STUDY ON THE PREPARATION OF AN ADAPTABLE BOTTOM-UP COSTING MODEL FOR INTERCONNECTION AND ACCESS PRICING IN EUROPEAN UNION COUNTRIES

A Final Report

for

Information Society Directorate-General

of the

European Commission

by

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The views expressed in this study are those of the consultants and do not necessarily reflect the view of the European Commission

While every care has been taken in the preparation of this model, including the compilation of data which can be used in default of country-specific inputs, Europe Economics cannot accept responsibility for any decisions which may be made by National Regulatory Authorities (NRAs) or others on the basis of model calculations.

TABLE OF CONTENTS

1 INTRODUCTION

1.1 Terms of Reference

This report presents the results of a project commissioned by the Information Society Directorate-General of the European Commission from European Economic Research Ltd (Europe Economics) in December 1998.

The objective of this study is to provide an adaptable "bottom-up" model capable of calculating the forward-looking, long-run average incremental costs (LRAIC) of interconnection services for a variety of European Union (EU) Member States. The Terms of Reference require that the model should estimate the cost of three interconnection services: (1) **local level interconnection**, (2) **single transit interconnection**, and (3) **double transit interconnection**. The model should have the following features:

- It should be restricted to costs associated with the "core" (conveyance) network, so that interconnection charges would not include contributions to assets that are dedicated to the end customer.
- It should model the incumbent's current switching centres.
- It should be designed primarily so as to measure the costs of call termination, though it should also be able to measure call origination costs.
- It should be sufficiently flexible to be deployed to estimate the cost of different networks, parts of networks, or different areas, where infrastructure costs and traffic profile and density can vary.
- It should enable costs to be distributed on a per minute basis reflecting the relative time of day pricing of the interconnection provider (normally the incumbent operator).
- The interconnection costs should be averaged across regions.
- Finally, the model should be reconciled with a suitable top-down model and with at least one independent bottom-up model.

While every care has been taken in the preparation of this model, including the compilation of data which can be used in default of country-specific inputs, Europe Economics cannot accept responsibility for any decisions which may be made by national regulatory authorities (NRAs) or others on the basis of model calculations.

1.2 Background to the Study: LRAIC as the basis for regulation of interconnection charges

There appears to be general agreement across EU Member States that the availability of interconnection services on fair and efficient terms is a necessary condition for the creation and successful operation of a competitive telecommunications market. Interconnection is essential as all operators in a competitive market need to be able to terminate calls on other operators' networks, and to receive calls originated on other operators' networks.

In recognition of this, the Interconnection Directive includes an obligation for fixed network operators with significant market power (SMP) to set charges for interconnection to their network on the basis of objective criteria, and for these charges to follow the principles of transparency and cost orientation.[1] The term "cost orientation" implies that the price charged for provision of a service should reflect the underlying costs incurred in providing that service.[2]

The Directive requires that interconnection charges should be set so as to promote productivity, and encourage efficient and sustainable market entry. It also states that interconnection charges should not be below a limit calculated by the use of long run incremental cost, nor above a limit set by the stand-alone cost of providing the interconnection in question. The Directive goes on to say that interconnection charges based on a price level closely linked to the long-run incremental cost of providing access to interconnection are appropriate for encouraging the rapid development of an open and competitive market.[3]

In addition to meeting the objectives established above, sustainable interconnection charges should ensure reasonable cost recovery by an efficient incumbent operator. This implies that in addition to service-specific fixed costs, interconnection charges should take account of the forward-looking joint and common costs of an efficient operator.[4] Examples of such shared costs include the sites that house a local exchange and some shared ducts.[5] If the long run incremental costs of conveyance are defined to include a proportion of those shared costs, a decision will be needed on how they are most appropriately allocated between the different services.

Building a model to estimate long run incremental costs of interconnection using either a top-down or bottom-up approach can be a very demanding, expensive and time-consuming task. These models require a detailed understanding of network components and of their costs. For these reasons, as well as a possible lack of resources or relevant experience, only a few Member States have to date estimated the cost of interconnection services using detailed LRIC models. The Commission has, therefore, determined a range of 'best current practice' interconnection charges, based on the costs of interconnection services in the three lowest priced Member States, that National Regulatory Authorities (NRAs) could use as an interim step to set interconnection charges, in the absence of a forward-looking LRIC costing model. These charges are as follows:

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1 Directive 97/33/EC of the European Parliament and of the Council on Interconnection in Telecommunications with Regard to Ensuring Universal Service and Interoperability through Application of the Principles of Open Network Provision (ONP).

2 Commission Recommendation on Interconnection in a liberalised telecommunications market (Part 1 — Interconnection Pricing)

3 Directive 97/33/EC of the European Parliament and of the Council on Interconnection in Telecommunications with Regard to Ensuring Universal Service and Interoperability through Application of the Principles of Open Network Provision (ONP).

4 Commission Recommendation on Interconnection in a liberalised telecommunications market (Part 1 — Interconnection Pricing), page 6.

5 Cables can be buried or ploughed although generally only some buried ducts will be shared with other services, particularly access.

Table 1.1

"Best Current Practice" Interconnection Charges

Interconnection Service	Recommended interconnection charge for 2000 (ECU/100)
Local level	0.5 — 0.9
Single Transit	0.8 — 1.5
Double Transit	1.5 — 1.8

Source: "Falling Prices for Interconnection of Fixed Telecommunications Networks in Europe". European Commission IP/00/277, Brussels, 21 March 2000.

The Commission's 'best current practice' charges are seen as a practical way for NRAs to determine approximate interconnection charges. However, relying on estimates of this kind for long periods of time may be inappropriate, as there may be justifiable cost differences between Member States. Thus using "best current practice" for high cost countries would mean that inappropriately low interconnection charges are set, which may encourage inefficient entry and affect the ability of incumbents to recover their costs. On the other hand, setting unduly high interconnection charges is likely to deter entry and delay the flow of benefits to consumers that should result from competition.

It is therefore necessary to develop a more accurate method of estimating the interconnection charges, based on the relevant long run average incremental costs of connection in each country.

For this purpose it is not appropriate to define the increment as only interconnecting traffic, since this might imply that other traffic using the same network would bear the fixed costs (or most of them). Instead, the increment is defined as the "total service" i.e. as all narrow-band traffic and leased lines capacity using the conveyance network. The Commission makes its opinion on this matter clear in its Communication on Interconnection Pricing (OJ No L 73, 12.3.1998, p.42) when it presents its view on the long run:

> "Thus, the entire investment cost entailed in any point of interconnection, and any investment in network and switching capacity required to handle interconnected traffic, would be avoidable, and thus captured by the long run incremental cost measure. The total of all such measures, including the incumbent operator's own increment in traffic, would then form the total of all incremental interconnection costs. This figure would be divided up in a fair and transparent manner between the notified operator and those interconnecting, with the result that the cost of interconnection to any party is the long run average incremental cost (LRAIC)."

In brief, for an existing service, total service LRIC is the cost that would be avoided if the supply of the service were to be discontinued in its entirety. The average cost per call-minute on this basis is the long run average incremental cost (LRAIC) which is the basis for charging for interconnection services and the focus of this study.

1.3 Two Alternative Methods of Estimating Long Run Average Incremental Costs

Long run average incremental costs can be estimated in a number of ways, the two most common approaches being use of a top-down model and of a bottom-up model. These approaches are discussed in some detail in Chapter 2 but can be summarised here as follows:

- A **top-down** approach uses accounting data of an operator, and allocates costs to different services on the basis of views as to the relationships between costs and services. Assumptions need to be made about the scope for efficiency improvements, and to bring historic costs into line with current values.

- A **bottom-up** approach involves the development of engineering-economic models in order to calculate the costs of the network elements required to provide particular services, assuming modern technology and efficient methods of operation.

In principle, both approaches lead to the same answer if consistent assumptions are made about factors such as efficient methods of operation, and depreciation. Reconciliation of estimates prepared using the two methods is therefore a way of reviewing where different views have been taken on such factors.

Our focus in this study is the development of a bottom-up model which, as part of its development, has been reconciled with the results from a top-down model and an independent bottom-up model.

1.4 The Approach Taken

Our approach to developing the model involved:

- <u>The establishment of a Working Group:</u> In order to help to ensure that the assumptions made throughout the process are up-to-date, and relevant to the circumstances of different EU regions, Europe Economics and DG XIII established a Working Group of NRAs from EU Member States. Members of the Working Group assisted during the study by providing inputs and testing key assumptions.

- <u>Collection of network information</u>: We requested specific network information from each NRA in order to test the generic structure of our model. Some, but not all NRAs, were able to provide the relevant information within the timescale needed.

- <u>Collection of cost information</u>: We collected costs from publicly available sources (such as the Hatfield model[6] and OFTEL's bottom-up model[7]) and modified these costs according to engineering advice we have received.

- <u>Meetings with operators and the ETP</u>: Over the course of the study we held discussions with a number of operators in different parts of the EU and presented the study to the

[6] HAI Model Release 5.0a, HAI Consulting, Inc. February 16, 1998.
[7] OFTEL's Bottom up Network Model. [check source].

European Telecommunications Platform (ETP). These discussions assisted the project team to refine the parameters of the model and to determine the appropriateness of many of the assumptions made.

