>

Report on the LRAIC Model

Revised Hybrid Model (version 2.3)

IT- og Telestyrelsen

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1. Introduction

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As a consequence of § 7, section 1 and 2, in Act no. 450 of 10 June 2003 on changes to the Act on Competitive Conditions and Consumer Interests in the Telecommunications Markets, the rules governing the determination of the maximum prices by the IT- og Telestyrelsen using the Long-Run Average Incremental Costs (LRAIC) method is laid down in Executive Order no. 930 of November 19th 2002 on interconnection products and in Executive Order no. 60 of 18 January 2005 on the contents and use of the LRAIC price estimation method.

By ruling of 20 December 2002, IT- og Telestyrelsen determined the maximum prices on the telecommunications market using the LRAIC method for the first time.

§ 14, section 6, of Executive Order no. 930 states that every third year, IT- og Telestyrelsen must evaluate whether there is a need for general changes in the LRAIC price estimation method.

On 25 February 2005, IT- og Telestyrelsen commenced a public hearing in order to investigate the necessity of a general revision of the method. IT- og Telestyrelsen recommended such a general revision be undertaken.

Therefore, on 11 March 2005, IT- og Telestyrelsen submitted a request for data and supplementary information to TDC (the incumbent) and the LRAIC Working Group (the industry) to be used in the method revision process.

Subsequently, the comments from the parties were submitted to public hearing. Note on the hearing process of 17 May 2005 from IT- og Telestyrelsen treats the hearing and the hearing responses. It is stated in this note that there is a need for general changes to the LRAIC price estimation method as a consequence of – among other things – technological changes in switching and transmission equipment as well as changes in the demand for interconnection products.

This report sets out to describe the revised LRAIC price estimation method. The basis for the revised method is the LRAIC Hybrid Model (version 1.3); however, changes to the model (now version 2.3) emerging from the note of 17 May 2005 are included and emphasized accordingly.

1.1 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, cf. § 14, section 2, of Executive Order no. 930.

The LRAIC price estimation method consists of a cost base developed in Microsoft Excel, which is published on IT- og Telestyrelsen's homepage. The cost base – 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 IT- og Telestyrelsen's homepage.

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1.2 The first version of the Hybrid Model

As stated in § 14, section 2, of Executive Order no. 930, IT- og Telestyrelsen develops 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 Hybrid Model cost base is 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, IT- og Telestyrelsen established criteria and minimum requirements for the two cost analyses. These criteria and requirements were laid down in three Model Reference Papers, namely:

- 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

Each of these papers was released in English and Danish and has been published on IT- og Telestyrelsen's web page.

Having received the models, IT- og Telestyrelsen together with the parties determined whether the models met the criteria and minimum requirements in the Model Reference Papers and developed a profound understanding of the assumptions and methodologies underlying each of the models. Special focus was given to the data input and the net structure. This work is documented in the Report on the Characteristics of the Top-Down and Bottom-Up Cost Analyses, published in March 2002.

IT- og Telestyrelsen prepared a detailed identification of the most important sources of difference between the two cost analyses. In accordance with § 15, section 2, of Executive Order no. 930, the purpose of this work was to control the results of the Bottom-up Cost Analysis through a comparison with the relevant results of the Top-down Cost Analysis. This comparison led to the identification of parts of the Bottom-up Cost Analysis that might gain from certain adjustments as well as a general verification of the assumptions behind the model.

This work is documented in IT- og Telestyrelsen's report on model differences ('The Reconciliation Report') that was published in May 2002.

This process led to the construction of the first draft version of a LRAIC Hybrid Model by IT- og Telestyrelsen that was developed as a consolidated balancing of the results from the two cost analyses. Technically, the Hybrid Model was based on the Bottom-up Cost Analysis incorporating elements from both analyses, cf. § 15, section 2, of Executive Order no. 930. In the autumn of 2002, the draft version of the LRAIC Hybrid Model was submitted to two public hearings on the basis of which a final version of the LRAIC Hybrid Model was determined in December 2002.

Using the Hybrid Model (version 1.3) for the first time, IT- og Telestyrelsen fixed the maximum prices for interconnection services in December 2002. Since then, version 1.3 of the model has been used as the basis of an annual maximum price fixing involving minor updates of relevant model parameters.

1.3 Revisions to Hybrid Model in 2005

As mentioned above, it has been decided to evaluate and revise the LRAIC price estimation method that lies behind the LRAIC Hybrid Model (version 1.3) in 2005. Using inputs from the tele industry, IT- og Telestyrelsen has been responsible for the revision of the method, which has resulted in a new draft version of the model (version 2.0) that has been submitted to public hearing.

All major changes to the Hybrid Model (version 1.3) are described in this report, which – as a consequence of the revisions to version 2.0 emanating from the public hearings – describes version 2.3 of the model.

1.3.1 Overview of Hybrid Model Reports

As well as the Hybrid Model itself, IT- og Telestyrelsen has prepared two reports to describe this phase of the process. These are:

- *this report on the features of the Hybrid Model itself*. 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. Special attention is given to the differences between versions 1.3 and 2.3 throughout the report.

- a user guide. This guide provides practical guidance to interested parties about how the models work and on the nature and role of each of the spreadsheets.

1.4 Summary of Results

The main results produced by the Hybrid Model (version 2.3) for use in 2006 are presented in table 1.1 below, which includes a comparison to the relevant results from model version 1.3 for the year 2005.

Table 1.1: Results for main interconnection services and raw cobber	Hybrid Model (version 1.3) (2005)	Hybrid Model (version 2.3) (2006)
Local interconnection (øre per minute)	3.12	2,76
Regional interconnection (øre per minute)	4.60	4,10
National interconnection (øre per minute)	5.61	5,58
2 wired raw cobber[1] (DKK per year)	803	770

[1] Excluding costs for the NTP

2. Overview of Methodology Used to Build the Hybrid Model

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 on 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 elaborated below. Finally, a more practical approach to the LRAIC method demands that it is decided, which specific services to be included by 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 is equivalent to a measurable version of marginal costs, i.e. the cost associated with providing a very small, literally infinitesimal, change in output.

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 and last definition of the increment. The two main increments are the sum of all services in the access network for the access increment and all services in the core network for the core increment. These are described in detail in chapters 5 and 6, 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 and the access network is already present; similarly, the incremental cost of an access network are the costs incurred when adding an access network and 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 naught, 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 of LRAIC will be closer to the first than the third definition.

The definition of the increment used for LRAIC means that fixed costs[2] 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 (however, not the trenching and duct costs shared between the two networks). These shared costs – shared by a number of services using a network – will comprise a significant proportion of an operator’s cost base.

2.1.1 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 the core and access, described below, provide a useful basis for measuring the costs of the two main increments.

2.1.2 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 calling rate) or to consider and increased number of subscribers by keeping the volume of traffic constant (implying a decrease in the calling rate).

Assets within the core network include:

- Exchanges (excepting any line cards)
- Transmission links between the exchanges
- Transmission equipment (e.g. Add-Drop multiplexers and cross-connectors)
- Optical fibre and trenching between all levels of exchanges.

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

2.1.2.1 Access

As defined above, costs in the access network primarily depend on the number of customers and only to a very limited extent on the number of calls. Consistent with this, an alternative definition of access is that it is the service allowing the customer to make and receive calls.

Both definitions suggest that the access network includes all cable and trenching costs associated with customer lines between the customer's premises and the concentrator. Moreover, the definitions suggest that the access network includes the line card within the concentrator. This is consistent with the first view since line card requirements are driven by the number of subscribers or, more accurately, by the subscriber requirements for lines. It is also consistent with the second view since the line card is essential when making and receiving calls.

Assets within the access network include:

- The line card within the concentrator
- The dropwire to the subscriber
- Trench (including any duct) between the concentrator and the customer's premises
- Cabinets
- Cobber cable and optical fibre in this part of the network
- Other assets as man holes, masts, etc.
- Network Termination Points (NTP)

2.1.2.2 Other Increments

In practice, there will be several other increments in addition to the core and access increment. Examples of such increments 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. Instead, the use of common costs by these increments are not estimated in details.

2.1.2.3 Other Main Assumptions

The LRAIC Hybrid Model is based on a Bottom-up Cost Model, which is 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 exchanges in the existing network are populated with equipment, however, modified as a consequence of more effective technology.

The use of the scorched node assumption is described below.

2.1.3 The Scorched Node Assumption

The legislation in Denmark requires the LRAIC price estimation method to adopt the scorched node approach to modelling. Following § 2, section 4, of the Executive Order, this implies 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 only is constrained by the existing number of sites and their geographical placement. 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 exchanges in TDC’s network comprise the constraint in the Hybrid Model:

- A Remote subscriber stage
- A local switch
- A transit or tandem switch

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.

2.1.4 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 factor for the particular services’ use of network elements.

2.2 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, data-related traffic, and other services.

The hybrid model accounts for all of these services. To exclude some would result in an under-dimensioned network and increased costs for the remaining services. The increased costs would arise, as the shared costs, such as duct, would be allocated to fewer services. The models should include and categorise services under the three broad headings – PSTN, leased lines, and other services – described below.

2.2.1 PSTN Services

PSTN services include standard call services that originate and terminate in exchange lines. They comprise a broad variety of services; Table 2.1 lists the most important of these.

Table 2.1: PSTN services

Core network	Access
Local calls	PSTN Line Rental
National calls	ISDN 2 Line Rental
International calls – Inbound	ISDN 30 Line Rental
International calls – Outbound	ADSL Line Rental*
International calls – Transit	Internet Line Rental*
IC Local Area	Raw copper
IC Within Area	Dark fibre
IC Between Areas	
IC Transit – Within Area	
IC Transit – Between Areas	
Fixed to mobile	
Mobile to fixed	
IN Basic	
IN Advanced	
Operator Services	
Other calls	

** Where the demand for these services has not been included in other categories, such as PSTN or ISDN line rentals.*

2.2.2 Leased Lines

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

- *Retail customers*, who usually require leased lines to provide a permanent connection between customer premises
- *Other operators*, who usually require leased lines to provide a permanent connection between networks
- *The network operator*, who require leased lines for a variety of reasons

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

2.2.3 Other Services

Other services using the core network will increase in importance over time. Examples include cable television, Virtual Private Networks (VPN) and packet-switching technologies such as frame relay.

3. Costs

>

This chapter describes the assumptions made by IT- og Telestyrelsen regarding unit costs (direct and indirect) and operating costs.

The following chapter contains a discussion of the assumptions and the approach used to annualise these costs.

3.1 Defining Costs

There are two methods of defining costs within the wide definition of the core and access increments selected by IT- og Telestyrelsen.

The first method is to look at costs that are directly attributable to services within the increment. For example, line cards are directly attributable to the PSTN part of the access service within our 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 PSTN). “Common” costs arise only when two increments (for example, access and core) actually share costs.

The relationship between directly attributable, shared, and common costs is shown in Box 3.1 below.

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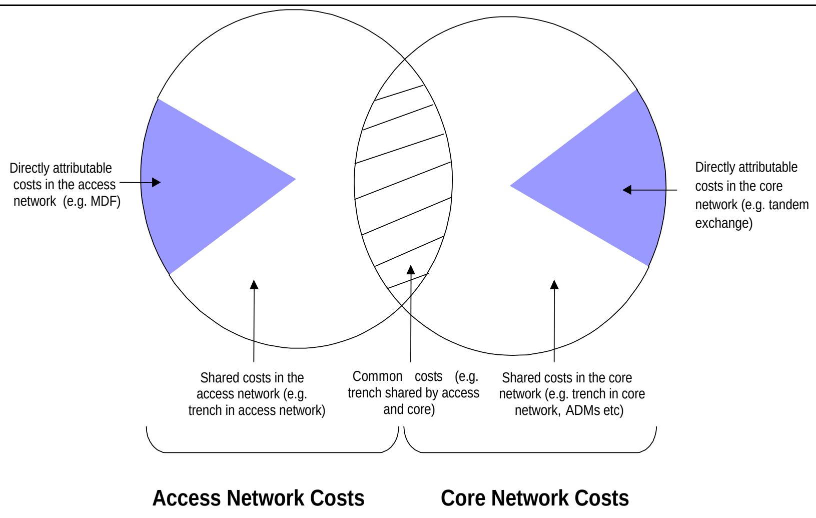
Box 3.1: The relationship between cost concepts



Directly attributable costs are the costs 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 inputs varying 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 may still be calculated. Second, assets and operating costs that are fixed with respect to the level of output but that are service specific.

Shared costs are the costs of those inputs necessary to produce two or more services within the same increment, if 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 PSTN, leased lines, and data services.

Common costs are the costs of those inputs necessary to produce one or more services in two or more increments, if it is not possible to identify to which extent a specific increment causes the cost.[3] 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 shared costs since the trenching is likely to be used by two or more service. However, some trenching will be used by both the access and the core network. In these instances, the costs will be common[4].

[3] The definition of common costs used in the Act includes both common and shared costs as defined here.

[4] A possible objection to this is that the scale of the trenching, and consequently the cost, may be greater if both the core and access networks use the trenching. In practice, though, the cost differences of using trenching for just access (or core) or access and core will be small or even naught.

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 personnel department)

Network costs measure the cost of those inputs necessary for the network to run. They can be divided between direct and indirect network costs. A direct network cost is defined to be one where the level 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 level of inputs and, hence, cost depends on choices made concerning other (direct) inputs and, therefore, only indirectly on external factors such as the level of demand. 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 the costs, which may be associated with supplying interconnection services at wholesale level. These are typically costumer 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 company running the network 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 Add-drop multiplexers Fibre
Indirect capital costs	Accommodation
	Power
	Security
	Air-condition
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	Customer related costs
	Billing and billing systems

3.2 Unit Costs

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

3.2.1 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).

3.2.2 Cost Estimates in the Hybrid Model

According to IT- og Telestyrelsen, 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, IT- og Telestyrelsen has investigated cost estimates from the various sources and developed a consolidated estimate based on all information available. However, in this process, IT- og Telestyrelsen has favoured the cost estimate, which was better justified or documented. This means that more emphasis or weight has been placed on estimates accompanied by robust and documented evidence.

The choice of price data used in the updated version of the Hybrid Model has been based on a qualitative assessment of the estimates and documentation available. When IT- og Telestyrelsen 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. When the equipment price used as benchmark is publicly available, it is used without further adjustments.

The Swedish telecommunications regulator (PTS) has informed IT- og Telestyrelsen 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. When used as benchmarks in the LRAIC Hybrid Model (version 2.3), a conservative stance has been taken by adding 11.11 to the equipment price from the Swedish LRIC Hybrid Model.

Furthermore, IT- og Telestyrelsen has access to various international benchmark prices that may be true and fair for use in the Danish LRAIC Hybrid Model. Documented and evaluated price information from the Swedish model as well as other benchmarks has, thus, been used as a qualified basis of comparison with the estimates from other sources.

IT- og Telestyrelsen 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)

3.2.3 Data Input and Confidentiality

IT- og Telestyrelsen is of 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 the data input used, and to supply IT- og Telestyrelsen 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 IT- og Telestyrelsen and thereby to get access to the underlying confidential data.
- Moreover, when the cost estimates used are dependent on confidential data, IT- og Telestyrelsen has estimated the cost for a type of equipment where cost estimates are available from more suppliers.

