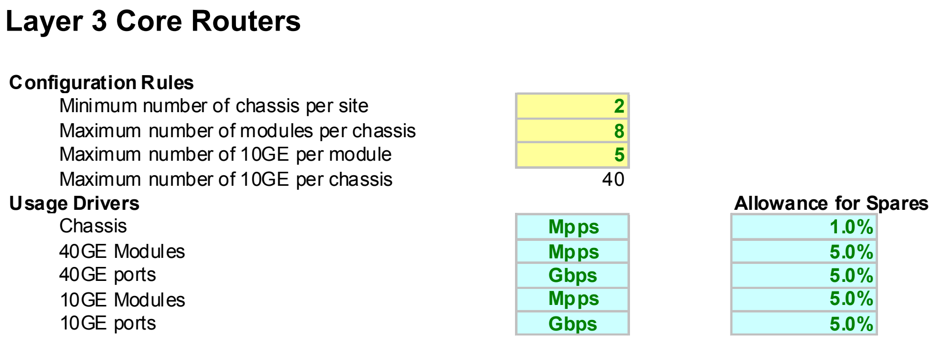
Usage Drivers		Allowance for Spares
Chassis	Mpps	1.0%
10GE Modules	Mpps	5.0%
10GE ports	Gbps	5.0%
1GE Modules	Mpps	5.0%
1GE ports	Gbps	5.0%



Layer 3 Distribution Routers

Configuration Rules	
Minimum number of chassis per site	2
Maximum number of modules per chassis	8
Maximum number of 10GE per module	2
Maximum number of 10GE per chassis	16

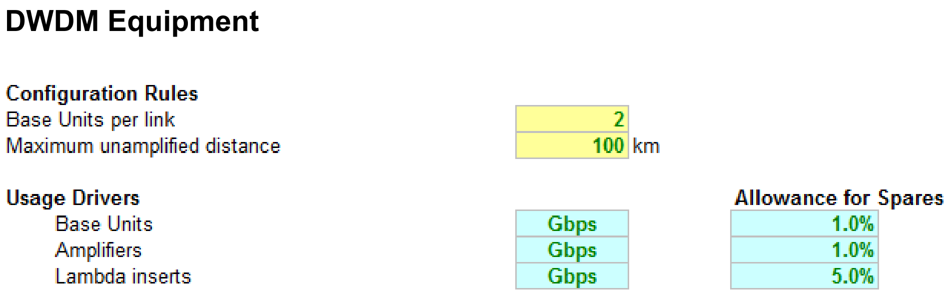
Usage Drivers		Allowance for Spares
Chassis	Mpps	1.0%
Modules	Mpps	5.0%
10GE ports	Gbps	5.0%



Layer 3 Core Routers

Configuration Rules	
Minimum number of chassis per site	2
Maximum number of modules per chassis	8
Maximum number of 10GE per module	5
Maximum number of 10GE per chassis	40

Usage Drivers		Allowance for Spares
Chassis	Mpps	1.0%
40GE Modules	Mpps	5.0%
40GE ports	Gbps	5.0%
10GE Modules	Mpps	5.0%
10GE ports	Gbps	5.0%



DWDM Equipment

Configuration Rules		
Base Units per link	2	
Maximum unamplified distance	100	km

Usage Drivers		Allowance for Spares
Base Units	Gbps	1.0%
Amplifiers	Gbps	1.0%
Lambda inserts	Gbps	5.0%

IP-TDM Media Gateways

Configuration Rules				
Minimum number of chassis per site	1	per	Distribution	Layer site
				13 Sites
Include OLO facing line cards in Core Model costs?	No			
Media Gateway Controller	1	per	150,000	BHCA
Distribution Sites				
Media Gateway - Chassis	1	per site		
Media Gateway - Front Card	1	per	1,440	BH Erlangs
Media Gateway - Back Card	1	per	720	BH Erlangs
Edge Sites				
Media Gateway - Small	1	per	22	BH Erlangs
Media Gateway - Medium	1	per	44	BH Erlangs
Media Gateway - Large	1	per	132	BH Erlangs
Usage Drivers			**Allowance for Spares**	
Media Gateway Controller	Call		1.0%	
Media Gateway - Chassis	Min		1.0%	
Media Gateway - Front Card	Min		5.0%	
Media Gateway - Back Card	Min		5.0%	