The model prepared as part of this study is intended to provide NRAs with a tool which they can use to identify the major categories of costs that will be incurred by their incumbent operators. This in turn should help them when considering the appropriate level of interconnection charges in their Member State. Understanding of the issues involved will, in general, be enhanced if NRAs collect and input data specifically relevant to their Member State and, over time, tailor the model to the particular circumstances prevailing in their Member State.

1.5 Model Outputs and Limitations

We have explained that bottom-up models provide estimates of interconnection services by modelling the cost of the major network elements involved in the efficient provision of the service. The network elements modelled as part of this study are:

- remote concentrator units (RCUs);
- local switches (LS);
- tandem switches(TS);
- remote concentrator unit to local switch transmission link;
- local switch to tandem switch transmission link; and
- tandem switch to tandem switch transmission link.

These network elements are combined in different ways to create the relevant interconnection service. These combinations will be determined by the routeing factor for the particular interconnection service. For example, local level interconnection will, on average, use less than one remote concentrator, and one local switch. To the extent that a remote concentrator is used, the service will also require a transmission link between a remote concentrator unit and local switch. Local level interconnection will not require a tandem switch, or the use of any other transmission links.

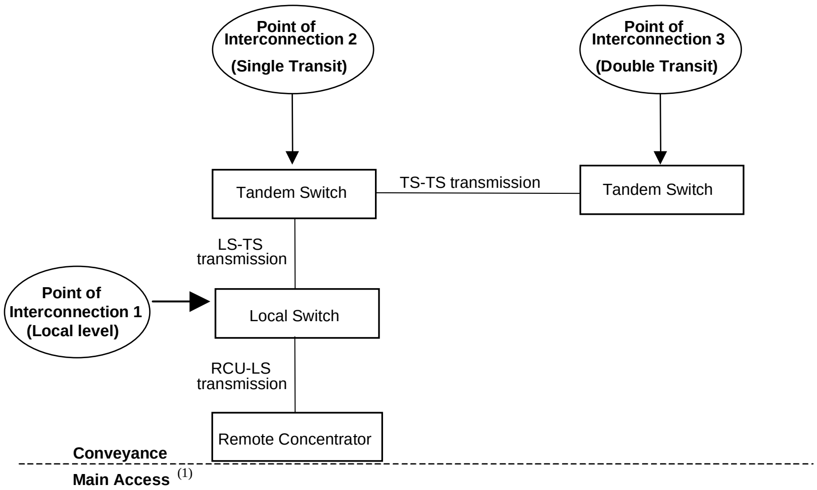
The model estimates the long run average incremental costs of the three specified interconnection services, as illustrated in Figure 1.1 which follows.

- **Local level interconnection**: a competitor interconnects at Point of Interconnection 1 and pays for a local switch, a transmission link between the local switch and the remote concentrator, and a remote concentrator.

- **Single transit interconnection**: a competitor interconnects at Point of Interconnection 2 and pays for a tandem switch, a transmission link between the tandem switch and the local switch, a local switch, a transmission link between the local switch and the remote concentrator, and a remote concentrator.

- **Double transit interconnection**: a competitor interconnects at Point of Interconnection 3 and pays for the same elements as single transit but, in addition, also pays for an extra tandem switch, and a tandem to tandem transmission link.

Figure 1.1
Illustration of Interconnection Services



(1) Some access will be direct to local switches

The model estimates the cost of each of these services by calculating the cost of each network element and the average use of each made by a call of each of those services. The required capacity of the system is estimated from current traffic along with allowances for holding times, failed calls, and growth.

Other features of the model reflect the Terms of Reference, and can be summarised as follows:

- It models the costs of the “core” (conveyance) network, so that the costs modelled do not include contributions to assets dedicated to the access network (“local loop”).

- It models the incumbent’s current switching centres (“scorched node approach”), as well as providing an alternative option that can perform a preliminary optimisation (“modified scorched node approach”). The modified scorched option offers a high level approach, using either benchmarks or a node database.

- It allows NRAs to use either data from their Member State or “default” data for operating costs and equipment prices (in other words, estimates are provided as part of the model to be used in default of data more specifically relevant to the Member States).

- Changes can be made to some of the assumptions in the model to test the sensitivity of results to input modifications.

It is important at the outset to explain clearly what a model of this kind can do and what are its inevitable limitations.

The model will provide estimates of the average cost of switching and transmission network elements and the average cost of interconnection per minute for each of the three defined interconnection services. The accuracy of the estimates for each Member State, of course, depends on the quality of data provided by the user — comprehensive and high quality data input, leading to good quality estimates.

We would highlight at this stage the importance of the inputs relating to:

- Capital costs. The default costs provided in the model have been collected from publicly available sources, responses from operators, and engineering advice. Individual switches may be configured differently and this will affect the cost of the switching components. Operators are likely to have more than one supplier of switches in their Member State and may receive significant volume or other discounts from these suppliers. For these reasons, we would recommend that NRAs engage in a process of data collection involving the incumbent, new entrants, and if possible, suppliers, to refine the default cost estimates in the model ensuring that they are relevant to the prevailing circumstances in their Member State.

- The approach to estimating operating costs in the default data is based on ratios derived from data from operators with assets of different ages rather than new assets. This limitation can be overcome by users of the model adjusting the level of operating costs to that which it is judged would actually be incurred by the incumbent were it operating efficiently, or by an efficient new entrant.

- The model estimates the forward-looking costs of an efficient operator's network architecture and technology. Most incumbent operators are likely to be some way off this definition, and as a result, this assumption may lead to cost estimates which are controversial. For example:

  - a full SDH transmission network is assumed in the model presented here. Such a network is unlikely to be in place even in a generally efficient operator. It may, moreover, be argued that it would be cost effective to maintain PDH on some routes that carry low volumes of traffic especially in transmission between the remote concentrator and the local exchange.[8]

  - the optional optimisation module will only provide a high level indication of an efficient, forward-looking mix of nodes in any particular Member States. Regulatory Authorities may decide to undertake a more detailed analysis of whether the optimisation results for their Member States provided by the model are appropriate.

It is also worth noting that the experience with models of this nature is that a number of iterations have been required before the main parties concerned agree that the model is representative. For example, in the UK, it took the regulator (DGT) over two years to estimate the long run incremental costs of BT's network. In other cases too, robust and up-to-date data may not be

[8] As manufacturers may now be running down PDH production, care should be taken if comparing against expensive custom made PDH equipment.

readily available. The model is adaptable, but can only approximate the first best approach if the data input take into account factors that reflect the operating environments in different countries.

The Working Group was asked to provide country-specific data in the course of 1999, and the responses were used to help to develop the model. Unfortunately, a number of NRAs were unable at that stage to provide data to the project team and as a result, the model has not yet been tested in all EU Member States. This task remains to be carried out by the NRAs.

1.6 Structure of this Report

The contents of this report are as follows:

- Chapter 2 sets out in more detail the conceptual framework for the study;
- Chapter 3 presents the main options available when using the model;
- Chapter 4 describes the methodology for modelling switching costs;
- Chapter 5 describes the methodology for modelling transmission costs;
- Chapter 6 describes the methodology for modelling infrastructure costs;
- Chapter 7 describes the results and outputs from the model;
- Chapter 8 describes the reconciliation exercises undertaken as part of the study; and
- Chapter 9 discusses use of the model for policy purposes.

Seven appendices are also provided:

- Appendix 1 discusses different methods for optimising the network in the model;
- Appendix 2 outlines our approach to determining the demand for network elements;
- Appendix 3 presents the methodology for estimating non-network costs;
- Appendix 4 discusses some issues surrounding working capital;
- Appendix 5 details the depreciation options available in the model;
- Appendix 6 presents the sources of the cost data used throughout the study; and
- Appendix 7 provides the sources of the default values used throughout the model.

A stand-alone executive summary showing some indicative results for the UK and Sweden is also provided along with a comprehensive manual to guide users of the model.

2 CONCEPTUAL FRAMEWORK

As indicated in Chapter 1, this study is concerned with the interconnection of telecommunications networks and principally with the costs incurred with call termination on the networks of operators designated by the national regulatory authority as having significant market power. The interconnection services considered are for the total service of local level, single transit, and double transit interconnection.[9]

However, in order to identify the costs of those services it is first necessary to define the increment for which costs are to be measured.

2.1 Our Approach to Increments and Services

Telecommunications networks consist of two parts— access and conveyance. This study is concerned only with the long run incremental costs of conveyance. This approach raises a number of issues such as:

- the distinction between the access and conveyance network; and
- the relationship of the services forming the relevant increment.

2.1.1 Distinguishing the conveyance network from the access network

The incumbent's network consists of an access network (which is also referred to as the local loop) and a conveyance network (also referred to as the core network). The interconnection costs that the model can measure are those associated with the conveyance network; the study does not consider the costs of the access network.[10]

The core network includes the traffic sensitive components of the switching network (such as ports, switch blocks, and processors), the transmission network (multiplexing equipment, line termination equipment, digital cross-connects etc.), and the infrastructure involved in the transmission network (ducts and cables). The costs of the core network are usually recovered through traffic related charges (on a per call or per minute basis or a combination of both).