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

For **other types of data input** than unit costs, IT- og Telestyrelsen 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 input be accessible to all parties. In this case, the data used are highly dependent on confidential data supplied by TDC. As a consequence, IT- og Telestyrelsen has chosen to submit a public version of the model containing masked data instead of the underlying values actually 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 (for services that are LRAIC regulated, the deviations are all less than 2 percent).

3.3 Operating Costs

In the Model Characteristics report dealing with the Top-down and Bottom-up Models, IT- og Telestyrelsen acknowledged the difficulty in modelling operating costs in a bottom-up model, but noted that only sparse documentation and justification had been provided for the mark-ups – and for the event based costs – used in the model.

In particular, IT- og Telestyrelsen stated that it had not been sufficiently documented whether the operating costs had been calculated according to MRP guidelines and how the operating costs related to actual operating costs of operators.

As a consequence, IT- og Telestyrelsen chose to rely heavily on mark-ups and event based costs with some modifications in version 1.3 of the Hybrid Model (see for instance chapter 3.3 in the Model Documentation, October 2002). The mark-ups were to a large extent estimated on the basis of TDC's Top-down Model.

With the purpose of ensuring a high degree of transparency and a more direct modelling of operating expenditures. IT- og Telestyrelsen has chosen to introduce a new method with the latest update of the model – the Functional Area method (FA method). The method has been used for various similar tasks, including 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, cf. 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 exempted. Accordingly, it is ensured 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.

To maximise the transparency of the model, the cost categorisation is – to the largest extent possible – made comparable to the previous cost categorisation in TDC's Top-down modelling.

The method follows the following two main steps:

> Statement of costs per functional area

> Allocation of costs

These main steps are described in detail below.

3.3.1 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	Switching – management and planning Switching – maintenance Network Management System Transmission – management and planning Transmission – maintenance Access – management and planning Access – maintenance	Switching – installation Transmission – installation Access – installation	Corporate Overheads Human resources Finance Support systems Administration	Customer oriented costs Billing Debtor handling Other IC specific costs

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 (solicitors, engineers, etc)

IT- og Telestyrelsen 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.

Data from the Danish Metalworkers Union (Dansk Metal) is used for the technicians, and for the academic employees, data is collected at The Association of Danish lawyers and Economists (Danmarks Jurist- og Økonomforbund) and The Society of Danish Engineers (Ingeniørforeningen i Danmark). Further, the data has been analysed and compared to wage statistics by one of the LRAIC project group members.

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, course activity, and general administrative activities (see note under table). Furthermore, extra costs such as higher wages for managers have been taken into account by adding 50 percent of the wage for 8 percent of the employees (4 percent extra in total). The cost of employees on maternity leave has also been considered.

The yearly wage costs are entered into the consolidation model as input for the calculation of the working capital. The calculations are specified in table 3.3 below.

Table 3.3: Personnel Category and (average) Wage Level

Personnel Category	Yearly wage (DKK)	Weeks on maternity leave	Wage (incl. managers[2] and maternity leave)[3]	Hours per day	Hourly wage[1] (DKK)
Technicians	400,000	0.2	416,842	7.4	283
Administrative personnel (e.g. secretaries)	300,000	0.5	313,143	7.4	213
Academic employees (e.g. lawyers and engineers)	490,000	1.0	515,539	7.9	328

[1] *Assuming 199 working days per year (252 possible days, 25 holidays, 5 extra holidays, 10 days of illness, 10 days for administrative work and 3 days for course activity)*

[2] *4 percent mark-up on the yearly wage*

[3] *Extra cost = weeks on maternity leave *[(yearly wage/52) – 3.484 DKK (unemployment benefit per week)].*

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.

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, therefore, 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 (total of 30 percent mark-up incl. 4 percent for managers) has been added to all personnel groups, in the same way as before.

3.3.2 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. switching, maintenance, transmission installation, and access installation.
- Interconnection related costs, which are directly related to the commercial operation of interconnection – e.g. customer 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 Director's fees, legal assistance, etc.

3.3.2.1 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 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 the event-driven method

> α_{ij} = allocation scale for network element j and area i

In practice, this transformation is developed in the consolidation model as depicted in the ‘C_FA_Costs’ sheet.

3.3.2.2 Allocation of interconnection specific costs

Some costs relate specifically to the exchange of traffic or wholesale access services. According to table 3.2, 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. Switched interconnection is assumed to cover 75 percent of the interconnection specific costs, while wholesale access and interconnection services cover 20 percent and 5 percent of the interconnection specific costs, respectively.

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.

Lastly, a call related mark-up of 0.331 øre per call for IN and NP costs is used for switched interconnection. This mark-up covers 3.5 percent of IN/NP annualised capital costs and 3.5 percent of IN/NP operational costs.

3.3.2.3 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 3.4

Table 3.4: Mark-up for Other Annual Indirect Common Costs, incl. Operational Capital

	Mark-up (pct.)
Services in the access network	16.5
Services in the core network	17.6
Co-location services	17.1
Other services	17.8

These mark-ups are based on calculation of a common mark-up for all the services. The common mark-up was found to be 17.14 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. It should be noted that according to the calculation of the co-location specific costs, there is consistency between the method previously used for calculation of mark-up for co-location and the method used in version 2.2.

3.3.2.4 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 costs 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 following two examples illustrate the method:

1. *Operational and maintenance costs for exchange equipment.* At first, the operational and maintenance costs for exchange equipment are calculated from an average personnel usage per central. These costs usually make up 5-6 pct of the GRC for exchange equipment. Lastly, the figures are calibrated and pro rata validated with the figures from the hybrid model (version 1.3).

2. *Cost of maintenance of the access network.* An average percentage of error per line of 4.2 is assumed. This corresponds to 130,000 errors per year. Furthermore, costs for changes, renewals and updates must be added, corresponding to approx. 5 percent of the total number of lines, about 160,000 annual changes. This results in a total of 290,000 calls per year corresponding to an average personnel load of two calls per day. This is a number, which matches other telephone companies' experience.

The relationship between personnel and non-personnel costs is predominantly based on TDC's data from the 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 hown and transferred to the consolidation model.

3.3.2.5 Efficiency Study

IT and Telestyrelsen has prepared an analysis of TDC's operational costs, according the report "Efficiency Study" from European Economics. IT and Telestyrelsen does not find that the report on its own gives rise to further adjustments for efficiency of the operational costs included in the draft of the revised hybrid model. It should be noted, however, that the FA method in itself aims at an efficient modelling of the operational costs, whereby a further adjustment should not be necessary.

3.3.3 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 was used as in the first 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. This is the method used. Cash could also be defined as a percentage increase in sales revenue (in the equation (2) above, and these are seen as being equivalent).

In equation (2), it should be noted that the debtor days is the weighted average days for the different services.

(3) RLWC = debtor days/365 * (total costs including all costs of capital) * (1+ percentage of revenue required as cash)
- wage creditor days x wages / 365
+ electricity creditor days x electricity costs /365
+ equipment supplier creditor days x suppliers' costs /365
+ other supply cost days x other supply costs /365

The creditor costs may be determined from the total costs of the company, excluding cost of capital. This is obtained from the LRAIC model, since the equipment suppliers' costs (annual capital expenditure) is approximately equal to the depreciation.

Sum of depreciation, electricity, wages and other supplier costs is the total cost calculated by the LRAIC model when the cost of capital is set to zero. Thus, the total cost - when cost of capital is set to zero - is assumed to be equal to the creditor costs.

As a result, we can re-write (3) as:

(4) RLWC = debtor days/365 * (total costs including all costs of capital) * (1+ percentage of revenue required as cash)
- [wage creditor days/365 x % of total cost due to wages
+ electricity creditor days/365 x % of total cost due to electricity costs
+ equipment supplier creditor days/365 x % of total costs due to equipment supplier costs
+ other supply costs days/365 x % of total cost due to other supply costs] x [total cost of the business, excluding any CoC]

The [total cost of the company, excluding CoC] is derived from the LRAIC model, when CoC is set to zero.

The model calculates the RLWC using equation (4), but a further simplification is incorporated: we ignore the percentage of revenues required as cash and interpret this as an increase in debtor days (this is in agreement with the guidelines).

3.3.3.1 How the Figure is used in the Model

The total Working Capital (WC) is determined using the above formula (4) and using slightly modified input values compared to the input values that were used in the original bottom-up model.

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 85 for Core. This difference highlights the difference in payment methods. Raw copper is prepaid quarterly, whereas interconnection services in the overall net are paid at 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 the following table. These are unchanged in comparison to those used in version 1.3 of the LRAIC-model.

Table 3.5: Estimates for Working Capital used in the Hybrid Model

Type of cost	Estimate
Core services	1,36 pct.
Access services	-0,67 pct.

3.4 Building Costs for Exchanges, incl. Technical Houses

To ensure that the value of the property used for housing equipment, such as exchanges and technical houses reflects the real costs, IT- og Telestyrelsen has developed a more precise assessment of each property than in the previous model, where the public valuation of property was directly used. IT- og Telestyrelsen has, therefore, implemented a model where the public property values as informed by TDC were adjusted by a factor representing the difference between the market price and the public valuation in each geographical area.

3.4.1 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, IT- og Telestyrelsen has 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). IT- og Telestyrelsen 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 geo-type.

> The market value of buildings in each geo-type 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 geo-type.

> Land costs per m^2 are allocated to indoor property costs per m^2 in relation to land area per building area for each geo-type.

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.

>

Table 3.6 shows the calculated costs per category with and without the correction of the public valuation.

Table 3.6: Property Costs per Geo-type, incl. and excl. Technical Houses, DKK/m²	Urban	City	Land A	Land B	Average
Corrected public valuation incl. technical houses	10.392	4.918	3.701	3.969	7.324
Public valuation incl. technical houses	7.412	4.602	3.694	4.064	5.799
Corrected public valuation excl. technical houses	10.376	4.704	3.179	3.190	7.254
Public valuation excl. technical houses	7.390	4.377	3.172	3.290	5.683

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:

- The Cost of Capital (CoC)
- Asset lives
- Price trends

4.1 Annualisation Methodology

4.1.1 The FCM method

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

The concern of the FCM method 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 method, including the one used in the LRAIC Hybrid Model: Tilted annuities.

4.1.2 Tilted Annuity as Annualisation Methodology

According to the legislation, IT- og Telestyrelsen 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 LRAIC 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, always considering any changes in equipment prices and thus updated the model with new volumes. This principle is also used for the price estimation for 2006 and the years following, meaning that the prices for 2006 are based on information relevant for the year 2005.

The costs are annualised in order to ensure that the costs are recovered over the economic lifetime of the asset. The LRAIC Hybrid Model uses a tilted annuity, which calculates the sum of depreciations and capital costs. A tilted annuity is consistent with the use of the FCM method. A tilted annuity calculates an annuity charge that changes between years at the same rate as the price of the asset is expected to change. This results in rising annualisation charges if prices are expected to fall over time. 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.

4.2 The Cost of Capital

As in version 1.3 of the LRAIC Hybrid Model, the CAPM and WACC methods are used for the calculation of the Cost of Capital for an effective, Danish SMP provider of the LRAIC modelled services.

IT- og Telestyrelsen has conducted an evaluation of the parameters used for the previous WACC calculations from 2002 and has found reason for a re-estimation of some of the parameters. The ones in question are the gearing, the debt risk premium, the corporate tax, and the risk free interest. The market risk premium and beta are left unchanged. This re-estimation leads to a new estimate of the WACC of 8.4 percent, which is a decline of 2.45 percentage points compared to the estimate in version 1.3 of the Hybrid Model.

The cost of capital must be determined following the underlying assumptions in the LRAIC Hybrid Model and thereby reflect the cost of capital, an optimally run supplier of access and core network with SMP status would have in the long run in Denmark. Although it is the costs of an efficient operator in Denmark rather than the cost of capital for TDC that is to be determined, IT- og Telestyrelsen has found it useful in some areas to focus on information concerning TDC (or TDC's network activities) or existing foreign operators.

In the section below, the parameters used in the calculation of the WACC are described. Emphasis is given to the changes made under the previous method of calculation.

4.2.1 Estimation of Cost of Capital: WACC

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 (WACC) specifies the total cost of capital a company has by utilising capital. 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
- R_E is the return on equity
- R_D is the return on loan capital

4.2.2 Return on Equity

According to the Capital Asset Pricing Model (CAPM), the cost of equity of a company is computed using three factors: The risk free interest rate, the market risk premium, and the β-value of the specific company.

$$R_E = R_f + \beta_i \bullet [E(R_m) - R_f] \text{ , where}$$

- R_f is the interest of a risk-free asset
- $E(R_m)$ is the expected return from a general market portfolio of assets
- $E(R_m) - R_f \equiv R_E^{Premium}$ is a risk premium for investments in the market portfolio
- β_i is the systematic risk of investments in a specific asset

4.2.3 Risk-free Interest

As in version 1.3 of the Hybrid Model, the effective interest rate on a government bond with duration of 10 years has been used as an estimate for the forward looking nominal risk-free interest. The effective interest rate for the bond has been estimated as the average of daily observations throughout a full year. A period of a year is considered sufficient, as this makes it possible to use relatively recent information and all short term fluctuations in the market are levelled.

In 2002, the risk-free interest was estimated to be 5.1 percent. The corresponding estimate based on the average interest on government bonds with duration of 10 years yields a new estimate in 2005 of 3.4 percent.

4.2.4 Market Risk Premium

As it is more risky to invest in stocks (equity) than investing in the risk free government bonds, investors demand a risk premium when investing in stocks. In 2002, IT- og Telestyrelsen used a market risk premium of 3.75 percent. This choice was made by evaluating 7 different studies of the Danish risk premium – forward looking as well as using historical approaches – that applied arithmetical as well as geometrical averages based on time periods of 50-100 years.

IT- og Telestyrelsen has found no reason for changing the market risk premium used in version 2.2 of the Hybrid Model, as only few supplementary studies have been conducted since 2002, and as the market risk premium typically shows perceptible fluctuation in a relatively short time span as this. Furthermore, IT- og Telestyrelsen has noted that in 2005, the Danish Energy Regulatory Authority (DERA) has found it true and fair to use a premium of 3.75 percent as part of the regulation of the gas transmission and distribution networks.

4.2.5 Beta

When an agent invests in any given stock, he is assumed to run two types of risks - a systematic and an unsystematic risk. The unsystematic risk is caused by the risk connected to the specific stock. The investor may avoid this risk by spreading (diversifying) the investment on a number of different assets. Obviously, a collection of assets (a portfolio) will always exist eliminating the unsystematic risk.

The systematic risk, related to the investment, is due to the fact that it is generally risky to invest in the stock market. This risk is denoted by β and is measured as the covariance between the return of the specific stock and the return of the market portfolio put in relation to the variance of the return on the market portfolio. For the investor it is not possible to avoid the systematic risk, which is why a risk premium will be demanded. The magnitude of this will vary with the covariance of the specific stock and the overall market fluctuations.

As in the previous versions of the model, β is estimated through a comparison of the fluctuations in the TDC stock with the S & P 500 index (used as market portfolio) over a period of 5 years. IT- og Telestyrelsen finds the S & P 500 index to be appropriate as market portfolio, as it is a broad index that is often used in stock market analyses to determine beta values. Furthermore, IT- og Telestyrelsen has noted that the TDC stock is traded internationally and listed at the New York Stock Exchange. Using the S & P 500 index, a Bloomberg-adjusted β_{ungeared} of 0.63 is observed, which is lower than in 2002 (0.70). On the basis of β-estimates calculated by various investment banks, IT- og Telestyrelsen at that time chose an β_{ungeared}-estimate of 0.8.