IMS

Configuration Rules		1	per	200,000	Voice subscribers
	minimum of	1	per	Distribution	Layer site
					13 Sites
Each IMS contains					
Session Border Controller		1	per	2,000	BH Erlangs
	SBC at Edge location?			No	
IMS Core					
Softswitching		1	per	125,000	BHCA
RTU licences		10,000	per	10,000	Residential subscribers
		10,000	per	10,000	Business subscribers
Fixed per IMS		1	per	1	IMS
Application Service - VoIP		2	per	50,000	Voice subscribers
Application Service - Centrex		1	per	50,000	Business subscribers using it
Proportion of business subscribers using Centrex		10%			
Usage Drivers				**Allowance for Spares**	
Session Border Controller		Min		1.0%	
Softswitching		Call		1.0%	
RTU licences - Subs related		Subs			
RTU licences - Call related		Call			
Fixed per IMS		Subs		1.0%	
Application Service - VoIP		Subs		1.0%	
Application Service - Centrex		Subs		1.0%	

14. Appendix C: Worksheet Audit

>

14.1 Description of worksheets in the Access Model

14.1.1 Input sheets

I_Interface
This sheet contains inputs from other parts of the model that are shared with Access via Excel links. It provides information about the original input source to allow the user to locate the yellow or blue (modifiable) input cell.

I_Network_Demand
This spreadsheet is split into three sections. The first and third sections refer to demand at the network level (for copper and fibre respectively), the second section extracts information from the first section, in terms of means of transport of the different services (this needs to be done because xDSL services share, most of the times, copper pairs with PSTN and, therefore, when allocating costs to services this needs to be taken into account).

I_Dimensions
This spreadsheet is a reference for the user in terms of cost and service categories used throughout the model. It is useful as a summary of the “dimensions” of the model.

I_Access Routing Table
This table lists the access services in the vertical dimension and the network services in the horizontal dimension.

I_ASM-PDP
This worksheet allows certain inputs to be defined relating to the ASM-PDP links. Section 1 contains a table used to assess the likely degree of trench sharing between multiple ASM-PDP links. The reduction factor is applied to the aggregate crow-fly distance of all ASM-PDP links for a particular sample area. Section 2 is used to select the fibre cable used to connect the Street Cabinet DSLAM back to the ASM location for ASM-PDP links.

I_Share_Routes
This sheet specifies the amount of street trench and duct shared with other networks or utilities. Routes shared with the core network are calculated in the core model and fed into the access model.

I_GIS Trench and Duct
This sheet contains geographic data, focused on the road network, used to drive the estimates for the amount of trench (and duct) required. Sections 1-2 contain the size of the road network (in km), based on inputs from the DAV database, and define the amount of trench km per road km by roadtype. Then, the propensity of different constructions to share routes by different terrain type is defined together with the proportion of the mix of ducts used in different terrain types.

I_GIS Zones
This spreadsheet is by far the most complicated of the Input spreadsheets. It mainly contains information used to work out distances between the different parts of the access network (from RCU to PDP, from PDP to SDP, from SDP to NTP). These are

then used to work out copper requirements. This spreadsheet is structured according to the 20 MDF areas that have been selected in the bottom up model as sample areas to estimate copper requirements. It contains data (in Section 3) on the number of NTPs in each sample area and over the whole network as well as number of PDPs and SDPs (in Section 6). The section now also allows for an alternative set of PDP quantities under an NGN scenario. If inputs in this sheet are changed, the macro in *C_Cables and Nodes* must be re-run.

I_Fibre
This sheet collects data on the amount of fibre in the network by fibre size and geotype. Table 1 contains a calibration scenario, for both rings and spurs, while Table 4 shows an actual scenario. The sheet calculates the fibre mix which would be installed if the network was being built now, based on the Modern Equivalent Asset.

I_Cost of Nodes
This spreadsheet contains cost information (unit costs, equipment and installation, price trend and asset lives) for cabinets, including boards within cabinets, and NTPs. Costs for active street cabinets are shown separately. The sheet also contains inputs for economic depreciation parameters.

I_Cost of Links
This spreadsheet contains cost information (unit costs, equipment and installation, price trend and asset lives) on the following network elements:

> Trench and duct

> Miniduct (trench and duct)

> Copper cable

> Fibre cable

Section 3 (Cost of copper cable per km) allocates the number of copper pair-km between SDP-NTP, ASM-PDP and PDP-SDP cables. The underlying assumption made is that it is the higher cable sizes that are used for ASM-PDP cables and the lower sizes for PDP-SDP or SDP-NTP cables. The entries in the cross-over points (ie the cable size used for both) was calculated by use of the goal seeking function in Excel. The sheet also contains inputs for economic depreciation parameters.