There are two issues surrounding the division between the access and core network. The first relates to the impact of LRIC charges on an operator which has not re-balanced its retail tariffs. The second relates to the division between the access and core network.

The implication of focusing on the conveyance network depend partly on whether retail tariffs are aligned with costs. In some Member States the incumbent operators may still be recovering some of their access costs (cost of provision of lines and other non-traffic sensitive costs) through call charges rather than of through line charges. If so, there may be an access deficit contribution

[9] These services are similar to the "best practice" interconnection charges published by the European Commission.

[10] The access network (or local loop) refers to the final links between the customer and the exchange (or concentration point). These costs are a significant part of total telecommunications costs and are usually recovered through line rental charges to customers. The Terms of Reference for this study specify that interconnection charges should not include contributions to assets which are dedicated to the end customer.

added explicitly or implicitly to the network charge. Our model makes no allowance for any access deficit contributions, which would need to be calculated separately.

There is also room for debate over where to draw the line between the access and core network. In future as the reach of fibre moves closer and closer to the customer, the access network may become a less significant part of telecommunications networks. Even today, local loops are getting shorter as operators move the conveyance network closer to customers' homes.

Nevertheless, the traditional access network is likely to remain an important feature of almost all operators in the EU over at least the next three to five years, and our model reflects that. In common with a number of other bottom-up models, we have drawn the line between the access and core networks at the line card, which may be located at a remote concentrator unit or at a local switch.

2.1.2 The relationship of the services forming the relevant increment

2.1.2.1 Defining the conveyance increment

The default increment measured by the model is a conveyance network that provides PSTN services and leased lines. From this, the costs of the PSTN can be determined.

The major implication of this decision is that the long run incremental costs derived by the model will include those costs that are shared by other services forming part of the increment. These costs will include a large proportion of the transmission electronics costs and almost all the infrastructure costs. These shared costs are allocated to each of the services forming the increment on the basis of capacity, including leased lines.

The model does, however, allow users to see how the costs would vary if the increment were defined in a different way. For example:

- NRAs could estimate the costs of the PSTN by treating the PSTN as a service that is provided assuming an access network is in place and assuming that a conveyance network providing leased lines is also in place. In this case, the long run incremental costs of PSTN will be smaller than the costs under the "default" increment as they will exclude some transmission electronics costs and the costs of the infrastructure;

- NRAs could also estimate the costs of a conveyance network that provides only PSTN services. In this case, the costs will be higher than those from the "default" increment as they would include all of the costs that are shared with leased lines. This option does not measure the stand-alone costs of the PSTN as it does not attribute all of the common costs to the PSTN service.

2.1.2.2 The PSTN service within the defined increment

The service in question for the purposes of this study is conveyance, and in particular, those services that use the public switched telephone network (PSTN). As discussed above, this service forms part of the broader increment measured by the model which we have defined as a network which provides PSTN and leased lines.

At present, the PSTN in most countries is designed to carry mainly narrow-band services (voice grade telephone calls including slow speed fax and data services that operate in the voice band) and leased lines. However, it currently also services some broadband services, and the Internet.

In many Member States, the existing PSTN is being seriously affected by the growth of non-voice traffic, particularly Internet traffic. This growth, driven by longer holding times for some data calls, is placing unexpected demands on switches to the point that switch congestion is threatening service levels for all users.

Although data will continue to be carried over the PSTN in the short to medium term, we expect that many incumbents will start to stream data traffic onto a separate data IP[11] network in order to prevent congestion on the PSTN from long holding-time Internet traffic. Such streaming will involve taking Internet traffic away from the PSTN networks, by-passing the local exchange and the traditional circuit-switched voice telephony network by using a packet based data network.[12] If this approach is adopted, the PSTN will continue to carry narrow-band services (including some data).

The introduction of Asynchronous Transfer Mode (ATM) will also facilitate the development of an overlay network to the PSTN that will take some pressure off the PSTN. ATM is similar to older forms of packet switching because bandwidth is allocated on demand, making it better able to accommodate unpredictable data traffic. The size, nature, cost, and associated interconnection charges of the IP/ATM network, however, are not modelled in this study.

The long run incremental costs of conveyance could be calculated either by assuming that the network needs to be dimensioned to carry all existing traffic, some of which will be data/Internet traffic, or by assuming that some traffic will be streamed off in the future. The model user will need to take a view on these points when specifying the capacity margin to be assumed.

2.2 Concepts Affecting the Modelling

In order to estimate interconnection charges, the Terms of Reference required us to estimate the costs of a forward-looking conveyance network using a bottom-up, “scorched node” approach. The purpose of this section is to outline the concepts behind the cost estimates used throughout the study.

2.2.1 Long run

The “long run” in the definition of LRIC and LRAIC is the time horizon within which the firm can undertake capital investment or disinvestment to increase or decrease the capacity of its existing productive assets. The entire investment cost entailed in any point of interconnection, and any investment in network and switching capacity required to handle interconnected traffic would be avoidable and thus captured by a LRIC measure, as would costs which are variable in the shorter term.

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11 Internet Protocol (IP) has developed into the de facto network protocol for the Internet. It is able to route and transport all the elements of a multimedia service.

12 A packet based data network only requires capacity when data is transported. This differs from the current circuit switched PSTN where an end-to-end dedicated channel is held for the duration of the call, irrespective of whether data is being transmitted.

LRIC measures forward looking costs, meaning those costs that a firm would incur in future, in producing the service using the best-in-use or well established technology and operating at an efficient level. This also implies that assets be valued at current costs rather than historic costs.

The definition of forward-looking costs includes the forward-looking joint and common costs of an efficient operator. Our approach is explained in the next chapter.

2.2.1.1 Forward-looking technology

The model makes certain assumptions about the nature of forward-looking technology. The engineering concepts that underlie this LRIC model are aligned with a conventional PSTN configuration connecting a local access network which is at least virtually if not physically "tree and branch" with a core network which, at least in virtual terms, is circuit switched.

It assumes, for example, that all switches are digital and that the transmission technology is solely SDH. The existing networks of most incumbent operators in EU Member States will not fully comply with these assumptions, particularly the assumption regarding SDH. Indeed, even an efficient, forward-looking operator may use PDH on some thinner routes where this is effective. The configuration of the transmission network is also generic in the model and assumes that RCUs are connected to one local switch in the form of a ring (called an RCU ring), that local switches are connected to tandem switches in rings (local switch rings), and that the tandem to tandem network is meshed in the form of a partial ladder. Such a configuration may not be appropriate in some Member States and NRAs will need to discuss with the operators in their Member State the implications of this generic configuration.

The network hierarchy assumed in this model may also not be fully applicable to existing networks. We have assumed that a forward-looking network will have two levels of switching — local switches and tandem switches. Some EU Member States may, however, be operating with three or four levels of switches. We believe that operators may be migrating to a flatter network structure, although other layers can be considered part of the tandem layer for the purposes of the model.

We recognise that telecommunications networks are approaching a transition in the medium term in which the more heavily used local access networks may well be rings and operate as Area Networks in the way that computers are often wired in local areas networks (LANs). Increasing use of ATM within the core network is likely, making the conventional costing of circuit switched networks look increasingly old-fashioned; and in time adaptations will be needed to the engineering assumption on which this model is based, to reflect at these changes.

2.2.2 Bottom-up versus top-down models

As already noted, the two most common approaches to estimate forward-looking LRIC are the top-down and the bottom-up approach. Both of these approaches are introduced in this chapter; as we report later on the reconciliation of the results from our model with the results of top-down and other bottom-up models.

2.2.2.1 Top-down modelling

A top-down approach uses data from company accounts, and allocates costs to different services according to views on the relationships between costs and the different services.

Top-down models are therefore based on data which reflect recent business performance, which may or may not result from efficient methods of operation. Assumptions therefore need to be made about the scope for efficiency improvements. Top-down models also rely heavily on the availability of cost accounting systems capable of allocating costs to network elements (such as switching, transmission etc.).

Top-down models can produce very different results according to the precise assumptions on which they are based. They are particularly sensitive to assumptions regarding asset lives and the type of depreciation profile - straight line or declining balance etc. If capital costs are only available on a historic cost basis, top-down estimates could be very different from those derived from a model which uses current costs.

Top-down models have proved time-consuming to develop partly because a large part of the cost base in telecommunications is not directly related to final services. As such, the calculation of fully distributed cost requires a considered view to be taken a complex set of interlinkages between the costs to be apportioned, and then the development of models which take account of such interlinkages.

2.2.2.2 Bottom-up modelling

A bottom-up approach involves the development of engineering-economic models which are used to calculate the costs of network elements which would be used by an efficient operator in providing interconnection services.

Bottom-up models can be built in a variety of ways but will usually perform the following tasks:

- identify demand over the network element and adjust for unsuccessful calls, holding times and an allowance for growth;
- apply routeing factors to determine the level of usage of different network elements;
- choose the forward-looking switching and transmission technology;
- determine the number of nodes in the network;
- dimension the network to meet the derived demand;
- determine the cost drivers of different network elements;
- collect the asset prices, estimates of operating costs, and other relevant network and non-network costs;
- calculate the amount of equipment required in the network; and

- estimate the unit cost of network elements and from that derive the cost of interconnection services.