IT- og Telestyrelsens is of the view that a telecommunications provider supplying interconnection services in both the access and core networks operates different businesses and accordingly faces risk to different extents. As a consequence of the same line of reasoning, the British regulator (Ofcom) has conducted several analyses[5] revealing that it is associated with a lower systematic risk – and hence a lower beta value – to operate in the access network.

The consequence of lowering the beta value in the access network would be that the corresponding beta value in the core network should rise by the same fraction. If this was not done, TDC would be facing a risk of under compensation of the investment costs.

IT- og Telestyrelsen has chosen a non-differentiated approach – resulting in a general beta value used in both networks – as it is assumed that potential investors judge TDC as a general service provider and not as two companies operating each their network.

IT- og Telestyrelsen finds – in spite of some indications of a lower beta value than in 2002 – that the most appropriate β-value for the Hybrid Model is still 0.8. In the public hearing following the publication of model draft version 2.0, IT- og Telestyrelsen noted that the LRAIC Working Group suggested a beta value of 0.8 for telecommunications providers operating in both networks (core and access). Finally, it is also noted that the Swedish regulator (PTS) uses values for β_{ungeared} in the interval 0.85-1.00.

On this basis, IT- og Telestyrelsen has chosen to uphold a value for β_{ungeared} of 0.8.

[5] http://www.ofcom.org.uk/consult/condocs/cost_capital2/statement/?a=87101

4.2.6 Gearing

The gearing denotes loan capital as a proportion of the total financing needs of a company. Generally, the demand for return on equity will be higher than the demand for return on loan capital. An increasing gearing will lead to an increasing debt risk premium as creditors demand a higher interest rate if there is less certainty in getting repaid.

In financial theory it is, therefore, assumed that an optimal financing structure minimising the cost of capital actually exists. This is called target gearing. In practise, this optimal gearing is very difficult to determine and it will vary according to the type and form of the company.

In version 1.3 of the Hybrid Model (2002), a gearing of 30-45 percent was used. The gearing used was estimated as a combination of the target gearing and the actual market gearing of TDC, Telenet. The business area ‘Telenet’ does not exist today, but it is possible to calculate a corresponding gearing for the business areas of TDC that are regulated. The areas in question are ’Exchange of traffic’ (011), ‘Rent of infrastructure capacity’ (012), and ‘Co-location’ (014).

IT- og Telestyrelsen has followed the market gearing for these business areas for some time and notes that as of October 2005, a gearing of 48 percent may be calculated – in spite of substantial increases in the TDC stock value in the same month. For TDC A/S, a gearing of 43 percent is found. Finally, IT- og Telestyrelsen notes that the gearing for TDC A/S has been above 35 percent ever since.

In comparison, the Swedish regulator (PTS) has used a gearing of 20-40 percent. This is irrespective of the fact that the actual gearing of the incumbent, TeliaSonera, was substantially lower (20 percent) at that particular time. The English regulator (Ofcom) also uses a gearing of 20-40 percent.

On the basis of the actual gearing of TDC, IT- og Telestyrelsen finds it appropriate to adjust the gearing used in the Hybrid model (version 2.2) to an interval of 35-50 pct.

4.2.7 The Return on Loan Capital

Just like investors in equity demand a market risk premium, creditors demand a debt risk premium in addition to the risk-free interest in order to lend capital to a specific company. The premium is assumed to rise with an increase in the gearing, cf. the discussion above.

For version 1.3 of the Hybrid Model (2002), the debt risk premium was estimated to an interval of 1.0-2.0 percent for a gearing of 30-45 percent.

The British as well as the Swedish regulators (Ofcom and PTS, respectively) use a smaller interval. PTS uses a debt risk premium of 1.0-1.4 percent, while Ofcom uses a premium of 1.5-2.0 percent. Both operate with a gearing of 20-40 percent.

In the Account on Telecom Competition of 2003, IT- og Telestyrelsen has previously analysed the debt risk premiums for Danish telecommunications companies with different market gearing. The conclusion of this was that a gearing of approx. 37 percent demands a risk premium of 1.5 percent, while a gearing of approx. 60 percent demanded a premium of approx. 2.0 percent. There was a large variation in the observations, though, and that is why the results give only an indication and not a final result.

A TDC bond issued on 9 August 2005 has an effective interest rate of 3.59 percent and a remaining life of 5 years. As a comparison, the effective interest rate on a government bond with duration of 5 years was 2.83 percent on the same date. This information can be used to calculate a risk premium of less than 0.8 percent[6]. This risk premium is partly a consequence of TDC's actual market gearing of 43 percent.

In conclusion, IT- og Telestyrelsen sees a need for reducing the debt premium interval used in 2002 for different levels of gearing as well as a general decrease in the debt risk premium for the upper part of the interval.

On the basis of the different inputs stated above, it is IT- og Telestyrelsen's opinion that the lower bound of the debt risk premium should be kept at 1.0 percent (while the lower bound of the gearing is changed from 30 to 35 percent, cf. section 4.2.6), while it is reduced to 1.25 and 1.50 percent for the two high gearing levels of 42.5 and 50.0 percent, respectively.

4.2.8 Tax Rate

In 2005, the corporate tax in Denmark has been reduced from 30 to 28 percent, which has been adjusted accordingly in the model. The tax rate is used in the calculation of the re-geared beta value.

4.2.9 Determination of Cost of Capital

IT- og Telestyrelsen's choice of parameters for the determination of the cost of capital plus the computed WACC values at a gearing between 35 and 50 percent is shown in table 4.1 below. As a consequence of the increased risk for creditors, cf. section 4.2.7, the debt risk premium increases above the interval 1.0-1.5 with increases in gearing.

[6] The two bonds are not completely comparable. Among others, the TDC bond has a remaining life closer to 4½ years and than 5. Still, the bond is thought to give an indication of TDC's interest costs for loan capital.

Table 4.1: WACC calculation			
Gearing	**30 pct.**	**40 pct.**	**50 pct.**
Risk free interest	3.40	3.40	3.40
Debt risk premium	1.00	1.25	1.50
β-ungeared	0.8	0.8	0.8
β-re-geared	1.11	1.23	1.38
Market risk premium	3.75	3.75	3.75
Return on equity	10.50	11.11	11.89
Return on debt	4.40	4.65	4.90
WACC	**8.37**	**8.36**	**8.39**

As illustrated in the table, the calculated value for the WACC lies in the interval 8.36-8.39 percent. IT- og Telestyrelsen has calculated the return on equity for TDC by using the Dividend Growth model. The preliminary result of this calculation for 2004 is approx. 9.3 percent, which is lower than the return of equity estimated in the CAPM model, cf. table 4.1 above.

Referring to the calculations above, IT- og Telestyrelsen has chosen to use a cost of capital of **8.4 percent**.

4.3 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 integer, values have generally been rounded to the nearest number dividable 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*
Cobber cable	20
Access fibre	20
Cabinets / distribution points	15
NTPs	10
Line cards	10
MDF	15
Signalling points	10
International Gateway	15
POI	15
Power supply unit	15
Security guard	1
Site maintenance	1
Site preparation	10
Air conditioning unit	15
Security system	10
Cross-connects	15
Core duct	40*
Core trench	40*
Core fibre	20
Radio links	15
Sea cable	15
Man hole	40
Transmission equipment	10
Splicing box	20
Buildings	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.

It should be noted that the asset lives for trench and duct have been extended from 30 to 40 years when compared to version 1.3 of the Hybrid Model. At the same time, the asset lives for trench and duct in soil have been reduced to 20 years, though, as the cable is ploughed in the ground in this geotype.

The reason for extending the asset lives to 40 years for trench is that the previous asset lives of 30 years are found to be too short. Benchmarks from Great Britain (40 years), Germany (35 years), Sweden (40 years), and USA (51 years) all indicate that asset lives are substantially longer than 30 years. At the same time it is noted that an economic asset life of 40 years is probably much lower than the physical live.

Finally, the asset life for NTP equipment has been reduced from 20 to 10 years, while the asset lives for man holes and splicing boxes have been extended from 15 years to 40 and 20 years, respectively.

4.4 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, IT- og Telestyrelsen believes that a historical period of no longer than five years (i.e. the price development from 2000 to 2005) 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 index for relevant sub indexes 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).

In table 4.3, the price trends in the original LRAIC model are compared to the price trends in the LRAIC hybrid model.

Table 4.3: Comparisons of Price Trends in the LRAIC Hybrid Model, Percent, Pro Annum					
Category of cost	**Hybrid Model 2004**	**TDC**	**LRAIC Working Group**	**Benchmark**	**Hybrid Model (version 2.1)**
Duct in access network	3	5		2	3
Trench in access network	3	2,6		2	3
Copper	0	2-15		1	6
Fibre in the access network	-5	-5	0	-1	-5
Cabinets/distribution points	1				1
NTP	0				0
Line cards	-8	0			0
MDF	-2	-2			-2
Signalling	-8	0			-6
International Gateway	-8				-8
POI	-5				0
Power supply	-4	0		-2	0
Security guard and security system	0			1	0
Site maintenance					0
Site preparation					0
Air conditioning	0	2		1	2
Cross cable	-5	0			0
Trench in primary network	3	3		2	3
Duct in primary network	3	3			3
Fibre in primary network	-5	-5	1-2	-1	-5
Radio link	-8	-8		-8	-8
Sea cable	-8	-8		-4	-8
Man hole	-3	3			3
Transmission equipment	-8	-5	2-3	-3-5	0
Splicing box	-10	-8			-8
Buildings					0
Land					4
IT, cabling and pc's	-6				-6

4.4.1 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 IT- og Telestyrelsen is that this index provides a good indicator for the price of digging trenches. Table 4.4 shows the latest development in this indicator.

Table 4.4: Changes in Indexes for Regulation of Tenders for Earth and Asphalt Work, Percent, Pro Annum[7]		
	Earth work	Asphalt work
2001	3,9	2,9
2002	1,0	1,7
2003	1,9	-0,2
2004	3,5	3,4
2005	5,6	7,7
Average 2003-2005	3,2	3,1
Average 2001-2005	3,6	3,6

Source: Statistics Denmark

The official statistics above show a positive price trend of between 3.1 and 3.6 percent for earth and asphalt work. Based on this, IT- og Telestyrelsen has used a price trend of **3 percent** in the 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.

As the international benchmarks also support this, the same price trend (3 percent), has been used for duct as well (as in the original version of the LRAIC Model).

4.4.2 Cobber Cables

The price for copper cables is to a large extent dependent on the price of raw copper. Table 4.5 shows the latest available figures for the price development on copper from Statistics Denmark.

The information indicates that the price of copper is increasing. The past two years (2004 and 2005) has thus seen an annual increase of 6 to 7 percent. The previous years (2002 and 2003) witnessed a drop amounting to 3 to 6 percent. The underlying monthly figures show annual increases of 13 to 15 percent beginning by mid-2004. These figures are presently slightly decreasing.

[7] The numbers have been calculated on the basis of index numbers for the price development based on figures from the last five years from Statistics Denmark. For earth and asphalt work, figures from second quarter of 2000 to the second quarter of 2005 have been used.

Table 4.5: 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
Average 2003-2005	2,5	3,1
Average 2001-2005	1,3	1,7

Source: "Statistics Denmark".

The information from TDC indicates a price trend of approximately 2 to 15 percent. Taking the price development of copper cables into consideration the price trend is estimated to **6 percent** for the coming 3 years.

4.4.3 Storage and Factory Buildings and Land

The price development for storage and factory buildings and land can be found in table 4.6 below:

Table 4.6. Changes in the Index for Storage and Factory Buildings and Land, Percent, Pro Annum[8]		
	Business buildings	Land
2001	-4.9	3.9
2002	4.6	0.8
2003	-1.7	4.8
2004	-11.7	10.3
2005	13.8	1.0
Average 2001-2005	-0.3	4.1

Source: "Statistics Denmark".

The prices of storage and factory buildings have fluctuated considerably in the period of 2001 to 2005. The same development can be identified regarding the prices of land albeit to a lesser extent.

[8] The numbers have been calculated on the basis of index numbers for the price development based on figures from first quarter 2000 to 2005.

>

Thus, IT- og Telestyrelsen has decided to base its estimate for the price development on the average of this development spanning the 5 year period. As it can be induced from the table above (4.6), the average prices for storage and factory buildings have decreased by 0.3 percent whereas the average prices for land have increased by 4.1 percent. Therefore, IT- og Telestyrelsen has decided to settle the price trend for storage and factory buildings to **0 percent** and the price trend for land to **4.0 percent**.

5. The Access Model

This section sets out to describe the methodology and assumptions behind the access model. Modelling of the access network is predominantly unchanged in relation to the current LRAIC model.

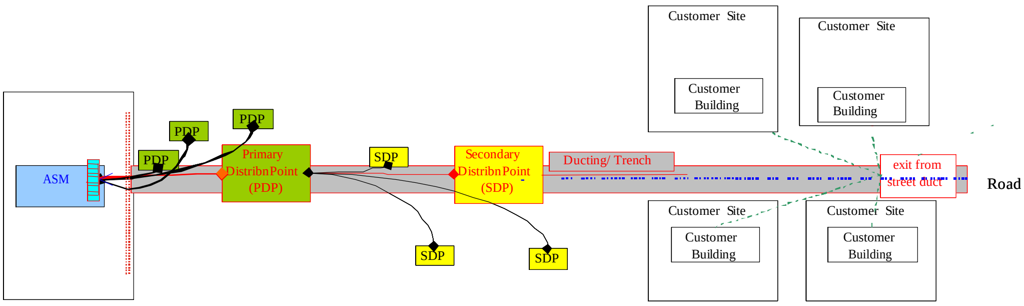
5.1 The Access Network in Denmark

The access network connects the end user with the centrals in the transmission network. Subsequently, the related costs primarily depend on the number of customers, and less so on the number of calls. Consistent with this, access can alternatively be defined by the services that allow the customer to make and receive calls.

Both definitions suggest that the access network includes all costs for cable and trenching associated with customer 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. 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 making and receiving calls.

A schematic representation of TDC's access network is provided in Figure 5.1 below.

Figure 5.1: Schematic outline of Local Access Network



Assets within the access network include:

- The line card in the Ericsson Access Subscriber Module (ASM)
- The trench from the line card in the ASM (incl. the MDF) to the Primary Distribution Point (PDP)
- Primary Distribution Point (PDP)
- The trench from the PDP to the Secondary Distribution Point (SDP)
- Secondary Distribution Point (SDP)
- The trench from the SDP to the final drop wire ("Exit From Street Duct", EFSD)
- The final drop wire ("Exit from Street Duct", EFSD) to the Network Termination Point (NTP) at the customer premises.

Cables from the subscriber stage to the EFSD are dug into trenches, in which ducts are placed, in which again the copper cables are placed. In comparison, the drop wire from the EFSD to the NTP is laid in special ducts ("mini ducts").