I_Opex Costs
This sheet allows the user to specify a mark-up for annual operating cost as a percentage of capex (equipment or installation) for major cost categories such as trench and duct, copper, fibre and NTPs. Opex costs for some types of assets are calculated in two stages:

> Events: How often does something happen that requires operating costs to be incurred?

> How much operating cost does each event cause?

These are multiplied together, then multiplied by the volume driver to derive the cost per year. The results feed through to *C_Resources*.

14.1.2 Calculation sheets

C_Trench by Zone
This is worksheet performs the calculations necessary to split the trench and duct costs between ASM-PDP links and PDP-NTP links.

Section 1 (Sample Zones) contains road lengths by segment classification for each of the 20 sample areas. In Section 2 (Trench km by road type), this information is then used, together with the relevant road to trench conversion factors, to calculate the normalised trench length for each weighted sample area. The total trench length estimated for each weighted sample area needs then to be allocated between the primary (ASM-PDP) and the secondary network (PDP-NTP). This has been done by calculating the estimated length of the primary network and subtracting this estimate from the total estimate in order to obtain the estimated length of the secondary network.

Section 4 (Mix of Duct types) is an expanded equivalent to Section 4 of worksheet *I_GIS Trench and Duct* and Section 4 of worksheet *C_Trench and Duct*. The note detailing how the amount of Large Duct was estimated has been used to calculate values for each of the 20 sample areas. These values are normalised to give the 500 km inputted in worksheet *I_GIS Trench and Duct* and then used to derive the trench and duct information for each sample area split between ASM-PDP and PDP-NTP.

C_Trench and Duct
This is based on inputs from *I_GIS Trench and Duct* and calculates the total trench and duct kilometres by road type for each of the four geotypes. This is then broken down further by terrain type (for trench) and duct type.

C_Share_Routes
This spreadsheet works out the amount of shared trench and duct to be allocated to the core and access network on the basis of the inputs in *I_Share Routes* (in terms of both length of common trench and allocation key to the different increments) and the calculations performed in *C_Trench and Duct* that estimate the total amount of trench and duct in the access network.

C_Cables and Nodes
This is by far the most complicated spreadsheet in the whole model. However, most of the calculations performed in this spreadsheet are aimed at estimating the length of the loop by geotype and part of the network. It is important to bear in mind that most of the calculations shown in this spreadsheet refer to the sample area identified in cell J3. All information is then aggregated by multiplying the results of each sample zone by the weights attributed to each zone (in *I_GIS Zones*) in order to derive results for the whole network.

C_Resources
This spreadsheet lists all the results in terms of capital requirements and operating costs for each geotype and for the country as a whole. The spreadsheet also shows assumptions on unit costs, asset lives and price trends.

14.1.3 Output sheets

O_to_Consolidation
This spreadsheet lists all the results in terms of gross replacement costs (split into equipment and installation costs) and operating costs. The spreadsheet also shows assumptions on asset lives and price trends and the network elements to which the different cost components are then allocated to. In addition to national outputs, results are also shown separately for each geotype.

O_Key Statistics
This sheet summarises key inputs and calculations from different sections of the access model for the number of trench kilometres, copper and fibre pairs, and NTPs. It then goes on to calculate statistics such as trench kilometres per NTP and copper/fibre kilometres per NTP.

14.2 Description of worksheets in the Core Model

14.2.1 Utility sheets

In common with other models, the core model contains a number of utility sheets such as *Changes, Version History, Map* and *Colour Codes*. In addition, it includes an *Overview* sheet, which extracts key results and feeds them into the Consolidation model. The *Notes* sheet contains a full list of modelled products and defines the names of product group prefixes and range names, which will be used throughout the model. Named ranges not only improve transparency within formulae but also enable users to modify individual product names in *I_Product_Demand* without corrupting the model calculations and look-ups. This helps to make the model more robust and improves flexibility.

14.2.2 Input sheets

I_Interface
This sheet pulls in inputs from other parts of the model that are used by the Core model. These are shown in tan colour coding, together with a note indicating the original source of the input (Access, Co-location or Consolidation). This allows users to locate the original (yellow or blue) input cell, which can be modified if required.