2.2.3 Scorched earth versus scorched node

One of the key decisions to be made with bottom-up modelling is whether to adopt a "scorched earth" or a "scorched node" assumption. The objective of following either of the two approaches is to ensure that the incumbent has the right incentives to invest efficiently in its own network in the future, and that new entrants receive the correct economic signals that assist them in deciding between building their own networks or paying for interconnection with the incumbent's network.

The scorched earth basis assumes that optimally-sized switches would be employed at locations optimal to the overall transmission design, as if the network were being redesigned on a greenfield site. However, designing and agreeing an optimal network is not a straightforward or uncontentious task. Moreover, it may be considered unreasonable not to allow the incumbent to recover costs associated with the existing network configuration, given that it must in practice largely take it as given.

The scorched node basis, on the other hand, assumes that optimal technologies would be employed to perform equivalent functions at existing nodes, and that optimal transmission technologies would be used to connect up these nodes. The scorched node approach can be modified in order to replicate a more efficient network than is currently in place. This could be achieved by changing the nature of some nodes (e.g., from a local exchange to a concentrator) in order to achieve a more efficient network.

2.3 Cost Concepts

In this study, we have reflected the EC definitions proposed in the 8 April 1998 recommendations concerning accounting separation and cost accounting.[13] We make a distinction between directly attributable, indirectly attributable, and unattributable costs.

2.3.1 Directly attributable costs

Directly attributable costs are those costs that can be directly and unambiguously related to a product or service. Directly attributable costs include the following:

- (annualised) costs of equipment specific to the service;
- directly related costs such as installation;
- network related operating costs (such as maintenance).

2.3.1.1 Equipment costs

In order to determine the annual costs of providing a particular service, the cost of productive capital employed must be established.

[13] Commission Recommendation of 8 April 1998 on interconnection in a liberalised telecommunications market. Part 2 — Accounting separation and cost accounting.

The Commission Recommendation of 8 January 1998 on interconnection in a liberalised telecommunications market (Part 1 - Interconnection pricing) recommended that current costs be the basis of the incumbent's accounts for the purposes of interconnection.

Current costs are not always easy to identify and may mean different things to different operators. To a new entrant operator about to build a network, current costs will generally equate to costs of new equipment. On the other hand, to an incumbent operator current costs may need to be measured with reference to a modern equivalent asset (MEA) with the same, or similar, service potential.[14] This will usually be measured by adjusting the cost of a modern asset for functionality, capacity and so on to give the adjusted replacement cost.

The MEA asset valuation of an incumbent operator may, therefore, differ from the replacement cost valuation of a new entrant – even though both are attempting to measure current costs. This is likely to be important when trying to reconcile the results of any bottom-up model with the results on an incumbent operator. The different asset values, however, should yield equivalent depreciation charges.

2.3.1.2 Operating costs

Another category of directly attributable costs is network-related operating costs. The prime elements are those concerned with maintaining the network; and providing, rearranging or ceasing service to customers.

A common way of estimating operating costs in previous bottom-up models has been to use a ratio that reflects the share of operating costs for an element to the capital cost. However, such an approach has a number of limitations including:

- there is no general and stable relationship between investment and operating expenditure; and
- expenditure in previous periods may have been generated by assets which do not belong in a forward-looking MEA approach to costing.

The use of a ratio to estimate operating costs may under-estimate costs if the "best practice" ratios used reflect the costs of an operator in a more favourable situation than the one whose costs are actually being modelled. On the other hand, the ratio may over-estimate costs if it is based on an existing mix of assets rather than new assets, since an existing mix of assets may imply higher operating costs than newly installed assets.

The present model therefore allows users to adjust the assumed operating costs to levels thought to be most appropriate for an efficient operator.

[14] The rate at which modern asset can be introduced is limited by practical constraints such as manufacturing capacity and lead times. Therefore it could be appropriate for a mix of technologies to be used as the modern equivalent for valuation in telecommunication market to be a mix forecast to be in place in three years time.

2.3.2 Indirectly attributable costs

Indirectly attributable costs are those costs that can be apportioned to products or services on a measured non-arbitrary basis reflecting the relationship of the costs with directly attributable costs. They include many network costs such as transmission equipment which will be shared by services within the defined increment (in this case, PSTN and leased lines). Other network costs such as the accommodation costs associated with exchanges of a local exchange (such as site costs) may be shared by the access and core networks.

The Commission's Recommendations as accounting separation and cost accounting provided some options for allocating some of these indirectly attributable costs and these are summarised in the table below. The level of information suggested in the table may not be available in many Member States, in which case assumptions will have to be made.

Table 2.1
Commission Recommendations for Allocating Some Indirectly Attributable Costs

Shared cost	Method of Allocation
Duct	Direct to access or network components where possible, otherwise allocate to components based on the amount of duct used to provide different services
Power equipment	Allocate to primary plant groups on the basis of the use of the systems to support each plant - e.g. kilowatts per hour. Assets should then be allocated to products in the same way as the relevant primary plant groups.
Network management systems	Allocate to primary plant of the different networks provided on the basis of use of the systems to support each plant - e.g. time spent to control local exchanges, tandem exchanges and international exchanges. Costs should be attributed to products and services in the same way as the related primary plant group.
Site	Allocate to products, services and network components on the basis of the space occupied (i.e. floor space) to support each product, service or network component.

Source: Table 5.1, Commission Recommendation of 8 April 1998 on interconnection in a liberalised telecommunications market. Part 2 — Accounting separation and cost accounting.

2.3.3 Unattributable costs

Unattributable costs can only be attributed on a largely arbitrary basis. These costs generally include some common costs such as corporate costs (head office etc.).

2.4 The Treatment of Shared and Common Costs

This model draws on the classification of the costs described in section 2.3, and also uses the following definitions:

- <u>shared costs</u>: these include those costs which are shared by the services within the increment and cannot be directly attributed to any of the services within the increment. For example, duct and fibre in the conveyance network is shared by PSTN services and leased line and cannot be directly attributable to either service. In this study, however, as the increment is defined broadly to include PSTN and leased lines, the *incremental costs* of the conveyance network will *include* those costs shared by the services within the increment;

- common costs: these are defined in this study as those costs that are common to different increments. These include the costs that are common to the access network (an increment not measured as part of this study) and the conveyance network. Examples of common costs include the sites and the duct that is shared by the access and conveyance networks.

The definitions of shared and common costs may differ from one Member State to the next and will depend on how the increment is defined. NRAs and operators will need to agree on how each of these costs should be treated and assess the appropriateness of the approach adopted in the model.

Shared and common costs may represent a significant proportion of an incumbent operator's costs. Excluding them from the cost base could, therefore, lead to an under-recovery of costs for that incumbent. Indeed, the Commission has stated that LRIC-based charges need not preclude the use of justified 'mark-ups' as a means of recovering the forward-looking joint and common costs of an efficient operator as would arise under competitive conditions.[15]

As discussed above, the default estimates include the shared costs as the increment is defined broadly. The common costs, on the other hand, can be treated in a number of different ways. Some models, for example, have added a mark-up over the "pure" LRIC amount, while others use simple allocation rules to include a proportion of these common costs into the LRIC estimates.[16]

The approach adopted in this model is to identify the costs both with and without the proportion of common costs which can be attributed to the conveyance network. This provides information to the users of the model and allows for NRAs to assess the impact of different approaches to the treatment of common costs.

The default results provided in the model include common costs although NRAs can also select to display the results excluding common costs.

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[15] Commission Recommendation of 8 January 1998 on interconnection in a liberalised telecommunications market. Part 1 — Interconnection Pricing, (98/195/EC), L73/43.

[16] An example of the former approach is the use of a fixed allocator. This is a term used to describe a non-discriminatory way of allocating common costs across services. A similar approach was taken by OFTEL in the UK with their use of equal-proportion mark-up to determine how much of the burden of recovery of common costs should fall upon conveyance and how much upon access.

3 OPTIONS WHEN USING THE MODEL

This section outlines the structure of the model and some of the key decisions that NRAs will need to make when using it. The section also discusses how the output of the model can be used, and the impact of technological developments on the model.

3.1 Structure of the Model

The model consists of the following five inter-related sections:

- assumption sheets: these require NRAs to enter data relating to the demand for services in their Member State and assumptions regarding certain technical parameters. These sheets are mainly blank, although some default values have been provided to guide NRAs.

- optimisation options: the model is based on the "scorched node" assumption and provides scope for some variation within that constraint.

- cost input sheets: these contain default cost estimates for the components that make up network elements and "best practice" ratios which may be used to estimate costs for which data are difficult to collect. These default estimates can be modified by NRAs in the light of Member State specific estimates.

- calculation sheets: these estimate the capacity required and the amount and mix of systems to carry that traffic.

- results sheets: these calculate the total and per-unit costs of network elements. The unit costs are then combined with relevant routeing factors, and used to determine the costs of the three interconnection services which are the subject of this study.

The decisions that NRAs will need to make when deciding how the model should be used once the required information has been inputted include:

- deciding whether the network for which costs are to be estimated is to be optimised and, if so, which option to use;

- deciding which annualisation option to apply to different categories of assets; and

- the treatment of network operating costs.