5.2 Overview of the Hybrid Access Model

IT- og Telestyrelsen's preferred approach to modelling access was described in the bottom-up MRP and used in the hybrid model. The preferred approach may be described as follows:

- selecting a statistically significant sample of exchange areas from each geo-type
- setting the boundary for each of these exchange areas on the basis of the boundaries in the SMP operator's own network
- on the basis of detailed maps – the most likely source are GIS[9] maps – determining the optimal layout of a network, given the known number of subscribers for that exchange area, the dwelling and street pattern
- repeating the procedure for each of the exchange areas and then aggregating up to estimate costs for the geo-type for a whole and in turn for Denmark (e.g. if the proportion of subscribers examined in a particular geo-type is 10%, costs are multiplied by 10).

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

Separate information for each of these distances is requested as the dimensioning rules for these different parts of the access network will differ. For example, the slow and erratic growth in the secondary access network makes it much more difficult to dimension than in 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 customer premises. This is referred to as "mini duct" in the hybrid model.

5.2.1 Modelling Key Network Elements

The access model calculates the cost of the major network elements in the access network, such as:

- Trench and duct

[9] Geographical Information System

> Mini-duct
> Copper
> Cabinets
> Network Terminations Points (NTP)
> Fibre

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 5.1: 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 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 geo-types. For each of the sixteen types of road, a factor (ranging from 0 to 2) has been assumed to convert road length into trench length. These are referred to as "conversion factors".
Mini-duct	The amount of mini-duct is estimated by measuring the distance between the exit from street duct and sites.
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 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.
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.
Fibre	The modelled amount of fibre has been derived by modifying the existing fibre requirements, using MEA-adjustments. The hybrid model assumes that fibre is used to supply existing fibre customers; customers connected through copper will continue to be supplied by copper.
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.

5.3 Main Definitions and Assumptions in Access

The Main Distribution Framework, the 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 geotype, since two zones of the same geotype can still have very different tele densities.

The main assumptions in the access model are as follows:

> In general, customers are connected to the same ASM site as at present.
> Some sharing of trench and/or duct is possible with the core network, with other TDC increments and with other utilities.
> There is no sharing of copper cable with the core network, with other TDC increments or other utilities.
> No use of fibre in the access network for customers already connected by copper.

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 customers connected to these houses.

5.4 Modelling Key Network Elements

5.4.1 Trench

5.4.1.1 Road Classification

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 geo-type.

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, IT- og Telestyrelsen has used the databases from DAV and the totals have been updated, applying information from Statistics Denmark. The length of each road segment has been estimated using the MapInfo software.

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

Table 5.2 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**

5.4.1.2 Conversion Factors

The hybrid model estimates most of the conversion factors through an analysis of TDC "INCA" maps. Through these maps, IT- og Telestyrelsen 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, it has not always been possible to extract, from the available maps, a meaningful sample of roads for each of the 10 classes of road.[10] 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.

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

Concerns were also raised, during the 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. ITST 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 IT- og Telestyrelsen's conversion factors as estimated through analysis of INCA maps and the econometric method.

Table 5.3: 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 5.3 shows the conversion factors used in the hybrid model. The total length of trench is hereby estimated to 124.245 kilometres.

5.4.2 Mini-duct

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

- by measuring the number of customer 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 geo-type for a sample of streets.

Raster maps[11] 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[12] 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 ITST 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 by geo-type derived from this process is shown in the table below:

Table 5.4: Average length of min-duct (by Geotype) in the hybrid model

Geo-type	Average length (m)
City (Storby)	5.1
Urban (By)	8.5
Rural A (Land A)	15.4
Rural B (Land B)	10.9

[11] 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

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

5.4.3 Copper equipment

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

5.4.3.1 Overview

For the copper network, the model allows for a three-layer tree and branch structure: ASM - Primary distribution point (PDP); PDP - Secondary distribution point (SDP); and SDP - customer 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:

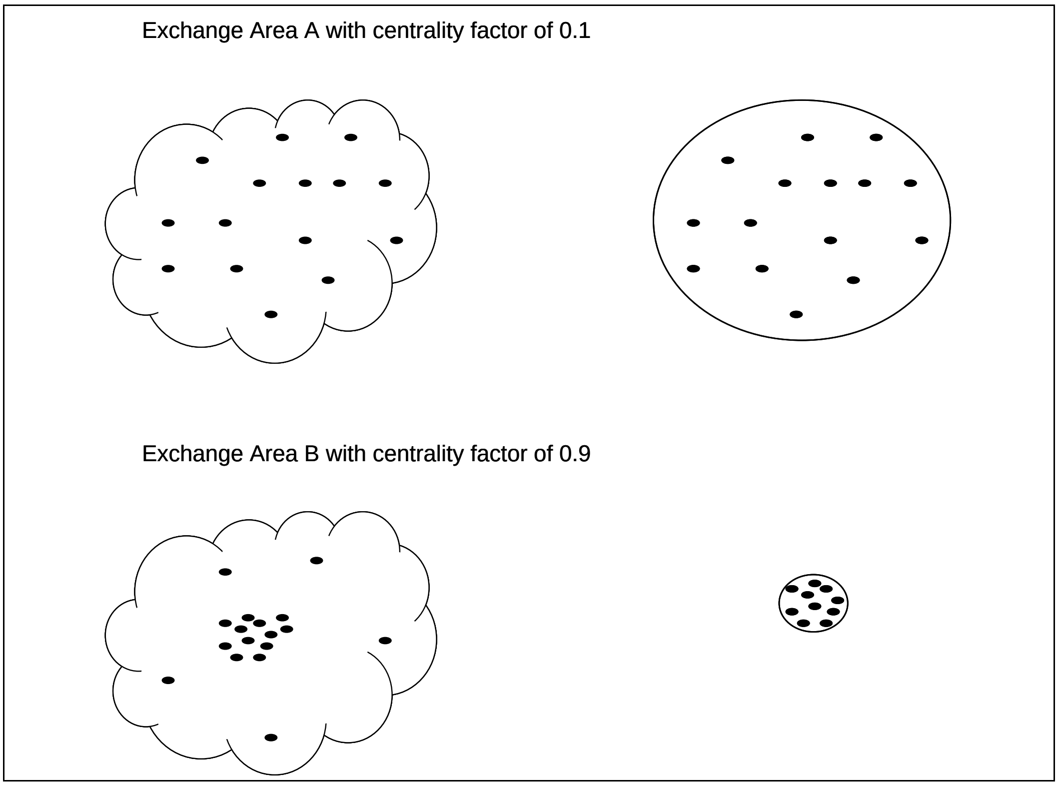
- Location of zone centre (grid reference)
- Location of switch (grid reference)
- Area in km2
- Weighting, i.e. the number of similar zones in the country. Different weightings can be given to each zone in the sample.
- Number of copper pairs.
- Parameters that define the dispersion of customers within 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 customer, 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 customers 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 customers 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 5.2 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 EFSD
- EFSD to customer 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 geo-type and then distributes the entire length-by-size amount over the different sizes of cable through the distributional assumption.

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

5.4.3.2 Average Distances of Different Parts of the Loop

The average distances in each part of the access network were affected by a number of variables, including:

> inputs such as average dimensions of customer sites and buildings, number of streets in a zone, street layout and street width.
> the inclusion of technical houses.

Inputs

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

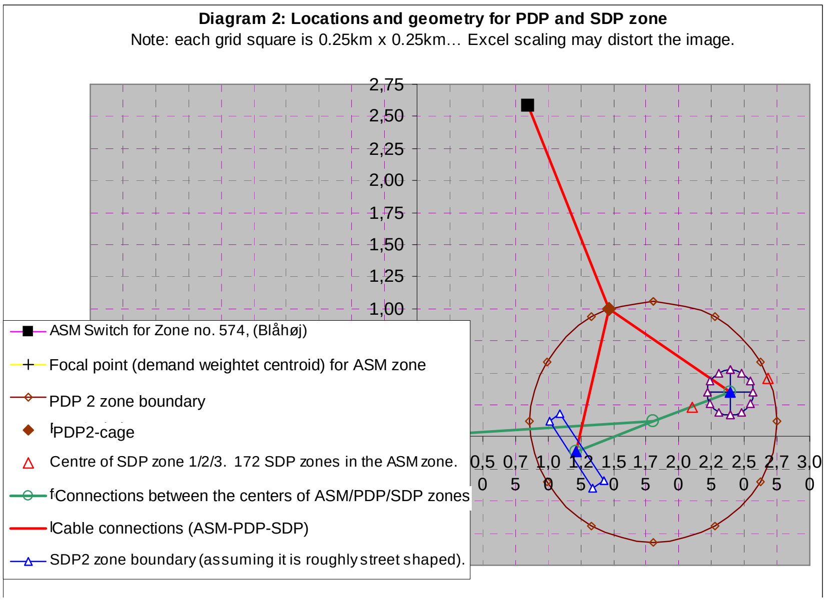
> From ASM to PDP. This distance has been estimated as the difference between the ASM and the centroid of the PDP zone (the elliptic function has here been used after the original area has been converted into an EHA) and the distance between the centroid of the PDP zone and the PDP cabinet (the location 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 customer 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 5.3: 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 customer, 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.

The inclusion of technical houses

As long as there is exchange equipment in technical houses, these meet the definition of a "node" as set out in the Model Reference Papers and, therefore, need to be included in the hybrid model. Technical houses are additional nodes that connect certain customers and are then connected to other exchanges by means of a fibre connection.

The inclusion of technical houses does not greatly affect the calculation of access costs in the hybrid model. This is largely because the number of exchange areas does not change; technical houses simply increase the number of nodes within an exchange area. Some exchange areas have more than one technical house.

Technical houses affect costs by altering (shortening) loop lengths. IT- og Telestyrelsen has included the average number of customers connected to technical houses for each geo-type to each of the 20 sample zones used in the model and then made an assumption regarding the impact the technical houses have on the loop length. IT- og Telestyrelsen has assumed that technical houses lead to a reduction in the ASM-PDP length of the loop for customers connected to technical houses. This reduction is inversely related to the centrality factor of the respective zone, reflecting the fact that the higher the centralization factor, the more likely it is that the few dispersed customers would have their PDP-ASM/TH length reduced by being connected to a technical house.[13]

In practice, this assumption — and indeed the inclusion of technical houses — has little impact on the results as relatively few customers are connected to technical houses.

[13] The reduction ranges from 50 per cent, for those areas with conversion factors equal to zero, to 100 per cent, for those areas with conversion factors equal to one.

5.4.3.3 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 geo-type.

5.4.3.4 Number of Cabinets

IT- og Telestyrelsen concluded that the average number of lines per SDP to be assumed should be in accordance with the experience from other EU countries. IT- og Telestyrelsen 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 PDS and SDP.

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

IT- og Telestyrelsen 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 5.5: Number of SDPs and PDPs in the access network	
Total number of PDPs in the network	11.600
Total number of SDPs in the network	431.551
Average number of working lines per PDP	225
Average number of working lines per SDP	5,7

The consequences of this assumption are shown below:

Table 5.6: Average number of PDPs per MDF area	
Geo-type 1	16,9
Geo-type 2	13,8
Geo-type 3	9,2
Geo-type 4	7,1
Whole network	**9,8**
Total number of PDPs in the network	**11.600**

Table 5.7: Average number of SDPs per MDF area	
Geo-type 1	1.731
Geo-type 2	873
Geo-type 3	255
Geo-type 4	126
Whole network	365
Total number of SDPs in the network	**431.551**

Table 5.8: Average number of subscriber lines in use per PDP	
Geo-type 1	1.773
Geo-type 2	599
Geo-type 3	123
Geo-type 4	52
Total network	**225**

Table 5.9: Average number of subscriber lines in use per SDP	
Geo-type 1	17
Geo-type 2	9
Geo-type 3	5
Geo-type 4	3
Total network	**5,7**

Different assumptions regarding the number of cabinets have an impact on the loop lengths. Presumably, 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 customers 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 customer) 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.

5.4.3.5 Cable Size

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

On the other hand, the hybrid model allows 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”[14] by “connection size”[15] (“connection size” excludes the adjustment for growth, at this stage).

> “Length by size” cable requirements by geo-types 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 geo-type. This would increase “length by size” cable requirements.

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

It is IT- og Telestyrelsen’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 reconciliation exercise has shown, working on the variable “length by size” allows us to separate the issues of connection lengths, connection number and their sizes. It therefore enables us to deal with the problem of cable distribution by size 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. IT- og Telestyrelsen has identified two important factors:

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[14] “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).

[15] “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.

- Different utilisation rates may have an impact on distributional assumption 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.
- Differences in number of PDPs and SDPs may have an impact on distributional assumption, 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.

5.4.3.6 Fibre Access Network

For the fibre network, the model works from an existing set of TDC data on the number of customers 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.

The model does not adopt fibre in the access network to serve existing copper connections – thus existing copper-supplied customers (PSTN etc) are assumed to be supplied via a copper network.

5.5 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 switch systems are shared with the access network. These costs are calculated in the core model and the switch costs that are relevant to access are transferred to access in the Consolidation model. These costs include line cards, the MDF and some switch building costs – the access part of the core switch 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).

6. The Core Model

This section describes the methodology and assumptions behind the core model.

The section entails a description of the modelled network, dimensioning of the network and the approach taken towards allocation of costs.

It should be noted that costs to exchanges (line cards, main distribution frame, etc.) and building & land related to the access network are summed up and identified in the output phase.

6.1 Approach to Modelling Core

Executive Order no. 60 as of 18. January 2005, regarding the LRAIC pricing method § 2, section 3, determine that the costing analysis:

> *"…must calculate the costs to produce the interconnection products in question in a network with an ideal configuration operated by an ideal company, based on the newest technological solutions and an optimally structured organisation."*

This regulation provides the basis for the optimisation of exchange equipment and makes it clear that this optimisation may include any mix of technological solutions that can be shown to be the most cost efficient.

The basis of the LRAIC pricing method in the years 2003-2005 has been the original LRAIC model finalised by the end of 2002. The modelled core network was founded on the same principles as for TDC's actual network and equipment - which was roughly equivalent to the newest equipment available in TDC's network.

In the process of updating the LRAIC model in 2005, the core network has been based on other and to some extent more "up-to-date" principles:

- The current three-layer network hierarchy is maintained based on SDH rings
- New technology is being implemented in the shape of new exchange equipment
- The overall network management is based on ATM as communications protocol.

Ericsson's ENGINE concept has been applied as paradigm for the exchange equipment.

The analysis has been based on the "scorced node approach" as depicted by the legal framework section 2.1.3. The Scorched node approach implies that:

- At least one switch is placed within each switching zone;
- 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 could be shared with other utilities or with the access network.

6.2 Overview of the Core Model

The Core Model contains different equipment elements:

> Telephony Server (TeS), which manages the overall routing in the network.

> Multi-Service Gateway (MSG), which is separated into transit og local.

> An ENGINE Access Switch Module (ASM), which in principle corresponds to a modern remote subscriber stage.

The model uses the following mix of exchanges:

> 5 TeSs

> 10 transit MSG exchanges

> 50 local MSG exchanges

> ASM Equipment is placed on all 1,693 sites in order to meet the ”scorched node” principle.

The five TeSs are distributed into five transit areas. The TeSs in each transit area is supplemented by two large transits MSG.

The number of local MSG is reduced from the current 105 local exchanges to 50 exchanges. This figure is calculated from TDC’s overview of exchanges in combination with a systematic reduction of the number of local exchanges derived from the traffic matrix in order to reduce the traffic derived from two or three exchanges to one exchange. With this reduction, the average number of subscriber lines will be approximately 60,000-70,000 lines.