I_Network_Elements
This sheet defines all network elements used in the core model, together with their relevant usage drivers.

I_Product_Demand
This sheet contains the input cells for the traffic volume data from TDC for the following type of services:

- Telephony (traditional and VoIP)
- Broadband and Bitstream, including Bitstream Transport, IPTV and Video on Demand
- Access products (PSTN, ISDN, raw copper)
- Remaining non-PSTN traffic, such as leased lines, mobile or cable TV.

Access products have been included to allow access-specific costs in the core model to be allocated to the correct network increment. The sheet also contains a section on xDSL, which is used to cater for geotype targeting of active street cabinets and also the NGA scenario.

Call volumes for voice services are measured in call minutes and number of calls completed for each call type, while volumes for data services are measured in subscriber numbers and gigabytes per subscriber per month. The sheet performs two key functions: translating the raw data supplied by TDC into Busy Hour Erlangs (BHE) or Busy Hour Gigabits per second, and allowing for growth in volumes.

This sheet has a significant impact on the costs. The larger the volume, the larger the network usage and the lower the average cost for each product. Note that the absolute volume of any one product has a limited impact, unless this product has a high percentage of the entire network's volume. For this reason a product with only one call minute per year can be modelled – it has negligible impact on the result of the others. BHE conversion factors and the average call length can have a significant impact.

I_Route_Table
This worksheet provides a formal routing table for all of the products included in the core model. It consists of two major sections: Section 1 – Routing Probabilities; and Section 2 – I_Route Summary Table, which feeds into *C_Route_Table*. For each product up to three routing possibilities can be defined, with percentage likelihoods attached to each one.

I_Route_Chart
This is an interactive chart, which highlights the different network elements and configurations used for each product, based on the routing factors specified in *I_Route_Table.*

I_Building and Land
This sheet contains assumptions and parameters for buildings and land, and calculations of annual unit costs of land and buildings. It also summarises (in Section 6) the accommodation-related overheads for different types of equipment, such as DSLAMs/MSANs, Edge Routers or Core Routers, based on inputs from *I_Costs*.

I_Technical
This sheet contains the various input information necessary to size the equipment used in the core network.

I_Trenching_Transit
This worksheet contains the inputs related to higher level trenching in the core network and also is used to calculate the necessary fibres (and fibre link speeds/usage) for the links at those levels.

I_DWDM_graphic
This is a non-functional (that is, graphic only) worksheet to provide an illustration of the potential DWDM network considered in worksheet *I_DWDM*.

I_DWDM
This worksheet allows the user to determine the extent of the modelled DWDM network.

I_Trenching_Local
This worksheet contains the inputs related to lower level trenching in the core network (that is, from the Edge Router downwards).

I_Node_Equipment
This worksheet is used to calculate the required node equipment at the DSLAM/MSAN sites in the core network. Each site is treated individually.

I_Costs
This worksheet contains inputs for the per unit cost of transmission, infrastructure and equipment, and common site costs. The sheet also contains inputs for economic depreciation parameters.

14.2.3 Calculation sheets

C_Equipment
This worksheet is used to calculate and summarise the costs of all equipment addressed by the core model.

C_Route Table
This worksheet takes feeds from I_Route Table and applies the routing factor inputs to traffic volumes, measured in Busy Hour Erlangs, Busy Hour Calls, Busy Hour Gigabits per second, Busy Hour Mega packets per second or number of Subscribers. For voice traffic, it applies the uplifts for call holding time and unsuccessful calls specified in *I_Product_Demand.* There are separate calculations for "required capacity" and "actual capacity". "Actual" values refer to Year 0 data inputs (from *I_Product_Demand*), which are used to calculate unit service costs. Values "to use" (or required capacity) are applied to projected traffic volumes for year 1, 2, 3 or 5 and are used for network dimensioning.

C_Trenching_Transit
This worksheet is used to calculate trench and trench related costs for the higher levels of the core network.

C_Trenching_Local
This worksheet is used to calculate trench and trench related costs for the lowest level of the core network (that is, from the Edge Router downwards).

14.2.4 Output sheets

O_Consolidation
This worksheet collects the cost for each cost category and then uses a look-up technique to pick up other parameters that relate to that cost category. These include equipment installation costs, scrap values, lifetimes, price trends, maintenance costs and various parameters used for the calculation of economic depreciation and other annualisation methods. The look-up technique is used widely in the model to save on processing power and reduce the size of the overall model. All the outputs from this worksheet feed directly into the Consolidation model.