3.2 Optimisation

Telecommunications networks are changing. Increased digitalisation and the falling costs of fibre are leading to significant changes in the way that networks are structured. For instance:

- increased digitalisation has reduced the number of levels of switches, resulting in a flatter hierarchy of switches;

- falling costs of fibre mean that the fibre — and hence the conveyance network — is getting closer to the final customer. This means that local switches, and particularly smaller local switches, are increasingly being replaced by remote concentrator units.

The purpose of this study is to measure the forward-looking costs of conveyance, constrained by the need to operate within the scorched node assumption. The user, therefore, needs to take a view on whether the current mix of nodes in a Member State is an appropriate basis for a forward-looking cost estimate.

While we can be reasonably confident that more and more local switches will be replaced with remote concentrators, the optimal mix for individual Member States will depend on factors including the population density and traffic profiles.

The model is structured in such a way that it can operate without any optimisation if the regulatory authority believes that the existing network is sufficiently forward-looking and efficient. Alternatively, the NRA can choose one of the two optimisation options that provide a ball-park estimate of the “modified scorched node” assumption. These are:

- option A which assumes some optimisation, particularly with regard to tandem switches, but re-allocates the number of remote concentrators and local switches using a database of all existing nodes (where available). This approach simply considers the number of lines at each node and connects that node to a remote concentrator unit if it falls below a particular threshold; and

- option B which relies on best practice ratios to determine the mix of all nodes. This approach determines the number of exchange areas required to meet the demand in a Member State of a given site and, using ratios, determines the appropriate number of local and tandem switches. These numbers are adjusted in order to satisfy the “scorched node” constraint.

In either case, the results are provided as an indication of what an optimised network may look like based on experience in Member States. The scope and limitations of each approach are described in Appendix 1.

3.3 Annualising Capital Costs

The investment costs used in the model need to be annualised in order to estimate the relevant costs for a particular year, and in particular for “Year 1”, whose costs are modelled here. This requires an estimate of the purchase price, asset lives, the price trend of each asset, the residual value of the asset at the end of its economic life, and the cost of capital. A depreciation profile is then selected, which together with the cost of capital, determines the capital charge in the relevant period.

Different depreciation profiles can have a large effect on the costs estimated for a particular year. This effect is particularly pronounced in bottom-up models since all assets are assumed new at the beginning of year 1. By way of illustration, table 3.1 shows the effect of the choice of depreciation profile on the annualised cost of an asset with an investment cost of €26,000, installation cost of €2,600, asset life of 10 years, projected (real) price change of equipment at negative ten per cent per annum, and residual (i.e. scrap) value at one per cent of equipment cost.

Table 3.1 – Year 1 Annualised Capital Costs using different depreciation profiles

Depreciation Profile	€
Straight line	5,720
Adjusted Straight line	8,580
Sum of digits (front loaded)	8,061
Annuity	4,655

In deciding which depreciation schedule is most appropriate for each type of asset, the relevant considerations include:

1. Likely movements in asset price over the life of the asset, due to factors such as trends in obsolescence costs and the productivity of capital assets. For example, new technology through reducing operating costs may result in a reduction in the value of existing capital assets.

2. Annual revenue generated from the output of the asset. For some assets, in the longer term, output will fall due to wear and tear. Revenue generated will fall, resulting in a reduction in the ability to recover the cost of the asset later in the life of the asset. In this case, depreciation should be higher at the beginning of the life of the asset and lower later. [17]

3. Annual running costs. If running costs rise during the life of the asset, the operator's ability to recover the cost of the asset will fall again suggesting that depreciation should be higher earlier in the life of the asset than later.

It is likely that a combination of factors will be taken in to account in considering the appropriate depreciation schedule. The model allows users a choice of the following methods.

(A) Straight-line

This may be appropriate, particularly if:

1. Real asset prices are expected to be broadly constant over the life of the asset.

2. The combination of expected movements in revenue and running costs does not lead to asset values falling much more quickly early in the life of the asset than later.

(B) Adjusted straight-line

"Adjusted straight-line" depreciation is based on the same formula as straight-line, except that it takes into account expected reduction in real prices of the asset, leading to an increased depreciation charge. It does not, therefore, produce a straight line deregulation schedule.

[17] In accordance with the accounting concept of accruals, where costs and revenues are matched with each other and dealt with in the profit and loss account of the period to which they relate.

(C) Sum of digits

If some combination of expected real asset prices, and expected changes in generated revenue and running costs requires that depreciation be higher earlier in the life of the asset rather than later, the sum of digits approach would provide a schedule which represents this. The calculation has the effect of charging more depreciation in the early years than in the latter years.

(D) Standard annuity

This calculates the charge which would recover the purchase price of the asset (depreciation) and the financing costs, in equal annual sums. The standard annuity calculation makes the same assumptions about asset values as in straight line depreciation.

3.3.1.1 Summary and implications of depreciation methods

The method of depreciation chosen depends partly on the type of asset being depreciated. If the asset faces little technological change, then a method with no front-loading, such as straight-line, may be appropriate.

Conversely, for assets facing rapid technological change an adjusted straight-line or sum of digits approach would be more appropriate since it would produce a front-loaded depreciation schedule. An example of such assets might be switches.

The standard annuity might be used for assets not expected to be affected by rapid technical change. Annuities produce constant annualised costs of depreciation plus the financing costs of the capital expenditure, and so help to maintain steadier prices over the expected asset lives.

3.3.2 Cost of capital

The required return on investment in the network and other related assets is the cost of capital. It should reflect the opportunity cost to investors, so that the return earned on network assets and other related assets would be broadly equal to the likely return on alternative comparable investments.

It is not the objective of this paper to discuss which method of calculating the cost of capital is to be preferred, nor is it necessary for the purposes of our model. NRAs may have different views on which approach they wish to adopt.

The Commission has noted that calculating the weighted average cost of capital (WACC) for a company as a whole is easier than for parts of the businesses and should be used if NRAs believe that a global cost of capital is appropriate for the regulated activities of the operator.[18] Alternatively, NRAs may wish to use a different WACC for, for example, the conveyance business of the operator, taking into account the different risk premium that may apply to this activity. In any case, NRAs would determine the appropriate cost of capital and input this into the model.

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[18] Commission Recommendations of 8 April 1998 on interconnection in a liberalised telecommunications market (Part 2 – Accounting Separation and Cost Accounting).

3.3.3 Network-related operating costs

One of the main limitations of previous bottom-up models has been their treatment of operating costs. These models have attempted to measure operating costs by relying on the relationship between a company's fixed assets and the associated operating expenditure. These ratios are based on the experience of operators in the US and the UK.

The use of such ratios to derive operating costs is open to criticism for a number of reasons including the following:

- they may under-estimate the operating costs if the best practice rates derived in other countries do not reflect the operating environment in some European Member States;
- they may over-estimate the operating costs which should be assumed in the model, as they are based on maintaining assets of mixed ages rather than the new assets assumed to be in place in the model. Newer assets should require lower operating costs.

These concerns have some validity, and these ratios are therefore used in the present model only to provide default values, or as a starting point. An "over-ride" has been included that will allow NRAs to adjust these ratios based on either existing operating costs or their own view of an efficient level of operating costs.

3.3.4 Non-network related capital and operating costs

The estimates used in this study are derived from publicly available sources and are shown in Chapter 4. Many of these ratios have been obtained from data reported to the FCC by US local exchange carriers (LECs) and from AT&T.[19]

It should, however, be noted that not all of these costs will be related to conveyance. Recent bottom-up models, such as the one used by the Australian Competition and Consumer Commission, have made adjustment to these benchmarks by making an assessment on the relevance of the cost item for interconnection (see Appendix A.3). The model presented here allows similar adjustments to be made.

[19] LECs are a good proxy for the local network (remote concentrator, local switch, and transmission between the remote concentrator and local switch), while AT&T data is applicable to the long distance network of incumbent operators. Most recent data for the LECs is year ending 31 December 1997; data for AT&T is from 1994, after which AT&T was not required to report detailed information to the FCC.

4 MODELLING THE SWITCHING NETWORK

4.1 Overview of the Switching Network

The switching network in our model has two levels — local exchanges and tandem exchanges (sometimes known as trunk or transit exchanges). This reflects the design of many modern networks that have, over time, reduced the number of levels in their networks. Analogue networks often had several hierarchical layers of transit switches but the economies of digital switching and transmission systems generally result in a structure that can operate with one fully interconnected layer of tandem switches. (Remote concentrators, which are included in our model, can also undertake some switching but are not usually considered to be a "level" of switching.)

For the purposes of the study the boundary between the access network and core network is taken to be the Subscriber's Line Card, which can be located at the local exchange or the remote concentrator unit.

4.1.1 Defining the network elements

There are three switching elements being modelled:

- Remote concentrators. The remote concentrator unit (RCU) is a small digital exchange, usually located away from a local exchange building and driven by the processor of its "host" local exchange. The model assumes that a remote concentrator relies on a local switch to supply a complete array of switching functions (except own switch calls).

  Two points may be noted. First, the study does not distinguish the costs associated with host concentrators, which can be considered to be a (line-related) component of the local switch. Second, it is assumed that remote concentrators, although not necessarily switching units, possess sufficient processing power to enable them to switch calls between customers connected to the RCU, if the signalling link to the local exchange fails.