The number and population of ASM correspond to the current population of RSS’ and HSS’.

All TeSs are co-located with a transit MSG, which again is co-located with a local Exchange MSG. Furthermore, all MSG are co-located with an ASM.

TeSs/MSGs communicate with the other MSG by using the ATM protocol. This protocol is by default deployed in the exchanges. Therefore, costs related to ATM ports have been allocated as a part of the price for standard equipment. The communication between ASM and MSG uses internal protocols.

It should be noted that there is a clear distinction between call management and traffic because TeS manages the overall routing of calls in the network, while MSG manages the corresponding traffic.

Exchanges are connected via the circuit switched transmission network. The topology for the transmission network is ring-based in a three-layer model where the structure still corresponds to TDC's network conceptually.

The transmission network is based on SDH rings connecting the remote subscriber stages to a ring of local MSG exchanges and a supplementary set of rings that connect local MSG exchanges to MSG transit exchanges. The transmission network structure between transit exchanges is also ring-based. Transit exchanges are connected by means of two rings with six connections between Jutland, Funen and Zealand.

Thus, the following three-layer network structure exits:

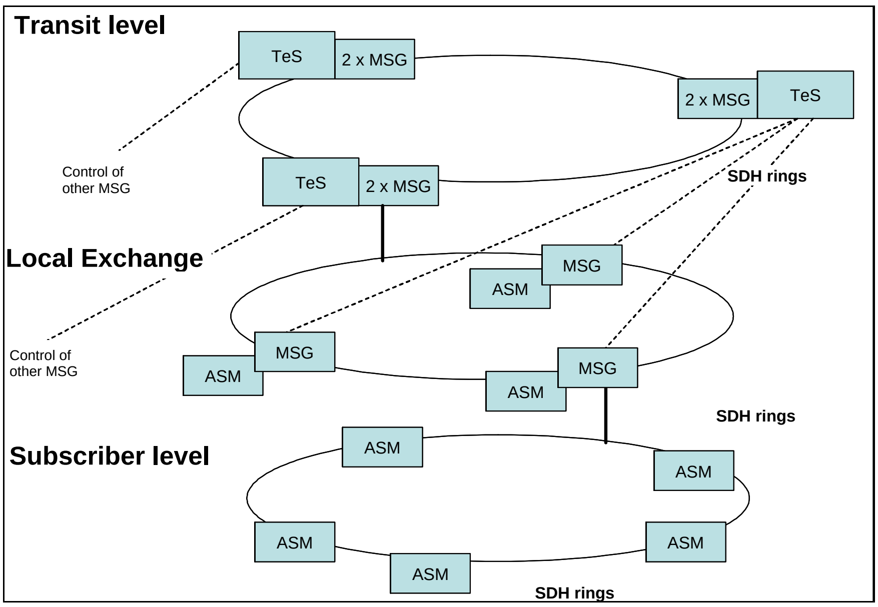
> *Access rings* – Subscriber stage: Access rings are used to connect access nodes (e.g. ASM).

> *Connectivity rings* – Local exchanges stage: Connectivity rings connect MSG within each transit area meaning an area controlled by a TeS.

> *Connectivity/Control rings* – The transit stage in the transport layer: Rings are used for transport routing of voice traffic but also to connect the signalling of each TeS to the MSG within each transit area. Thereby, the rings carry voice traffic as well as signalling information between transit areas. Signalling creates an increased demand for capacity (in excess of voice traffic) in rings of approximately 2 percent. The communication for the signalling traffic is based upon the ATM protocol.

The overall physical network structure is illustrated below.

Figure 6.1: Illustration of the physical network structure



With respect to resilience related to exchanges and transmission equipment, the model has been designed to be resistant to failure in the primary as well as the secondary transmission network. With regard to exchanges, it is assumed that each local MSG exchange is connected to two transit MSG exchanges and that 50 percent of the traffic is derived from each of these exchanges.

With respect to the transmission equipment, the ring structure ensures – in case of a broken fibre - that the traffic is allowed to flow in the opposite direction in the ring. The addition of the extra capacity to ensure network resilience implies that only a limited amount of traffic will be lost in case of a broken ring during busy hours for certain non-PSTN services (especially international fixed circuits). For PSTN services and most types of non-PSTN services there will be differences in the amount of traffic loss related to a broken ring.

6.3 Modelling of Important Network Elements – Structure of Exchanges

The optimal network structure has been based on the basis of a profound analysis of TDC's traffic. This entails 50 local MSG exchanges and 10 transit MSG exchanges. This is to be seen in the light of TDC's existing network, which encompasses 120 local exchanges and 10 transit exchanges.

This optimisation has consequences for the cost structure, particularly in terms of:

- Reduced costs related to local exchanges
- Changed routing factors for connections between remote subscriber stages and local exchanges
- Changed traffic flows in the different parts of the network - e.g. increased traffic in the remaining local exchanges
- Potentially derived effects on the lengths of trenches
- Derived effects on indirect costs and operating costs

In order to estimate the traffic matrix for the modelled network, it is assumed that the number of local MSG exchanges connected to the individual transit exchanges (covers the same area as in the modelled network) are reduced proportionally with the overall reduction of the number of local exchanges. Furthermore, the optimised local MSG exchanges are selected on the basis of size. Finally, the local exchanges that are converted into ASM in the modelled network are connected to the local MSG exchanges on the basis of a geographical "nearest to" principle.

On the basis of these assumptions, the optimised traffic matrix may be estimated where traffic flows from the selected local MSG exchanges are based on the sum of:

- Traffic flows from fewer local exchanges
- Traffic flows from ASM that previously served as local exchanges

It should be noted that the optimised network structure has a number of implications for the routing factors. These can be summarised to the following points:

> A larger number of end-users will be connected to the remote subscriber stages (ASM) than in the existing network, because an ASM replaces part of the existing local exchanges. The consequences of this may be estimated by comparing the number of subscribers in the remote units in the existing and the modelled network.

> The modelled local MSG exchanges will be larger than the existing local exchanges, which create more direct traffic streams. This leads to less traffic between transit exchanges. At the same time, it also leads to less traffic between local exchanges, because calls that previously used two local exchanges now to some extent will terminate within the same local MSG exchange.

The optimised traffic matrix is used to estimate a large number of vital parameters:

> The number of local MSG exchanges in the different size categories and the total and average number of lines for each size categories.

> The rings between remote subscriber stages and local exchanges are split according to size, and the relative traffic flows split according to the type of connection and the size category

> The number of local exchanges subordinated to each pair of local MSG transit exchange.

6.3.1 Basic Assumptions for the Network Dimensioning

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:

> PSTN traffic;

> leased lines; and

> 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 description in section **Fejl! Henvisningskilde ikke fundet.**), 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.

6.3.1.1 Routing Factors

The routing factors show the way in which the different network elements are used in the process of establishing a call. A local call can be routed through a remote subscriber stage and next to a local exchange from which it is directed to yet another remote subscriber stage. In this case, the call setup uses:

> 2 ASM or remote subscriber stages

> 1 local MSG exchange

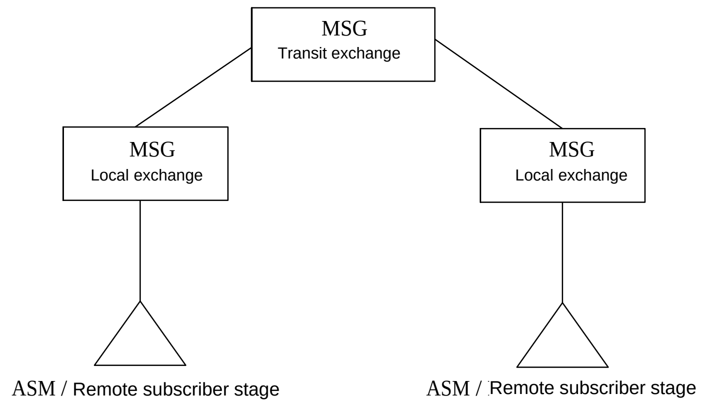
> 2 transmission connections between the remote subscriber stage and the local MSG exchange

In other cases, the call will use two local MSG exchanges and maybe even a transit MSG exchange. If a call uses two local MSG exchanges and a transit MSG exchange, it will also use two transmission connections between local MSG exchanges and transit MSG exchange.

In the hybrid model, the routing factors together with the traffic volumes are used in dimensioning the number of exchanges and transmission capacity (it should be noted that demand for transmission capacity is also driven by leased lines and data services). For some network elements, it is useful to consider a number of different types of utilisation. For local exchanges, the model estimates e.g. utilisation of access ports, trunk ports and processors.

>

Figure 6.2 Routing factors – an example



Routing factor of this type of call indicates the use of following network elements:	2 ASM 2 connections between MSG and ASM 2 connections between MSG local and MSG transit 2 MSG local 1 MSG transit

It should be noted that the routing factors for signalling and call setup connections are estimated separately, which is explained by the fact that they are used differently. E.g. for completing a local call (traffic) only one local MSG exchange, 2 ASMs and transmission capacity are required for call completion. For call management (signalling) additional elements are required i.e. TeS and transmission capacity for handover of signalling.

6.3.1.2 Busy Hour Conversion

The values for Erlang busy hour is of essential importance in the network dimensioning. The model uses the conversion factor BHE = yearly number of minutes /42/6/11/60 to convert the yearly number of minutes to Erlang in busy hour.

The yearly traffic load is first split by a factor 42 in order to calculate the traffic load per week with respect to the fact that traffic is not distributed evenly on all 52 weeks. In next step, traffic is further split by 6 in order to calculate traffic per day with respect to the fact that traffic is not evenly distributed on all 7 days of the week. The factor 11 reflects that 9 percent of the traffic occurs in busy hour. Finally, a factor of 60 is applied to convert the number of minutes to hours. The parameters applied are based on information provided by TDC.

6.3.2 Choice of Method for Network Dimensioning

The dimensioning of exchanges can be calculated in two ways (i.e. the amount of equipment required for each type of exchange can be calculated):

> *Method 1: Routing factor method* – traffic data for the individual routing factors are applied to the dimensioning of the exchanges. The model converts data for call minutes into Erlang in busy hour in the sheet 'I_Demand'. In the next step, a routing factor is applied to define the extent to which the different exchanges (and main network elements) and other parts of the transmission network are used by the different services. When the results for the individual services are summed, it is visible how much the different parts of the network are applied to deliver fixed network telephony services. The sheet 'C_Switching' uses these data to estimate the necessary amount of exchange equipment such as access ports and trunk ports.

> *Method 2: Traffic matrix method* – TDC's traffic matrix is applied directly in settling the required equipment in exchanges. TDC had delivered a matrix to NITA that shows the traffic flows between the different local exchanges in TDC's network. The traffic flows reflect the network structure in TDC's network. A number of iterations have been made on this basis in order to convert traffic flows to the composition of exchanges in the hybrid model (a more detailed description is provided below). Thus, the required amount of equipment can be estimated on the basis of traffic flows.

Both methods for network dimensioning have been used during the model development in order to ensure as correct dimensioning as possible.

However, the final model is based on the routing factor method where the results are calibrated against the traffic matrix. Thus, the final network dimensioning has been established in the best possible way by adjusting the individual model parameters in an iterative process.

Furthermore, the models are applied to define the required structure of exchanges.

6.3.2.1 Method 1: Routing Factors

The routing factors are the most critical input in dimensioning the exchanges by means of the routing factor method. Furthermore, a number of conversions of traffic data into Erlang in busy hour have to be made. Both elements are described in the following section.

Estimation of routing factors in the hybrid model

The routing factors in the hybrid model are estimated by use of the traffic matrix provided by TDC showing the traffic flows from the different local exchanges and within each local exchange. TDC delivered traffic volumes for traffic within the same local exchanges when the original hybrid model was developed (version 1.3). This has not been the case in the modelled version 2.3. Therefore, it is assumed that this traffic represents 20 percent of the national and local traffic.

>

This percentage is higher than the value measured in hybrid model (version 1.3), because the areas for the local exchanges are larger as mentioned previously.

A close study of the traffic matrix reveals a much larger Erlang level than in the corresponding traffic matrix in the previous version of the hybrid model (version 1.3) despite the fact that the traffic volume has dropped in the same period. Subsequently, TDC has informed the IT- og Telestyrelsen upon request that the higher Erlang level is due to the method applied in constructing the matrix. An approximation has subsequently been estimated.

Furthermore, it should be noted that the traffic matrix refers to the traffic volumes in the period 10-11 pm on Mondays. Traffic flows in this period are not necessarily scalable for the purpose of estimating the traffic flows in busy hour, because they vary on weekdays and time of year. Two factors have been applied to account for this: A factor that upscales traffic with 30 percent in order to account for the weekday, week and month and another factor that furthermore upscales with 5 percent to take account for the differences in traffic between the actual traffic matrix and the busy hour traffic.

Finally, the matrix shows the traffic flows between local exchanges and the international exchanges, co-location exchanges (local and national) and other types of exchanges. The traffic matrix that IT- og Telestyrelsen has received from TDC group all local and transmission exchanges together. Therefore, a formatting of the matrix is not required prior to the modelling. The matrix has been adjusted with factors previously described though. Subsequently, two versions of the adjusted matrix are constructed. The first one is related to the existing network, whereas the other is based on the optimised network structure previously described.

Then, the number of remote subscriber stages and locally situated subscriber stages connected to each local exchange and the corresponding number of subscriber lines (divided by type) are established. This is required in order to determine the changes in transmission capacity in the remote subscriber stages and the local exchanges in the optimised version of the model. This list is constructed by combining the traffic matrix with other data provided by TDC (size of concentrators, address and overlaying local exchanges).

On the basis of the above exercises and the original data, a matrix with the following characteristics is constructed:

- Headings at the top of the matrix and the margins show information regarding the code name of the transit exchange and the code name of the local exchange, respectively (all the local exchanges for any pair of transit exchanges are grouped together);
- Further headings to the right of the rows and at the bottom of the columns with transit and local code names show other classes of exchanges;
- A final set of rows provide headings for concentrators, specifically: number of RSS and HSS concentrators parented to any given local exchange; RSS subscribers by type of line; HSS subscribers by type of line; total subscribers by type of line; RSS, HSS and total weighted traffic with the weights determined by TDC planning rules for each type of line;

> The body of the matrix itself which shows traffic flows between pairs of exchanges (or in the case of non-local exchanges an exchange and an exchange grouping such as international exchanges);

> The data on number of concentrator numbers by local exchange; RSS and HSS lines by local exchange and so on.

The traffic matrix shows, for example, the traffic emanating from a concentrator parented to local exchange A and passing to a concentrator parented to local exchange B. It also shows the reverse flow, from local exchange B to local exchange A. While in general, this information is in an appropriate form for further analysis, it is sometimes necessary to combine these two flows if for example routing pattern and the number of ports are to be determined.

For example, if the rule for allowing direct routing between the local exchanges A and B requires the traffic to exceed 15 Erlangs (which is used a criterion in the model), it is the sum of traffic from local exchange A to local exchange B and from local exchange B to local exchange A, which needs to be examined in determining whether the traffic exceeds this level. To enable the model to do this, the original matrix was transposed, and the original matrix and the transposed matrix were added together to produce a combined traffic matrixINDSÆT FODNOTE 15 her****.