14.3 Description of worksheets in the Co-location Model

14.3.1 Input sheets

I_Interface
This sheet contains inputs from other parts of the model that are shared with the co-location model via Excel links. It provides information about the original input source to allow the user to locate the yellow or blue (modifiable) input cell.

I_Costs
This sheet contains the various cost assumptions for land and buildings, co-location site costs, power and cabling. In Section 5 it provides inputs for assumptions which make up hourly wage costs, such as working day assumptions and annual employment costs (fed in from the Consolidation model) for administrative staff, technicians and academic (professional) staff. Section 7 lists the service elements used in the co-location model. The prefix used for the full service element name indicates whether final costs will be allocated to co-location (eg. rack space) or access (eg. raw copper installation). A small number of services, such as preselection, local POI and interconnection capacity, are allocated to "other services".

I_Resource sheet
This sheet is used to define the assumptions on time resource requirements for various co-location activities.

Vertically, the I_Resource sheet is divided into different sections where assumptions about the manpower consumption for different tasks can be entered. Horizontally, the sheet has the different staff types (administrative, technician and academic). A weights column is used to allocate shared activities such as end user visits or transport time between services that are completed concurrently so as to avoid double-counting. This is explained in more detail in Section 10.2.2 of this report.

I_Demand
This sheet contains the various demand assumptions for co-location services. Where no demand data can be obtained, as for new services, a dummy value of 1 has been used to avoid products being excluded from the model and to ensure they receive an allocation of common costs, as appropriate.

14.3.2 Calculation sheets

There is one calculation sheet:

C_Costs
This sheet contains calculation and allocation of costs to services using the information in the input sheets. For each product, it shows the various parameters – such as installation costs, maintenance, price trends, lifetimes and opex trends – which will be used in the consolidation model to calculate annualised service costs, where appropriate.

14.3.3 Output sheets

O_Consolidation
This sheet contains cost at cost category level and demand at service level, which both are output to the Consolidation model. Information in this sheet is fed in from the *C_Costs* sheet. The calculation of final service costs, after addition of overhead and allocation of cost to co-location services or access (as appropriate), is carried out in the Consolidation model.

14.4 Description of worksheets in the Consolidation Model

14.4.1 Utility sheets

Control sheet
Instead of model maps the Consolidation model opens in a Control sheet, which is available in two language versions – Danish and English. This sheet contains buttons for a range of functions to aid navigation, take the user directly to important inputs such as parameters, overheads or cost of capital, update the sensitivity analysis or print out results. It also allows the user to open all linked sheets (ie. Access model, Core model and Co-location model) without having to open files individually in the model directory. Navigation buttons take the user to the overview maps in the other models when these are open.

The control sheet only functions properly if certain norms have been observed when modifying file names. The model version number can be changed without consequence, but more extensive name changes (eg. changing "Draft Revised Model" to "Final Model") may prevent the macros in the control sheet from working correctly unless the broad "model version" is specified in the *I_Parameters* sheet (Section 5). To alert the user to potential problems, the filename status is shown at the bottom of the control sheet. Errors can be rectified either by updating the model version parameter or by modifying the control sheet macros in VBA (it is recommended that this should be done by experienced Excel users only).

14.4.2 Input sheets

I_Interface
This sheet pulls in inputs from other parts of the model that are used by the Core model. These are shown in tan colour coding, together with a note indicating the original source of the input (Access, Core, Co-location). This allows users to locate the original (yellow or blue) input cell, which can be modified if required.

I_Parameters
This worksheet contains various parameter information carried across from the three feeder models, such as demand volumes and cost drivers. In Section 1, all the Network Elements from the different models are listed and summarised. A check is performed to ensure that all cost categories have been allocated to a network element.

Section 4 contains parameters for a range of annualisation methods, with an option to enforce use of a single method across all cost categories. This will override any annualisation options applied to individual assets in the *I_Costs* sheet. The model default is economic depreciation, which is simulated by a mix of tilted annuities and output adjusted tilted annuities, conditional on parameters related to cost structure, output trend and price constraints. The annualisation method is explained in detail in Chapter 4 of this report.