- Local switches. Local switches (LS) can be designated as either host switches or stand-alone switches. Both a host switch and a stand-alone switch provide full service without relying on another switch.

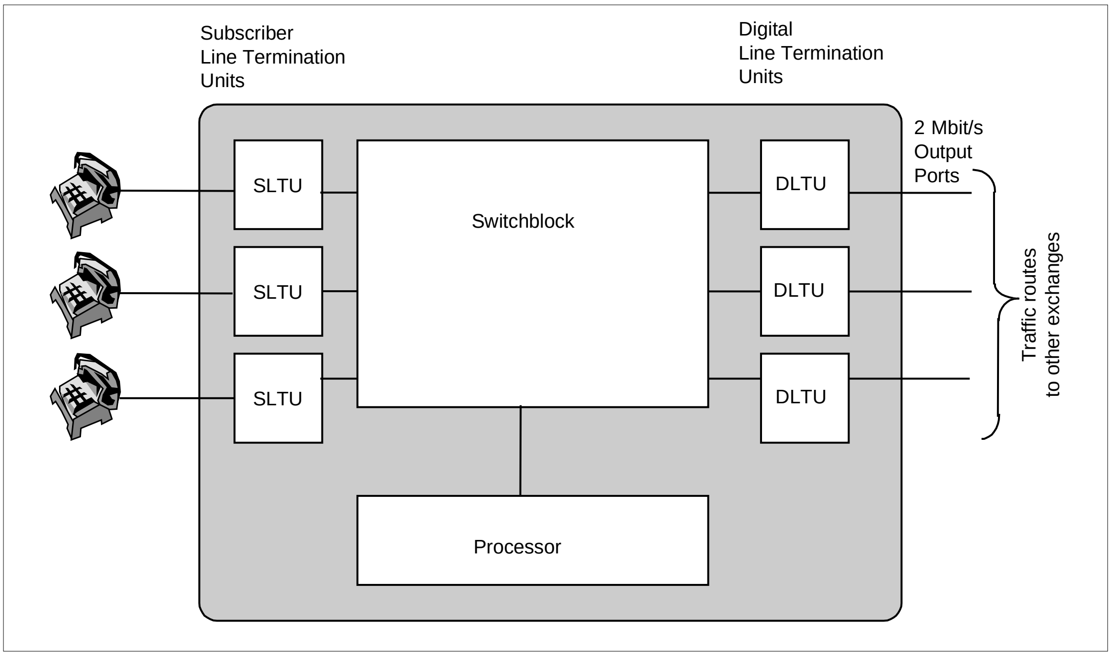
  Local exchanges may be directly connected to other local exchanges where the volume of traffic warrants it or route their traffic via tandem exchanges to obtain full connectivity between all customers.

- Tandem switches. Tandem switches (TS) have a similar configuration to local digital exchanges except that the elements concerned with the subscriber interface are not required.

  Tandem switches are often used to connect a number of local exchanges. Sometimes tandem switches are interconnected via higher level switches known as transit switches, although this higher level of transit switching is not considered in the model. Tandem switches will also often be co-located with local switches.

4.2 Cost Drivers of the Switched Network

A simplified configuration of a switch is shown below in Figure 4.1.



Remote concentrators and local switches consist of Subscriber Line Termination Units (SLTUs), Digital Line Termination Units (DLTUs), processors, and switch blocks. It is assumed that a tandem switch has all the same components, with the exception of SLTUs.[20] As the model is not concerned with the access network, the SLTUs are not modelled in this study.

Investment required in the network to meet the demand for switching elements consists of:

- processors for different types of switching elements;
- switchblocks; and
- digital line termination units (or ports).

4.2.1 Processors

A processor provides the stored program control (SPC) of the exchange and comprises processors and databases for storage of customer and network information needed to deal with calls and services. Historically, the size and cost is determined by the number of busy hour call attempts but, increasingly, the proliferation of new services and increased signalling is requiring more processing power and decreasing the BHCA that a processor module of a given size can handle.

[20] The concentration switching stage associated with SLTUs is assumed to be part of the SLTU and is not in the conveyance network.

We have split the costs of a processor into a fixed element (cost of basic processor for a switch that includes software costs) and variable element (that varies with the number of BHCA).

4.2.2 Switchblocks

A switchblock switches the calls through the exchange and comprises several semiconductor switching stages known as time switches and space switches. The size and hence cost of the switchblock is determined by the busy hour calls and their duration i.e. traffic intensity, measured in erlangs.

The cost driver for the switchblock is busy hour erlangs (BHE); the fixed cost element has not been explicitly modelled.

4.2.3 Digital line termination units (ports)

Digital line-termination units provide the standard ITU-T G703 2Mbit/s transmission interface into a digital core network. The quantity and cost is a function of the number of traffic routes to other exchanges, the circuits per route (30 circuits = 2Mbit/s) which depends on the circuit efficiency of the route i.e. erlangs per circuit. Separate analogue line-termination units are required to interface analogue exchanges during the network transition from analogue to digital, although these are not modelled in our network.

The cost driver, as for the switch block, is BHEs.

4.2.4 Other costs

There are a number of other ancillary costs related to switching that are also attributable to the switching elements. These include:

4.2.4.1 Site costs

The site costs required to support network components include the cost of land and buildings as well as the power and other ancillary services such as heating and ventilation.

The site will usually be shared by other networks such as access and data networks. The model requires NRAs to make an assumption about the share of site costs that should be attributable to conveyance and then on the appropriate split between switching and transmission.[21] The transmission costs are then attributed to each transmission link based on the number of multiplexers in each link.

As tandem switches and local switches are likely to be co-located, overall site costs will be reduced. The extent of co-location needs to be estimated by the NRA.

4.2.4.2 Signalling Transfer Points (STPs)

The processor communicates with other exchange processors by messages sent over signalling links, usually to the ITU-T Signalling System No. 7 standard. Signalling links can be directly

[21] The transmission network can be conceived of separately to the switching network although we assume that transmission equipment are located at switching nodes.

associated with the traffic routes that they control or signalling can be routed over a separate, independent signalling network. The “data” switches in separate signalling networks are known as Signalling (or Signal) Transfer Points (STP). They are usually inter-connected as a mesh configuration, each exchange being connected to two STPs for security against STP or link failure.

The cost of STPs is determined by the number of STPs in the network (a user assumption) and the unit cost of STPs. This cost is then allocated across all switching elements based on busy hour erlangs in each switching element.

4.2.4.3 Synchronisation-related costs

Synchronisation equipment ensures that all exchange clocks run at the same speed.[22] The synchronisation-related costs are driven by the number of tandem switches (as this is where we would expect the more complex work to be required), and allocated across all switching elements based on the number of nodes in that element.

4.3 Dimensioning the Switching Network

The starting point for the model is existing demand, which is measured by billed minutes and successful call attempts for those calls using the PSTN. This demand then needs to be adjusted to add unsuccessful call attempts, set-up time (defined as the time taken to answer a call), an allowance for growth, and an allowance for capacity utilisation. Taken together, these give the total demand for traffic using switches in the network. This demand is required for both call attempts (which determines the need for processors in the local switches) and for call minutes (which drive the capacity required in switch block and ports).

Once existing demand has been adjusted to include the above factors, the total demand is attributed to each switching elements through the use of “routeing factors”. Routeing factors show how intensively each network element is used for each type of call. For example, a local call may, on average use less than one RCU, between one and two local switches, and less than one tandem switch.

The network, however, does not need to be dimensioned for total traffic, but for the conventional “busy hour” level of traffic. It is not dimensioned to carry an unrepresentative surge.[23] In other words, the network must be able to meet the demand at the busiest hour of the year. To that end, the model requires information on:

- traffic in the conventional busiest hour of the year (in minutes); and
- annual billed traffic (in minutes).

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22 These are If the clocks that control the timing of digital exchanges. If these are not running at the same average frequency, then the digital bit stream [2 Mbit/s] coming into an exchange will be faster or slower than it can be switched and information will be lost — a phenomenon known as “slip”.

23 This issue is discussed in OFTEL, Long Run Incremental Costs: The Bottom-up Network Model, Version 2.2 March 1997, page 9.

From those two estimates, we can derive a percentage to apply to total traffic to estimate the dimensioned busy hour. NRAs and incumbents will need to ensure (by reviewing data on daily, weekly, monthly, and yearly peaks) that the busiest hour in the year (the yearly peak) is broadly in line with monthly peaks in order to avoid over-dimensioning the network.

4.4 Switching Set-up and Duration costs

The model produces the costs of the relevant interconnection services on a per minute basis even though the majority of costs are not incurred in that way. For that reason the model also allows users to see the switching costs broken down into a fixed (call set-up) cost and an on-going (call duration) cost. This information is provided as an additional feature of the model in a stand-alone sheet to demonstrate how costs can be shown in different ways, and does not affect in any way the calculation of the results in the rest of the model.

Some of the costs associated with switching fall neatly into these two categories. The costs of the processor, for example, are driven by (busy hour) call attempts and can be attributed to the per call set-up charge. Other costs such as the cost of the switchblock and the cost of ports, is driven by (busy hour) erlangs and could be attributed to the per-minute call duration cost.