A further matrix was created using Excel 'If' statements to categorise routes by type. The following classes of routes were identified:

> Own Exchange

> Directly between local MSG exchanges (within the same transit MSG exchange)

> Local MSG exchange – own transit MSG exchange – local MSG exchange

> Local MSG exchange – other transit MSG exchange – local MSG exchange

> Local MSG exchange – own transit MSG exchange – local MSG exchange in another area

> Local MSG exchange – own transit MSG exchange – other transit MSG exchange – local MSG exchange in another area

> Non-Classified Traffic

> Interconnection

> Local Interconnection

> Other (IN, INB, etc.)

> International Outgoing

> International Incoming

Using the Excel 'Sumif' function, traffic flows were estimated for each of the above classes of route. Routing factors can then be assigned to each of these routing classes.

For a number of these routing classes, the routing factors can be directly derived. For example, routing to own exchange involves 2 subscriber stages and 1 local exchange stage while a direct routing of the call involves 2 subscriber stages and 2 local exchange stages. However, certain issues arise regarding the other routing classes.

Firstly, while the number of subscriber stages is self-evident, the transit routing between these stages and the local exchange depends on whether the stage is remotely located or co-located with the local exchange. This was determined on the basis of the respective number of remote and host subscriber stage lines. It has been necessary to apply this measure, because TDC has not been able to provide the necessary data to establish a more precise measure.

Secondly, it is assumed that direct routing is performed with a blocking rate of 15 percent, while spill-over traffic is routed via transit.

Thirdly, the network usage is not always apparent for some of the routings which use other types of exchanges. A variety of assumptions has been made to identify these cases. For example, it is assumed that approximately 80 percent of the traffic between MSG and other international exchanges are routed directly, which is in line with the information previously provided by TDC.

Fourthly, TDC's network, in common with many incumbent networks, allows for direct routings between local exchanges and non-parented transit exchanges where traffic volumes exceed a certain level. This means that the traffic emanating from a given local exchange passes directly to the non-parented transit without being switched at the parented transit. However, it has been assumed in the model that this traffic is transmitted over both the local exchange to transit exchange link and the transit exchange link between the parented and destination transit exchange. This results in higher estimated transit to transit transmission requirements than shown in TDC's routing factors.

Fifthly, it is assumed that interconnection within a region involves a local exchange and a transit exchange while interconnection between more regions involves a local exchange and two transit exchanges.

The next stage of the analysis involves converting the above information into routing factors for specific call types. In some cases, e.g. international outgoing, there is a one to one correspondence. In other cases, the correspondence is less clear-cut.

For example: some parts of the traffic to own exchange, local to local traffic, local to own transit traffic; local to other transit and indirect traffic from local to other transit, which will be associated with local calls; some national calls and some both local and national. It is therefore extremely important to identify the separate routing factors for local and national calls from this information. To do this it would be necessary to have the separate traffic flows for local and national calls and categorise these by type of route. As a consequence, a composite routing for local and national calls was created based on the routing types, which these calls may follow.

For some interconnection services, the calculated routing factors are based on another interconnection structure than in TDC's actual network. For interconnection traffic within the same area it is assumed that one local MSG exchange and one transit MSG exchange will be required. This is standard practise in a number of Western European countries. However, this does not correspond to the approach taken by TDC, where regional interconnection typically requires two local exchanges. For interconnection between areas it is assumed that one local MSG exchange, one transit MSG exchange and one (interconnection) transit MSG exchange are applied. These routings imply a lower interconnection cost and correspond to routings in other models and the existing network.

Dimensioning of ports

Calculations of ports, more precisely access ports and trunk ports, is an essential part of the dimensioning.

For ASM, the numbers of access port minutes correspond to the number of traffic minutes. For local MSG exchanges, the case is more complicated. For the moment, two access ports are required for e.g. a local call, while the number of trunk ports will depend on whether the call is terminated in its own exchange (no trunk port is required) or passes directly through or indirectly to another local MSG exchange (two trunk ports required). Internet calls will require one trunk port on the local MSG exchange. For transit MSG exchanges, two ports are required for each transit exchange applied.

The routing table shows the need for ports for each type of exchange. Thus, it is applied for estimating the number of port Erlang, i.e. the need for port Erlang in busy hour (BHE). This is then converted into number of ports. For this purpose, the inverse normal distribution function is applied, where the probability related to the normal distribution function is 1 minus the blocking rate (0.25 percent). The average value (for the stochastic variable) is the number of ports per link (measured in BHE).

After this, the costs of ports are calculated as the unit price multiplied by the number of units corrected for modularity and degree of utilisation.

In addition to the dimensioning of ports, the model also calculates other ASM costs, cost of line cards and MDF.

Regarding ASM units, the number of units to be placed on a given position is estimated on the basis of the number of 64 kbit equivalents (subscriber lines) for different sizes of ASM and the maximum capacity of the modelled ASM units (2,130 subscriber lines).

Line cards are delivered in cassettes or cards and divided into 64 kbit, 128 kbit (ISDN2) and 2 Mbit (ISDN30). The model contains demand data for each of these categories divided by type of exchange. The number of cards within each category is estimated on the basis of these demand data and assumptions regarding growth, margin for reserve and utilisation level.

The number of MDF depends on the number of subscribers connected to the ASM. Cost data for MDF is defined for (and adjusted to) different sizes of ASM. Thus, the cost for MDF is calculated as the number of ASM sites multiplied with the unit cost for a MDF, defined for each of the different sizes of ASM.

6.3.2.2 Method 2: Traffic Matrix Method

Besides being used as background for estimating the routing factors, TDC's traffic matrix is used for estimating ports and busy hour call attempts. Thus, this method is an alternative to the previously described routing factor method.

It should be noted that the traffic matrix has been applied for calibrating the results derived from the application of the routing factor method in the final part of the network dimensioning. The method is described below. However, as previously mentioned, the final model is based in the routing factor method.

In order to estimate the number of ports for each local MSG exchange, BHE has been calculated for each type of routing. This entails e.g. that each local exchange total BHE (outgoing as well as ingoing calls) are calculated directly for the direct routes to other local MSG exchanges within the same transit MSG exchange area. Furthermore, the number of these routes is estimated for each local MSG exchange. The average traffic for each route is calculated by dividing the total BHE of the local MSG exchange for the direct routes with the number of routes. Subsequently, this figure is converted into the number of ports by applying an approximately Erlang B formula and multiplying it with the number of routes.

As mentioned above, the direct routes are dimensioned with a high blocking rate (15 percent) where the exceeding traffic follows hierarchical routing. The result is added to the normal traffic between local MSG exchanges – transit MSG exchanges – local MSG exchanges and converted from BHE to ports so that traffic is divided equally between the two exchanges in one transit MSG central.

In order to calculate the number of access ports for each local MSG exchange, the sum of in- and outgoing traffic for the local MSG exchange is divided by the total number of links (that is calculated as the residing and remote ASM).

The number of access ports is primarily dependent on the traffic flows in the "maximum" busy hour (i.e. the sum of the individual maximum traffic flows), while the number of trunk ports depend on the traffic flow in busy hour for the entire network (sum of traffic flows in busy network hour). It is assumed that the level of traffic in "maximum" busy hour is 15 percent higher than in busy network hour.

The number of ports can be estimated on the basis of the number of trunk ports in local MSG exchanges. As an example, all calls, being routed hierarchically, will require one or more transit MSG exchanges implying that a number of ports will be directed towards the local exchanges. Thereby, the sum of all local exchanges subordinated to one transit MSG exchange will also be equal to the number of locally directed ports in transit MSG exchanges.

However, other ports are also required on transit MSG exchanges, e.g. ports directed towards other transit MSG exchanges and towards international exchanges. This method applied for calculating the need for these ports is analogue to the one presented above. For each type of traffic (such as traffic involving two transit MSG) the traffic volume in BHE for each local MSG exchanges is calculated and divided by the number of routes. Then it is converted to ports multiplied by the number of routes and summed up for all local MSG exchanges subordinated to one transit MSG exchange (it should be noted that the traffic is split evenly between the two exchanges in the transit MSG exchange).

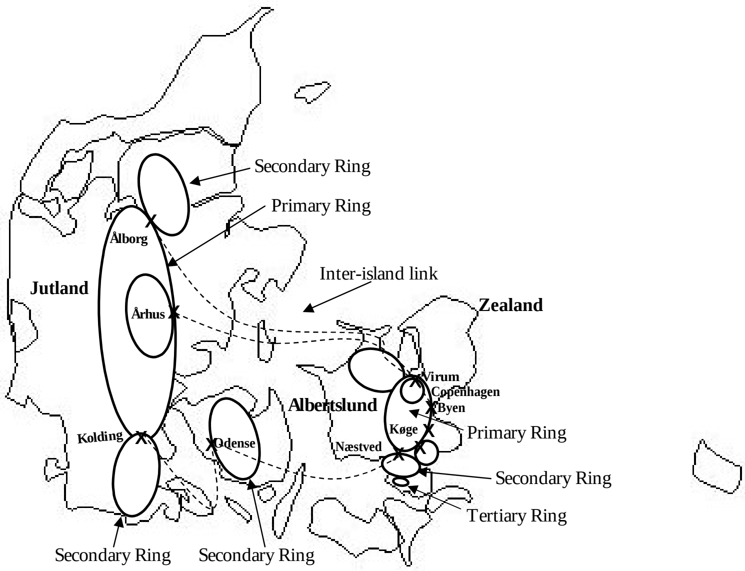
The model calculates call attempts in busy hour (BHCA) by means of BHE data. For each type of call and exchange, BHE is converted to BHCA by dividing by (1 minus the share of non-successful calls), dividing by call duration (in minutes) and finally by multiplying by 60.

The core model shows the ports for five different intervals for local exchanges. These intervals are created in the traffic matrix model based on the different BHE intervals and determining the number of local MSG exchanges that fall into the defined intervals (intervals are determined so that the model calculates on one hand a relatively small number of very small or very large local MSG exchanges and on the other hand a very large number of midsize local MSG exchanges)

6.4 Modelling Key Network Elements — Transmission Equipment

The hybrid model is developed on the basis of a ring structure. Figure 6.3 illustrates the modelled primary and secondary ring structures in Denmark.

Figure 6.3: Illustration of primary and secondary rings



There is a clear relationship between the configuration chosen and the most appropriate technology.

When considering different configurations, the hybrid model takes account of the following factors:

- the impact on resilience (double parenting provides more resilience compared to single parenting);
- the impact on network management costs (a ring structure usually implies less management costs than a point-to-point structure); and
- the use of cross-connects[16].

[16] When altering the configuration of the transmission network, the use of cross connects could be explored. For example, the increased flexibility they provide needs to be balanced against their high cost suggesting that they may not be appropriate for all services.

In the transmission calculation sheet (C_Tx), the transmission systems in the core network are dimensioned using the data in the network dimension rules, traffic demand and utilisation levels achieved for switched traffic.

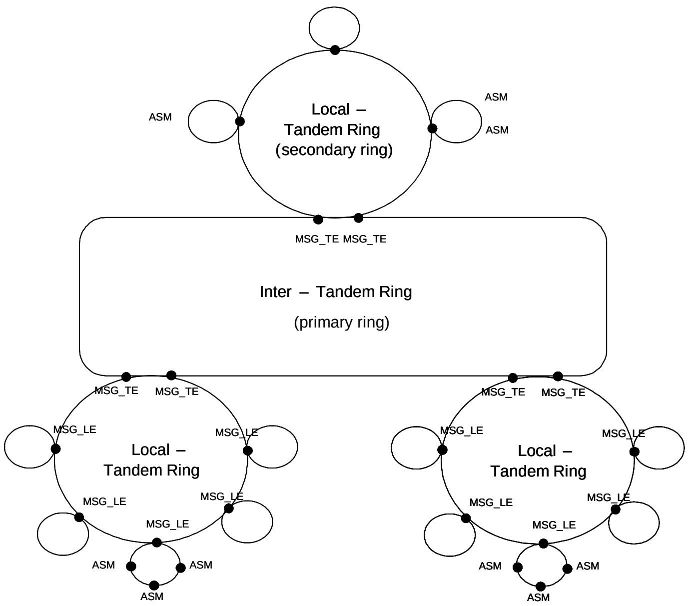
The calculated traffic intensity in busy hour for PSTN traffic defines the required number of BHE for each site category. This is converted into Mbits using the reverse Erlangs B formula discussed above.

The required capacity for leased lines and other services is added to the PSTN requirements, to give the total transmission capacity for each site link category. The capacity is corrected (uplifted) to ensure resilience. The correction factor for capacity is dependent on the type of traffic and the location in the network hierarchy (e.g. transit to transit connections have full protection, whereas other less important connections have a lower level of protection).

6.4.1 Ring Calculations

In the case of rings for ASM and local MSG exchanges, the average number of nodes is based upon TDC's actual data. The model segregates rings into three size bands and estimates the number of nodes for each of these sizes (one local exchange is assumed per ring) and the traffic carried per link.

Figure 6.4: Illustration of a ring based transport network

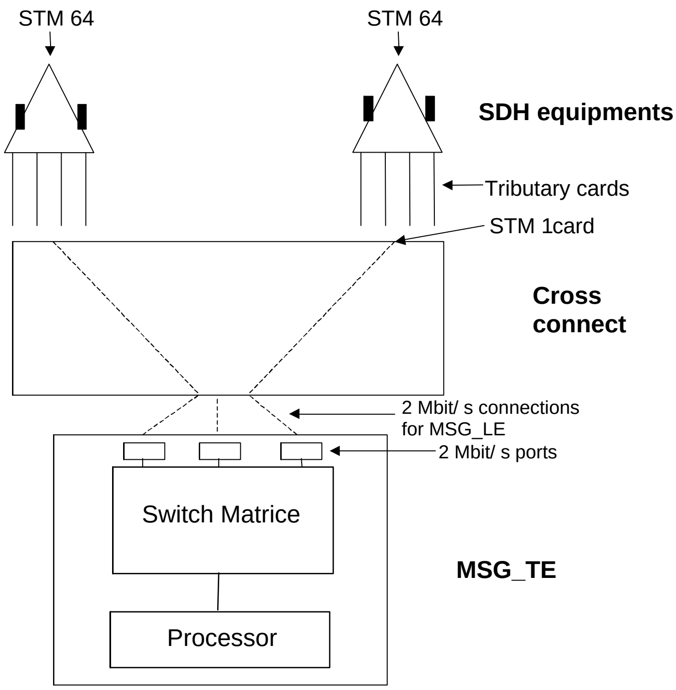


The ring capacity is calculated by taking the sum of PSTN and non-PSTN capacity per link, adjusted for diversity and multiplied by the number of links. It should be noted that capacity between host subscriber stages and the local MSG exchange is excluded from the calculation.

In the case of rings between local MSG exchanges and transit exchanges, the methodology is similar although certain differences should be noted. Firstly, it is assumed that each local MSG exchange is connected with two transit exchanges and that each ring therefore includes two transit MSG exchanges. Half of the local MSG exchange to transit exchange traffic is assumed to be routed to each transit MSG exchange. Secondly, the number of local MSG exchanges linked to each transit MSG exchange pair is calculated using data from the traffic matrix. Where the number of local MSG exchanges is modified to allow for network optimisation, the number of nodes per ring is also recalculated.

Thirdly, given the large number of nodes per each transit exchange pair is large; it is assumed that for each pair there are up to five rings. Currently, an upper limit of 8 nodes per ring is used in the model, which generally results in five rings per transit exchange pair.