I_FA_Costs
This sheet contains input information used to calculate the Functional Area costs. Although this is an input sheet, it contains some calculations as this increases transparency and eases audit of the calculations. Section 1 contains the functional area staffing for network costs, non-network costs and interconnection specific costs. Network costs are subdivided further into ongoing costs and one-off costs. Within Network Costs, inputs are provided for minimum staffing requirements for each functional area, plus an additional number of FTE staff that is linked to an opex cost driver, as specified in Table 1.1. Users may change the yellow-coded staffing inputs but should only modify the relevant opex driver after careful consideration. It is also possible to override the default inputs by adding values to the Options column, which may be selected in the FA cost option field at the top of the worksheet.

Note that input data must reflect wholesale costs relevant to modelled services only. No retail costs or other non-relevant costs related to the core or access network should be included.

In Sections 2 and 3 the staffing requirements, in full time equivalents (FTE), are then multiplied by the staffing costs for each type of personnel – administrative, technician and academic (professional). To derive total functional costs, non-pay costs for equipment and material are added to pay costs (in Section 4). Finally, Section 5 provides inputs for overheads and working capital, which are used to calculate common cost mark-ups.

I_Costs
This worksheet contains linked cost data from the core, access and co-location models. Each cost category is assigned a network element that relates to the equipment costs, installation costs and operating costs provided by the three models. Further, price

trends (projected price change), asset lives, scrap values, output trends and other parameters are imported to facilitate the annualisation of costs.
There are a number of input changes that may be performed in this sheet (light blue cells, cf. the style overview). They include:

> Allocation: All input costs must be defined to have an allocation – this specifies how the cost category (taken from any of the three models) is to be allocated. Thus the cost category "DWDM : Base Units : Core–Core" maps to the network element "TX path: L3 Core–Core" and "Acc.Copper.2 pair" maps the cost to the element "Acc.Cable.Copper, SDP–NTP".

> Expensed vs. annualised: All cost inputs must have a specification of whether the cost should be expensed or annualised.

> Annualisation option: The model allows the user to select from a menu of four different annualisation methods – straight line, standard annuity, tilted annuity and output-adjusted tilted annuity (economic depreciation). To manually select a method for an individual asset, the user can use the override column (Column AP), otherwise the model applies the calculated default method for economic depreciation. It is also possible to use a universal override, if the user wishes to apply a method other than the model default across all cost categories. This can be specified in *I_Parameters*.

14.4.3 Calculation sheets

C_FA_Costs
The sheet is used to allocate the various Functional Area costs across the various network elements. Vertically the sheet contains the network elements. Horizontally are the FA categories and their costs, as calculated in the *I_FA_Costs* sheet.

Column H shows the initial estimate of the operating costs by network elements that is an input from the core and access models. Column I sums the equivalent FA costs allocated to network elements. In columns K to AK the user may change the allocation keys used. The keys can only be 1 or 0, where 1= allocate and 0=don't allocate. The cost calculations are performed in columns AM to BM.

C_Costs
This worksheet performs the final cost calculations on the various cost components and then allocates them to the available network elements.

C_Services
This sheet allocates the network element costs to services and then adds on the relevant mark-ups. Section 1 is a matrix of the costs allocated to each model by network element and the horizontal axis and cost type on the vertical axis. Cost types are broken down into broad categories such as expensed equipment costs, expensed installation costs, annualised equipment costs, annualised installation costs and annualised operating costs. For access network elements, costs are further broken down by geotype.

The remaining sections allocate the network element costs to individual products and services and apply mark-ups for common costs to derive a final unit cost per product. The results are fed through to the *O_Output* sheet.

14.4.4 Output sheets

O_Output
This sheet provides a complete set of unit costs for the products and services modelled in Core, Access and Co-location. One-off costs are shown separately from annual costs, as appropriate. For access-related costs, outputs are shown by geotype as well as for the country as a whole.

O_Results
This is the final results sheet of the Consolidation model. It shows a more limited set of outputs than the *O_Output* sheet, focusing on results of particular interest or those which will have a significant impact on pricing decisions.

O_Sensitivity
The sensitivity sheet allows the user to check the sensitivity of any changes made to model inputs. It compares current results with previous results and shows percentage differences, calculated as current/previous. The default comparison in the revised hybrid model is with the previous model version (Version 2.4), which was first released in 2006 and updated on an annual basis for changes in demand. Section 4 of the worksheet provides a disaggregated cost analysis to allow the user to explore the relative importance of the various network elements that make up the unit cost of a product, and any mark-ups applied. Access costs can be analysed separately by geotype, if required.

15. Appendix D: Bilag vedr kortlagte andre tjenester for LRAIC 2010

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