A number of other costs, however, do not neatly fall into these categories. The site costs, the synchronisation-related costs, and the cost of signalling transfer points are common to both call set-up and call duration and will need to be allocated to each of those categories. The model allocates these equally to call set-up and call duration, although NRAs will be able to change these proportions to reflect their own view of the cost drivers of those types of costs.

5 MODELLING THE TRANSMISSION NETWORK

The transmission network consists of both transmission electronics and infrastructure. The assumptions regarding infrastructure are considered in the next chapter.

5.1 Overview of Transmission Assumptions

We have modelled a Synchronous Digital Hierarchy (SDH) transmission system, although we recognise that that the transmission networks of many incumbent operators are predominantly Pleisiochronous Digital Hierarchy (PDH). We believe that this approach is consistent with our assumption of a forward-looking efficient operator, as such operators are migrating to SDH network architecture.

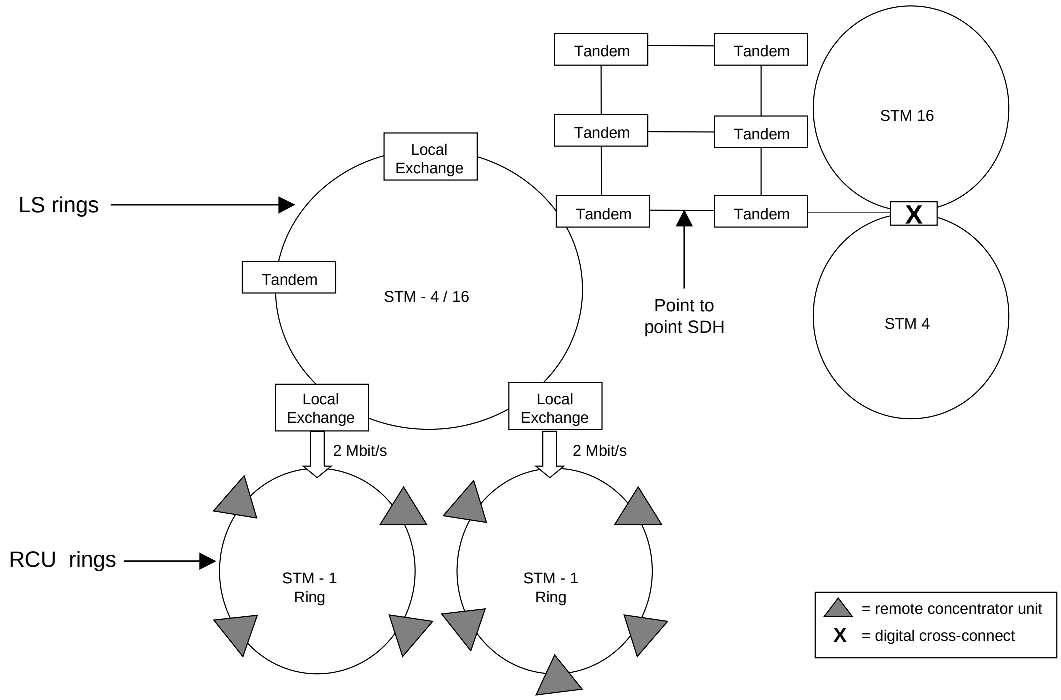
Despite requiring additional bandwidth, the SDH system is technically more efficient and probably more cost-effective than provisioning of bandwidth in small discrete blocks of capacity as is the case under PDH. In addition, SDH increases the potential for remote network management with fast, flexible provisioning, comprehensive protection mechanisms and end-to-end performance monitoring.

The transmission elements being modelled are:

- remote concentrators to local switches;
- local switch to tandem switch; and
- tandem switch to tandem switch.

New transmission and routeing technologies are rapidly coming on stream and the model that we have built assumes a technology which looks simplistic compared to what is about to be possible. Nevertheless, much of the network remains PSTN/ISDN and it is the costs of interconnecting PSTN/ISDN traffic that the model is designed to assess. Different technological assumptions will account for some differences between the costs as modelled and those occurring in an actual or a planned network. Figure 5.1 provides an overview of a transmissions system as modelled.

Figure 5.1: Overview of Transmission System Modelled



Not all networks in Member States will have all of these network components. Some networks, for example, may be configured so that the local switches are connected only to tandem switches rather than to other local switches. Full interconnection of all switches, therefore, would be achieved through the tandem switching layer.

The transmission network is arranged in the form of SDH rings that connect remote concentrators to local switches. The rings connecting a remote concentrator unit to a local switch are referred in this study as "RCU rings", while the rings connecting local switches to other local switches or to tandem switches are referred to as "local rings". The transmission network at the tandem to tandem level is assumed to be structured in a virtual "ladder" configuration which incorporates sharing of transmission routes by traffic (logical) routes, allowing savings to be achieved while traffic routes are fully inter-connected in practice.

All traffic routes are assumed to have both ways capability, allowing calls originating at either end to traverse the same traffic route. Transmission systems have separate "go" and "return" paths for the transmission of information originating at each end of the route; this is subsumed within the system and multiplexing costs.

5.2 Methodology for Each Transmission Element

5.2.1 RCU rings

The number and mix of transmission electronics required for RCU rings is determined by the dimensioned capacity for that part of the network (see section 5.3) and the stylised mix of systems inputted by NRAs.

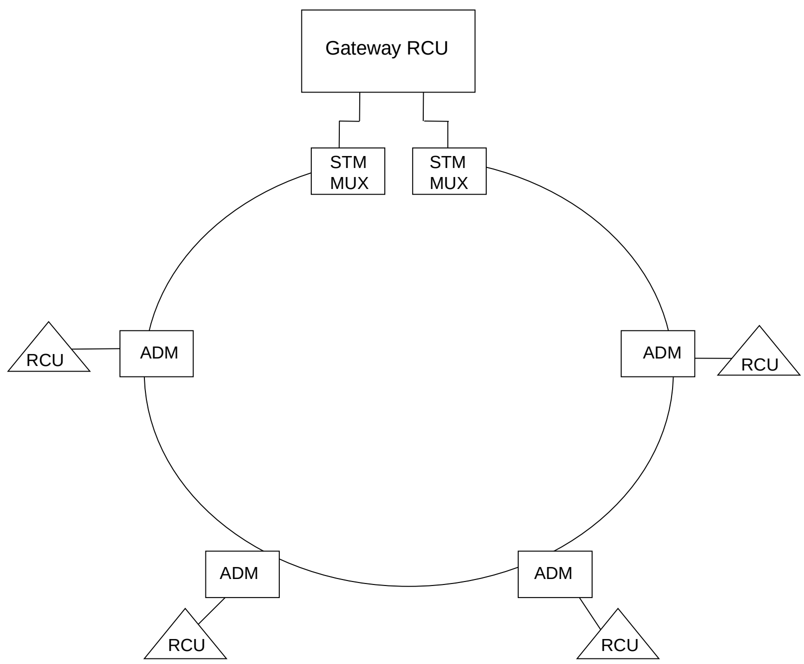
The dimensioned capacity determines the number of rings required in the relevant level of the network. If, for example, the dimensioned capacity was 100,000 Mbit/s, this could in theory be met by 715 STM – 1 rings.[24] In practice, however, some routes will require more capacity than others. In some cases, an STM – 4 or 16 may be required, although the latter would be unusual in a RCU ring.

The mix of systems in the model is determined by reference to the data entered by NRAs on the mix of systems in a stylised fully SDH network. That is, for each part of the transmission network, NRAs will need to assess how much of the capacity will be carried by transmission systems of a different size (ie an STM- 1, 4, 16, or 64).

The number of nodes connected to each ring is determined endogenously. Once the number of rings has been determined (based on the required capacity), the model determines the number of nodes on rings of different capacity. The size of the rings (ie the number of nodes connected to each ring) will vary inversely with the capacity requirements determined in the model.

Each ring has a "gateway" node and other nodes. The gateway node hosts the ring and has the multiplexing equipment of the relevant size. Other nodes are connected to the ring through add-drop multiplexors. In the case of RCU rings, the local exchange will be the gateway node and will carry the relevant multiplexing equipment. Each RCU will be connected to the node through an add drop multiplexor (ADM) (see figure below).

Figure: 5.2 Examples of an RCU Ring



The model calculates the transmission electronics required in the following way:

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24 An STM- 1 ring has a capacity of 155 Mbit/s but its payload is only 140 Mbit/s after allowing for the overhead for control and surveillance etc.

- the multiplexing equipment which determines the capacity of the ring is located in the gateway local exchange. There are two multiplexers per ring; and
- there is one Add Drop Multiplexer (ADM) per node, which in this model is equal to one ADM per RCU.

Regenerators may also be needed for longer distances to avoid degrading of the signal. The number of these is calculated as follows:

- the average length of each transmission link is divided by the maximum distance after which the signal needs to be regenerated (distance between two regenerators);
- this ratio is then rounded up to the next whole unit. In order to get the actual average number of regenerators needed for each transmission link, the previous number is scaled down by one[25]; and
- to get the total number of regenerators needed, the average number obtained is then multiplied by two to account for diversity and by the total number of physical routes.

5.2.2 LS rings

LS rings are similar to RCU rings except that they connect other local switches and tandem switches.