Figure 6.5: Illustration of STM-64 and cross connects



Despite the fact that up to five rings are modelled for each transit exchange pair, the capacity requirements on these rings are high. From a capacity stand-point, this means that STM-64s are the appropriate choice. However, based on the specifications we have seen, STM-64 tributary cards are at the STM-1 level or higher, whereas circuit switched ports are 2 Mbits. In order for the capacity added/dropped off on the tributary cards to 'communicate' with the switch ports we have assumed a further level of STM-1s for MSG_LE-MSG_TE rings. Cross connects have been applied for rings between transit exchanges.

Capacity requirements in rings between transit exchanges are high in the model. This is to a large extent caused by the large number of leased lines and traffic from data services. Therefore, separate rings for each of the greater islands have been modelled. Even though this does not solve the capacity issue completely, because rings should be dimensioned to the traffic between the islands it reduces the requirements for transmission capacity. In this respect, it should be mentioned that TeS has to communicate with MSG by the use of the ATM protocol. However, this signalling traffic represents a very small share of the total traffic and accordingly is part of the overhead in the dimensioning of traffic.

6.4.2 Cross Connects

Following discussions with technical engineers, we have assumed that cross connects are used on every transit node to carry traffic between the transit MSG exchanges.

The model currently assumes that all traffic uses these interconnects twice just like 50 percent of the non-PSTN. The remaining volume of non-PSTN traffic is assumed to occur at the 155 Mbit/s level without the use of cross connects.

6.4.3 The Impact of Other Services using the Transport Network

In addition to PSTN traffic, the transmission network is used by both leased lines and data services and needs to be dimensioned accordingly. Given the importance of density economies in the transmission network, particularly with respect to optical fibre and trenches, the impact of such traffic is to significantly reduce the cost of transmission traffic on a per unit basis.

The model uses detailed information regarding capacity for non-PSTN split into the type of service and the route in order to get a more exact approach for these services.

6.5 Modelling of Important Network Elements – Trench in the Transmission Network

The model uses the same approach to estimating trench as in the LRAIC Working Group’s original bottom-up model.

The relationship between beeline distance and the actual distance between exchanges (beeline conversion factor) is estimated by choosing a pilot area. After that, all located transit exchanges, local exchanges and remote subscriber stages are drawn on a map. In order to calculate the distance between sites, two distances were measured on the map:

> *Actual trench distance*: This distance was found by measuring, where possible, the distances along the main roads between the exchanges. Consequently, the resulting trench distances may not be the shortest distances possible.

> *Beeline distance*: This distance was measured as the simple beeline distance between the exchanges.

Subsequently, the beeline conversion factors were computed by dividing the actual trench distance with the beeline distance. Three beeline conversion factors were computed:

> A transit exchange beeline conversion factor: This factor was computed between the two transit exchanges in the sample area

> A local exchange beeline conversion factor: This factor was computed as an average of the beeline conversion factors between 4 local exchanges in the sample area. A simple average and a weighted average were computed.

> A remote subscriber stage beeline conversion factor: A ring was created between the remote subscriber stages with a local exchange as ring head. Along this ring, the beeline conversion factors were computed and again a simple average and a weighted average were computed.

Distances are calculated separately for each level of the network hierarchy. The main elements of the approach are now described.

For remote subscriber stages – local exchanges rings – the average distance between remote subscriber stages is estimated as is the average distance between the remote subscriber stage adjacent to the local exchange and the local exchange in question. This distance is adjusted for the beeline to walking ratio factor and then multiplied by the number of links.

For local exchange to transit exchange rings, the calculation consists of two separate elements:

> *Firstly*, the extra trench required is calculated as the minimum distance between the subscriber stages on neighbouring rings (assumed to be the same as the average distance between remote subscriber stages).

> *Secondly*, trench shared with remote subscriber to local exchange rings is estimated based on a formula, which results in a sharing percentage varying between 17% for remote subscriber to local exchange rings with a small number of nodes and 47% for those rings with a large number of nodes. Two points should be made about this shared distance. Firstly, the distance is not necessary to measure overall trench length, or fibre requirements, but is necessary to allocate trench between different parts of the transmission network. The model has been developed to ensure that no double or triple counting takes place as a result of shared trenches. Secondly, while this network design is certainly feasible it could be argued that it may not be desirable because it increases the potential for traffic loss if a break down in a duct takes place.

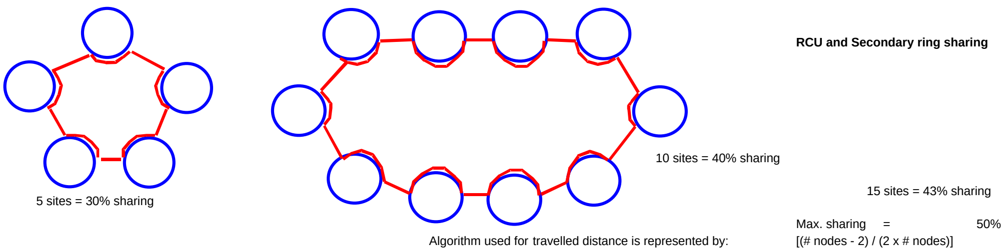
It is assumed that trench sharing does not exist between transit exchanges and other trench in the transmission network even though trench sharing in the access network is assumed. In the primary ring network, trench is connecting all sites in the two rings with six connections between Jutland, Funen and Zealand.

It is further assumed that there is trench sharing between the core and access networks, currently assumed to be 35%, and between the core network and other utilities. It is assumed that duct is applied in general and that trenches contains “4/5 pipes” duct.

This means that trench sharing with other parts of the transmission network is possible, because different “bores of duct” are applied.

In order to ensure consistency, it is assumed that separate fibre cables are applied where trench is shared between different parts of the network hierarchy. The very large volume carried and the fact that different logical ’MSG_LE - MSG_TE’ rings are assumed to employ the same physical rings, a cable with more than 24 fibres is required. Therefore, the model explicitly calculates the requirements for fibre based on the assumptions that a larger dimensioned cable is required when utilisation of the fibre exceeds 65 percent.

Figure 6.6: Assumptions related to trench sharing in the transmission network



The diagram shows smaller ASM rings (blue) connecting to larger secondary rings (red). As the numbers of smaller rings increase, the theoretical maximum amount of shared duct/cabling rises.

6.6 Detailed Description of Cost Calculations

6.6.1 Overview of the Model Cost Calculations

GRC for exchanges are calculated by multiplying the equipment prices in the sheet ‘I_Costs’ with the amount of equipment. Some of these costs are classified as call related, while others are minute or access related.

The necessary transmission capacity in the network covers the demand for both PSTN, leased lines and data services. The demand for each service is summed up in the sheet ‘C_Tx’ for different types of transmission connections. Furthermore, the sheet estimates the necessary capacity in rings for the different parts of the transmission network including the necessary equipment for providing this capacity. Requirements for trench, duct and fibre are also calculated in this sheet. Based on GRC, the transmission costs are calculated based on the equipment required. Finally, the sheet shows the cost categories for PSTN and non-PSTN for the most important types of transmission connections, respectively.

The results from ‘C_Switching’ and ‘C_Tx’ are summed up in ‘O_Consolidation’.

6.6.2 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. Exchange cost inputs are broken down into different component size categories as far as possible. Furthermore, costs for special services like i.e. IN services are included.

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

> Power supply unit – average power consumption is applied as 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 consumptions per square meter have 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. On the contrary it is not fair to assume that there is a distinct cost driver for allocation of cost to security guard and security system. 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. With regards to security guard there are no costs applied for inspection of ASM exchanges as opposed to the hybrid model (version 1.3)

Costs that relate to trenching, ducting, fibre and transmission 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, there are a variety of costs defined for each surface type. Also, there is a profile determining the likely amount of each type of trenching required.

6.6.3 Methods for Cost Allocation in the Model

6.6.3.1 Method for Cost Allocation Between Core and Access in ASM

In relation to the revision of the hybrid model, the IT- og Telestyrelsen has decided to apply a new exchange solution based on Ericsson ENGINE as a paradigm.

The RSS concentrators used so far are replaced by ASM. Furthermore, the product structure for the new units is different for the comparable RSS, why it has been necessary to update the cost allocation between core and access network.

The product structure for concentrator units is determined by the supplier and in this specific instance, by the equipment supplier Ericsson.

In this case, an allocation method is chosen where the basic equipment is allocated on the basis of an assessment of the functionality of the individual components in the basic equipment i.e. a detailed investigation of the cost allocation in the short term – and the derived allocation of cores and access weighted with the values for the individual components.

The following main groups of components are part of the basic equipment:

1) Line cards (PSTN, ISDN2, ISDN30)
2) Communication ports between ASM and local exchange, MSG: 2Mbps and/or STM-1
3) Chassis, Power Supply and Dummy Plate
4) Test card (TAU-C2 and TAU)
5) Controller cards, incl. cpu and storage and communication ports (AUS2 and AUS2-C2).
6) Basic software
7) Standard software, subscriber line dependent
8) Standard software for communication ports.

Ad 1) Costs for subscriber line card are by definition subscriber driven, meaning that all costs are 100 percent allocated to access.

Ad 2) Communication ports between ASM and MSG are 100 percent allocated to core traffic, being the sole cost driver.

Ad 3) These costs are common costs where the cost driver is assumed to be the number of cards. The costs are allocated based on the following consideration: A fully populated ASM chassis may contain 21 cards. A fully populated ASM will on average contain 13 subscriber line cards and 2 test cards (which is connected to access, because it is used to test subscriber lines). Therefore, these 15 card positions are allocated to access and likewise the two system cards and two communication ports towards the MSG are allocated to core.

Ad 4) Test cards are allocated 100 percent to access, because they are used to monitoring subscriber lines.

Ad 5) Controller cards incl. cpu, storage and communication ports (AUS2 and AUS2-C2). Both cards are allocated 100% to core.

Ad 6) Allocated to core and access

Ad 7) Allocated to access

Ad 8) Allocated to core.

Allocation of these costs is related with some uncertainty. Therefore, some of these allocations are based on estimates.

As a starting point it is fair to allocate a larger share to access than to core, because costs on the remote subscriber stage generally are related to access. This implies that 50 percent are allocated to access as a minimum, whereas 50 percent are allocated to core as a maximum.

However, it can be argued that up to 90 percent should be allocated to access, because the allocations in the previous version of the LRAIC model indicate a large proportion to access.

Based on the received price information from the parties on these main cost groups (from 1 to 8), a total cost of 209,150 DKK and an allocation of 63 percent to access and 37 percent to core is calculated.

This estimate is backed up by the fact that this allocation key is a cautious adjustment of the previous allocation key applied in model version 1.3.

Based on these reasons, 63 percent and 37 percent of the basis cost of ASM is allocated to access and core, respectively.

6.6.3.2 Method for Handling Shared Costs for other Services than PSTN

The transmission network is dimensioned to carry PSTN as well as non-PSTN traffic. However, non-PSTN should carry a reasonable share of the cost of using the transmission network.

This issue has been addressed in the core model by applying the total PSTN traffic measured as a share of all network traffic in order to exclude all non-PSTN traffic.

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

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. With respect to fixed costs, the depreciation profile is neither affected by increases nor decreases in traffic volume. For these cost categories, cost is allocated between PSTN and non-PSTN based on the actual volumes in the costing year (and <u>not</u> volumes incl. growth).

6.6.3.3 Method for Handling Infrastructure Costs

The share of trench shared with the access network is calculated and this share determines 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 inserted in the sheet with network dimensioning rules. Costs for land based access transmission is calculated directly in the access model. As a consequence, these have been removed in the core model in order to avoid double counting.

The share of sea cables applied in the access model is calculated as a share of the total costs for sea cables. This covers small islands that have no ASM equipment. Costs for transmission via sea cables related to the access network are summed up and transferred to the access model.

6.6.3.4 Method for Handling of 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.

6.6.4 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 depicts the minimum network capacity (and is used for network dimensioning applying method 1).

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 GRC’s and installation costs are added with the yearly operating costs (where the FA correction has been applied) in order to derive the yearly cost. Cost of capital, asset lifetime and the price development are combined in this calculation. The final costs of services are finally “uplifted” with a mark-up for overhead and costs related to operating capital.

7. 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 process.

7.1 Co-location

7.1.1 Definition of Co-location

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:

1) 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.
2) 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 connection with, cf. section 6(1) and 7(2),:

1) agreements on exchange of traffic; and
2) 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*.[17]

7.1.2 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.

[17] For the latest revision from the 14th of April 2005, please go to http://www.itst.dk/static/Samtrafik/standardaftaler/samhusning.pdf

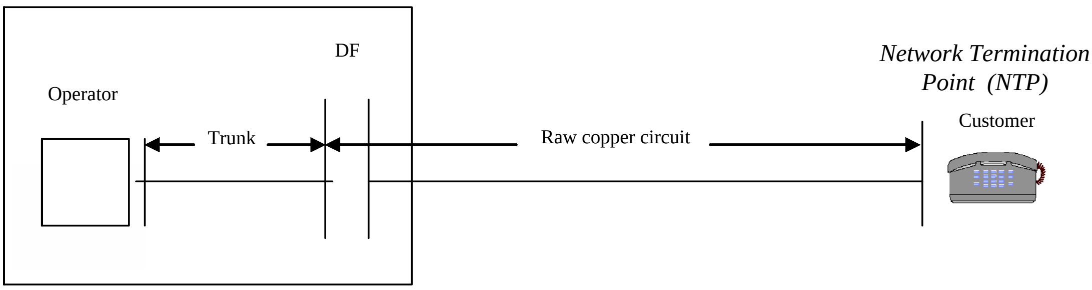
The access to a core network for the purpose of exchanging traffic is usually considered fewer than three headings:

1) *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.
2) *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.
3) *Direct connection*, where no additional equipment is needed.

7.1.3 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 below in figure 7.1.

Figure 7.1: 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.[18].

> *Virtual co-location.* In cases where it is not possible for the SMP operator to physically locate equipment in 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.

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

7.1.4 Modelling Co-location in the Hybrid Model

The hybrid model for co-location is the simplest of the three models feeding data into the consolidation model. It calculates the systems and areas required to meet various demands for co-location space and related services. 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 the costs of a range of “indirect” network costs and bundles them to form different co-location products and services.

The modelled co-location services are:

1) Co-location space (indoor m² and outdoor m²)
2) Rack space
3) Power supply (48 VDC 16 A 350 W, 230 VAC 10 A 700 W and 230 VAC 10 A 70 W)
4) Cables (8, 24, 100 and 300 pairs, and in-span)

7.1.4.1 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 upon the “access seeker’s” demand for capacity and upon 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.

7.1.4.2 Steps in Modelling Co-location

The steps taken during the development of the co-location model are:

1) Making a list of the co-location services (and other services) to be cost determined
2) Making a list of cost categories for each service to be cost determined
3) Inserting available information about the demand for each service (if relevant)
4) Defining the relevant input for each cost category
5) Equip each cost category with cost information and cost parameters

6) Defining relationship between demand and cost input on the one hand and the services on the other hand, i.e. establishing the formulas

7) Defining the interface with the other models, core and consolidation.

7.1.4.3 Demand

Demand data has been estimated by IT- og Telestyrelsen on the basis of data provided by TDC. The data is updated on a yearly basis.

7.1.4.4 Indoor Space

The total demand volumes are only necessary when the total costs for a shared cost category has to be allocated to demanded units. For indoor space, the total demand volumes are used to estimate the demanded unit share of the shared site costs.

7.1.4.5 Other Services

The actual demand volumes for other co-location services do not affect the unit cost of these other services because the cost categories have been modelled as costs per unit rather than total cost.

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.

7.1.5 Cost Categories

7.1.5.1 Cost of Building and Land

The costs for indoor and outdoor co-location space are calculated in the core model and split in two at the same time. The main reason being that land and buildings have different asset lives and price trends. Another reason is the need for modelling outdoor co-location space.

On July 4th 2005, TDC has delivered an updated data set containing information about valuations per site (public valuations from 2004 – 2002 for some sites). The data includes value of the land, building area in m^2 and total land area in m^2 for each site. IT- og Telestyrelsen has undertaken an analysis of the dataset plus information from Statistics Denmark, which documents the development in market prices over four quarters for production and storage facilities compared to the public valuation, c.f. section 3.4.

The cost per m^2 is remarkably higher for technical houses than for other exchange buildings. Because co-location takes place in exchange buildings and not in technical houses, it has been necessary to calculate a separate price per m^2 for co-location, which excludes technical houses. However, The technical houses are still used to calculate the price per m^2 which is applied in the rest of the model.

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

Table 7.1: Indoor and Outdoor Co-location Space excl. Mark-up		
Geo-type	**Annual cost per indoor m^2**	**Annual cost per outdoor m^2**
City	DKK 831	DKK 230
Urban	DKK 476	DKK 34
Rural A	DKK 351	DKK 12
Rural B	DKK 345	DKK 6

7.1.5.2 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:

1) Power supply
2) Air conditioning
3) Security system
4) Site preparation
5) Site maintenance
6) 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 the site cost category of “air conditioning unit”.

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

1) Power supply unit – average power requirement (kWh)
2) Air conditioning unit – average power requirement per m^2 (kWh/m^2 per exchange type)
3) 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.

Table 7.2: Annual Costs for Indoor Space per m^2	
Geo-type	
City	DKK 831
Urban	DKK 476
Rural A	DKK 351
Rural B	DKK 345

Compared to the Hybrid Model Version 1.3 in Version 2.3 common site costs are allocated to the remote subscriber stage. This, especially, has an impact upon changes in prices for geo-types Land A and Land B.

In relation to the price setting of the ongoing costs for rack space, a weighting of the annual prices for indoor space and the sale of co-location m^2 is developed.

7.1.5.3 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:

1) Room fit out
2) Cable trenches

The costs for the two categories are shown per rack space. One rack space is 1.5 m^2.

1) *Room fit out* includes costs for floor, lighting, fire alarm and planning.
2) *Cable trenches* include costs for the actual trenches, cabling and planning.

Regarding 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 and installation costs of 1/3 hour for a technician per rack space.

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

7.1.6 Power Supply

IT- og Telestyrelsen has individually modelled the different costs related to installation and the annual consumption for three power supply services.

For each of these, the following parameters are defined:

1) Materials
2) Number of hours for administration (order handling, etc.)
3) Number of hours for technicians (physical installation)

4) Annual consumption in kWh

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 230 VAC 10 A and Power 230 VAC service socket.

7.1.6.1 Cables

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

1) Cable increment (to allow for wastage during installation)
2) Cable price (DKK/m)
3) Digging (DKK/m), if any at all
4) Administration (order handling, etc.) (hours)
5) Technician (physical installation) (hours)
6) 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 10 m increments). In addition, it is assumed that there are no annual costs.

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

The results from the hybrid model for cables divided between a cost per 10 m cable and an off cost for the cable types 8 pair coax, 23 pair coax, 100 pair copper, 300 pair copper and in-span 48 fibre.

7.1.6.2 Overhead

Besides the directly modelled costs, IT- og Telestyrelsen has applied a mark-up to take the relevant overhead costs not modelled into account. The mark-up is not part of the co-location model, but is added directly to the cost of each service in the consolidation model. Overhead costs are described in section 3.3 of this report.

For co-location it is assumed that the cost of working capital net is zero. This is due to the fact that the determined price for co-location per m^2 is paid in advance whereas consumption is paid in arrear. 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 these oppositely directed items balance each other out.

7.2 ”Other Services” in the Hybrid Model

As mentioned, 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 IT- og Telestyrelsen 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:

1) Raw copper and shared raw copper
    - Installation
    - Request
    - New setup
    - Physical rearrangement
    - Change of trunk number
    - Technical assistance
2) Exchange of traffic
    - Establishment of pre-selection
    - Establishment and operation of regional points of interconnect
    - Establishment and operation of local points of interconnect
    - Establishment and operation of (2Mbit/s) interconnection capacity
    - Interconnection to value added services, including services with integrated (content) billing, and
    - Termination in/access to mobile networks via TDC’s network
3) Supervised access

Most of these services mainly consist of the operating costs and IT- og Telestyrelsen has decided to estimate the costs of the services separately. Apart from the two last services under exchange of traffic, the calculations are based upon the activities connected to the delivery of these services. The description of the tasks is based upon information from the LRAIC Work Group and TDC plus IT- og Telestyrelsen’s reading of TDC’s standard offers.

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

7.2.1 General Assumptions about Hourly Rate and Overhead Cost

When it comes to estimating work processes/tasks and derived costs of the individual service, the tasks and processes are generally divided into cost driving activities in order processing and carrying out the order.

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

To calculate the cost of delivering the service, the estimated time spent is multiplied with the hourly rate outlined in the LRAIC model. The hourly rates for administrative personnel, academic personnel, and technicians are shown in section 3.3.1. IT- og Telestyrelsen uses the same hourly rate as in the access model.

Furthermore, the cost base can contain other costs related to the order processing or actually carrying out the order.

IT- og Telestyrelsen has used a mark-up to take the relevant overhead costs not included in the hourly rate. These overhead costs are described in section 3.3.1. Similarly, working capital is taken into account. Overhead is not added in the co-location model, but as for all other services, in the consolidation model.

7.2.2 Handling Double Counting of Order Processing and Transport

In relation to each service, IT- og Telestyrelsen has evaluated to which extent a task is a natural extension of another service to which extent transport is shared with other services. Moreover, it has been 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:

1) If a task in relation to service B always is carried out as an extension of a task carried out in relation to service A, and service A is a technical pre-requisite for service B, then service B should only contain the extra, incremental cost derived from the extra work process undertaken in relation to service B. This implies that no party can be brought to pay for tasks not related to the ordered service.

2) If a task in practice is carried out at the same time as a task related to another service, but the services are not necessarily pre-requisites for each other, an adequate allocation of time consumption should be made. The allocation should take the frequency of how often the processes are carried out simultaneously.

In the actual model, this has been implemented as a weight (column *F* in the sheet *I_Resource*). If part of the time for transport is covered by another service, only the un-met share should be covered. The share is the weight.

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7.2.3 Raw Copper and Shared Raw Copper

7.2.3.1 In General

The order processing is assumed automatic to a substantial extent. Reception 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.).

It should be noticed that time spent upon cancellations and registry of trench is covered by the annual price and not the one off costs.

The tasks at the exchanges are assumed to be coordinated by the supplier with the tasks at the end-user. 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 company customers.

Apart from that, the saved time across services achieved from manned exchanges/distribution frames and from when several services share transport.

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 account for, for instance, 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 NTP is independent of each other in the sense that installation of NTP does not require installation of raw copper/shared raw copper. Thus, installation of NTP is billed separately at the price determined by LRAIC and not at the extra, incremental cost of simultaneous installation

7.2.3.2 Installation

Regarding installation of raw copper and shared raw copper, the following cost driving tasks should be regarded:

1) *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 as an automatic process.
2) *Physical coupling in exchange* – includes re-arrangement of cross thread plus establishment of connection from the wiring board via the MDF.
3) *Transport time to exchange* – covers the time spent on transportation to and from the exchange (when the exchanges are un-manned)
4) *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
5) *Transport time to end-user* – covers the time spent on transport between the exchange and the end-user

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

Because shared raw copper per definition is always installed on a copper pair, which is already in use, the time estimated only contain a limited amount in connection with 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.

7.2.3.3 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, IT- og Telestyrelsen has fund the following cost driving activities:

1) *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 and installation compared to the situation where only an installation order processing.
2) *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 regionally, which also reduces the need for transport. Therefore, a correction for double counting of time for transport (the share covered by new setup) is done in relation to the services installation of raw copper/shared raw copper and other conditions reducing the need for transportation.

7.2.3.4 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, IT- og Telestyrelsen has found the following cost driving activities:

1) *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 and installation compared to the situation where only an installation order processing.
2) *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 rearrangement 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 regionally 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.

7.2.3.5 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.

7.2.3.6 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 in the standard offers for raw copper and shared raw copper.

7.2.3.7 Inquiry

Inquiries are billed on an hourly basis and the rate is the LRAIC price 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.

7.2.3.8 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. The method used for local and regional points of interconnect is elaborated below.

Note that both regional and 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.

IT- og Telestyrelsen has noticed that especially the installation costs in practise will depend upon whether several 30-groups with different signalling and direction.

Because TDC previously has informed IT- og Telestyrelsen that normally only one interconnection bundle per point of interconnect is installed, IT- og Telestyrelsen has not found it reasonable to investigate this issue further.

7.2.3.9 Pre-selection

IT- og Telestyrelsen has identified the following relevant tasks connected to establishing pre-selection for a new subscriber:

1) *Processing of order* – includes all costs attached to pre-selection, including processing of order, confirmation, and registration of order. Moreover, the costs related to the implementation of pre-selection. The process assumed to be fully automatic.
2) *Customer service* – covers the cost concerning customers calling 147 (fault complaints)

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

7.2.3.10 Regional Points of Interconnect (incl. interconnection bundle)

<u>Installation</u>

The costs of installation are estimated on the basis of IT- og Telestyrelsen's evaluation of the relevant tasks and the time spent on them. The relevant tasks are

1) *Processing of order* – includes tasks in customer service to administrative personnel when receiving forms for traffic orders and orders for interconnect and transmission, putting orders in Columbus and processing the confirmation.
2) *Changes in the network* – includes planning and dimensioning of the necessary interconnection capacity, draw up signalling parameters, functionality and traffic data. This is assumed as tasks for technicians.

<u>Annual cost</u>

The *annual* cost for a regional point of interconnect is assumed to be wage costs for:

1) *Administration* – including both administrative personnel (e.g. billing, secretaries) and academic personnel (case processing)
2) *Network planning* – contains cost of network planning. Primarily, concerning quarterly meetings with the operator and the operator's quarterly traffic forecasts. This is assumed to be tasks for technicians.

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

It is assumed that resources spent on operating a local point of interconnect are less than operating a regional point of interconnect.

7.2.3.11 Local Point of Interconnect (incl. interconnection bundles)

<u>Installation</u>

The cost of installing a local point of interconnect is calculated in the same manner as for a regional point of interconnect. The relevant tasks are:

1) *Processing of order* – includes tasks in customer service to administrative personnel when receiving forms for traffic orders and orders for interconnect and transmission, putting orders in Columbus and processing the confirmation.
2) *Changes in the network*- includes drawing up the signalling parameters, operation and maintenance (e.g. surveillance), functionality and traffic data meaning Net's programming of a command file to the changes in the network relating to a regional point of interconnect. This is assumed as tasks for technicians.

When a local point of interconnect including interconnection capacity is installed, the same tasks as for a regional point of interconnect including interconnection capacity are assumed – not signal links and Access7, though.

For this reason – and because of economies of scale - in the LRAIC model it is assumed that 20 percent less resources are spent on installing a local point of interconnection compared to a regional point.

<u>Annual cost</u>

The annual cost of a local point of interconnection is calculated in the same manner as for a regional point of interconnection. The relevant tasks are:

1) *Administration* – including both administrative personnel (e.g. billing, secretaries) and academic personnel (case processing).
2) *Network planning* – contains the operating and maintenance tasks like individual repairs and "common" goods such as development of the network.
3) 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.

As for installation it is assumed that 20 percent less resources are spent on network planning for a local point of interconnection compared to a regional.

7.2.3.12 Interconnection Capacity

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

<u>Installation</u>

The cost drivers for installation of interconnection capacity are:

1) *Processing of order* – includes tasks for administrative staff, e.g., processing of order, confirmation, registration of order, and ordering hardware.
2) *Mounting of hardware*, also including the physical coupling done by a technician.

<u>Annual Cost</u>

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

1) An annualised cost of ETC hardware (trunk port).
2) 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 input. The annual cost of ETC hardware is calculated as a tilted annuity with an asset life of 10 years and the same prices trend as ports.

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

7.2.3.13 Interconnection to Value Added Services Including Services with Integrated Billing

Access to value added services falls under the LRAIC regulation as regards the conveyance over TDC's network. IT- og Telestyrelsen assumes that this bit of the services roughly corresponds to the service "interconnection between areas". IT- og Telestyrelsen therefore believes costs should be estimated as the cost of "interconnection between areas" plus the costs of the relevant value added services. This is consistent with the pricing structure in TDC's standard offer on interconnection.

7.2.3.14 Termination In/Access to Mobile Networks via TDC’s Network

The cost of termination in/access to mobile networks via TDC's network corresponds to a transit service plus the cost of (cascade billed) termination in/access to the mobile network. The transit part of the call falls under the LRAIC regulation. The cost of this service should be connected to the costs of transit. Earlier, IT- og Telestyrelsen has estimated the difference in cost to be 2 øre per minute and 1 øre per call. This difference, which covers TDC’s costs regarding cascade billing of access/termination charge, is also covered by the LRAIC regulation.

7.2.4 Supervised Access (with notice)

Supervised access with the participation of a technician is settled by the hour with 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.

Appendix A: Abbreviations

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ASM	Access Subscriber Module
BHCA	Busy Hour Call Attempt
CF	Centrality Factor
CoC	Cost of Capital
CVR	Cost Volume Relationship
DAV	Dansk Adresse og Vejdatabase
DDF	Digital Distribution Frame
DEA	Data Envelopment Analysis
DSL	Digital Subscriber Line
DSLAM	Digital Subscriber Line Add and drop Multiplexer
DWDM	Dense Wavelength Division Multiplexing
EFSD	Exit From Street Duct
EHA	Equivalent Homogenous Area
FCM	Financial Capital Maintenance
GBV	Gross Book Value
GIS	Geographical Information System
GRC	Gross Replacement Cost
HSS	Host Subscriber Switch
IN	Intelligent Network
ISDN	Integrated Services Digital Network
LE	Local Exchange
LRAIC	Long-Run Average Incremental Cost
MDF	Main Distribution Framework
MEA	Modern Equivalent Asset
MSG	Multi-Service Gateways
NTP	Network Termination Point
ODF	Optical Distribution Frame
PDP	Primary Distribution Point
POI	Point Of Interconnect
PSTN	Public Switched Telephony Network
RCU	Remote Concentrator Unit
RSS	Remote Subscriber Switch
SDH	Synchronous Distribution Hierarchy
SDP	Secondary Distribution Point
SFA	Stochastic Frontier Analysis
SMP	Significant Market Power
STM	Signalling Transfer Model
TE	Tandem Exchange
TeS	Telephony Servers
VPN	Virtual Private Network
WDM	Wavelength Division Multiplexerxer