The number and mix of LS rings is calculated in the same way as RCU rings. The number of rings then allows the model to determine how many local switches are actually connected to each ring provided that there are two tandem switches connected to each LS ring.

Each LS ring includes a gateway tandem switch, which contains the multiplexing equipment that determines the capacity of each ring. All of the other nodes in the ring are connected via an ADM.

The transmission equipment required in this part of the transmission network is determined as follows:

- the number of STM –n multiplexers is equal to the number of “gateway” tandem exchanges;
- the number of ADMs is equal to the number of other nodes connected to the ring (including the “host” exchange); and
- regenerators are based on distance in the same way as for RCU rings.

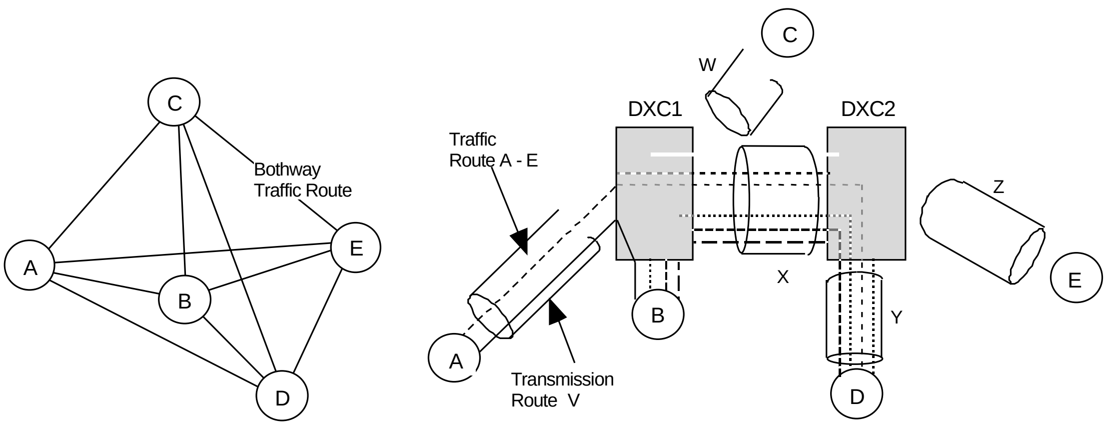
[25] For example, if the average length of the TS-TS transmission link is more than three times the distance needed between two regenerators, then the link will be split in four relevant components. Along these four components, the signal needs to be regenerated three times before it arrives at the termination point.

5.2.3 Tandem to tandem transmission

Tandem switches are not arranged in rings in the model. Rather, they are assumed to be connected in a "ladder" configuration which is a partial mesh, similar to a point-to-point SDH system (see Figure 5.3). This allows all tandems to be fully interconnected without the need to equip all of the tandem to tandem traffic routes with individual transmission routes. Digital cross connects are located at every tandem switch in order to provide greater flexibility at higher points of the network. In practice, Member States are likely to have a mix of configurations in their tandem to tandem transmission network with, for example, a mix of ladders and rings.

The number of physical routes in the tandem to tandem transmission network will necessarily be less than the number of traffic routes in the network (see Figure 5.3). This allows for savings to be achieved while allowing for full connectivity.

Fig 5.3
"Traffic" vs "Transmission" Routes



Total of 10 bothway "traffic" routes Total of 5 "transmission" routes

The figure shows 5 tandem exchanges (A to E) fully interconnected by 10 bothway traffic routes but the exchanges are physically interconnected via 5 SDH transmission routes. The traffic routes carried by each transmission route are interconnected via two SDH Digital Cross Connects (DXCs) as shown in the figure e.g. traffic route A - E is carried on transmission routes V, X and Z interconnected via DXC1 and DXC2. Tandem B is co-located with DXC1.

The model estimates the number of transmission (physical) routes in the following way:

- the total capacity required for TS to TS routes is determined; and
- this capacity is distributed to STM – 1, 4, 16 and 64 systems in the same way as for RCU rings and LS rings.

5.3 Allowing for Microwave Transmission

A forward-looking network would not generally consider microwaves as the most efficient means of transmission. In normal circumstances, digging cable and laying fibre would be more cost effective than building towers and equipping them. However, for particularly mountainous areas, microwave transmission could turn out to be more cost effective than laying fibre.

The model provides users with an option to include microwave transmission in their network. This functionality was requested by the Working Group of NRAs although default costs have not been provided. NRAs will need to populate the relevant sheet with costs and asset lives etc. with data from their own Member State.

The pieces of equipment which have been included in the model are the following:

- Radio Termination Equipment (RTE);
- masts;
- antennae equipment; and
- microwave sites.

For the TS-TS part of the network, users will need to input the percentage of routes served by microwave as opposed to through fibre in cables (Network Assumption - Technical). We have only allowed for microwave in this part of the network because it is the part of the network where route distances are typically longer. The number of physical routes served by microwave is computed by applying those percentages to the total number of systems in this part of the network. The model assumes one Radio Termination Equipment at each end of each microwave transmission route.

Towers are needed at each end of the each transmission route. Additional equipment is needed to regenerate the signal (the distance between masts has been assumed to be 75 Km). Three different specifications for towers have been considered (heavy, medium and light). The user has to specify which percentage of TS-TS routes is served by the different types of towers (Network Assumption - Technical).

Antennae equipment comprises all the electronic apparatus placed on each mast (dishes, antenna, waveguides, etc.).

The buildings on the TS – TS transmission links are not assumed to share costs with the access network. These site costs are entirely allocated to transmission, as opposed to switching.

5.4 Dimensioning the Transmission Network

The approach we take to dimensioning the transmission network is similar to that taken for the switching network in the following respects:

- it uses billed minutes as the starting point;
- it incorporates holding times and an allowance for growth;
- it uses routeing factors to determine the intensity with which each network element is used;

- it dimensions the network for the same busy hour as the switching network (but then includes leased lines as discussed below); and

- it then adjusts this capacity to allow for flows between nodes and to provide resilience.

There are, however, a number of differences, and these require explanation. The differences in question are:

- increasing the required capacity;

- adjustments to the stylised mix of transmission systems to meet demand;

- differences in the way the utilisation rates for the transmission components are used; and

- the inclusion of leased lines to derive the required capacity.

5.4.1 Increasing the required capacity

The use of billed minutes and overheads (such as unsuccessful calls etc), once adjusted for routeing factors is still likely to underestimate the usage that PSTN traffic and leased lines make of the transmission network. This is because traffic travelling over a particular part of the transmission network is likely to travel over multiple line systems. A local call that might have a tandem-tandem routeing factor of one, for example, may travel over three or four transmission systems within that part of the network. If the usage of these systems is not reflected in the transmission routeing factors, an adjustment will need to be made to the required capacity.

The model makes the following adjustments for different parts of the network:

- for RCU and LS rings, the resilience is included by the ring structure itself although NRAs could adjust this in the "transmission electronics" sheet;

- for the TS-TS part of the network, the traffic flowing across nodes over the transmission systems must be taken into account. The model provides an adjustment factor based on the number of tandem switches. This adjustment factor depends on the network configuration assumed in the model and may produce results that are not appropriate for every Member States. NRAs may, therefore, need to pay particular attention to the transmission capacity which will need to be carried by the TS-TS part of the network. Diversity under a ladder configuration is provided by increasing the number of transmission routes in the tandem to tandem transmission network in order to take account of additional capacity required. The default increase in the model is set at 15 per cent.

5.4.2 Adjusting the stylised mix of transmission systems to meet demand

The total capacity required on each transmission route (see Transmission Capacity) is initially allocated over the four different types of ring (STM 1, 4, 16, and 64) on the basis of assumptions made by NRAs on the mix of systems over different parts of the transmission network in a stylised fully SDH network. In such a network, we would expect there to be more lower capacity rings in the lower part of the network and higher capacity rings in the higher (TS-TS) part of the network.

Information on the mix of systems is requested for both PSTN and leased line traffic to take account of any differences in the mix between those two services.

The total number of nodes are then allocated to systems on the same basis in order to estimate the total number of nodes per ring. There can be no less than 3 and no more than 16 (user input) nodes per ring.

If the number of nodes meets these constraints, the number of line systems will be determined on the basis of the mix of systems inputted by NRAs. If, however, this mix of systems breaches the lower and upper constraints on rings, the model will re-allocate systems to meet these constraints by making the following adjustments:

- if the mix of systems produce a number of nodes per ring that exceeds 16, the model will include more rings in order to bring this back to 16. Such an outcome is likely if the total capacity in a part of the transmission network is low;

- if the mix of systems produces a total number of nodes which is more than three times the total number of rings but rings of a certain capacity carry less than three nodes, the model would re-allocate nodes from rings with more than three nodes to rings with less than three nodes; and

- if the mix of systems produces a total number of nodes which is less than three times the total number of rings, the model will alter the user-inputted mix of systems. This outcome is likely if the capacity required on a particular part of the network is too high. The adjustment made is to allocate more capacity to higher capacity rings. By allocating more and more capacity on the bigger rings, the network needs less rings to carry the traffic and, therefore, the condition on the minimum number of nodes per ring is easier to satisfy. The model re-allocates capacity on the different rings in an iterative way. Starting from the existing distribution, total traffic is re-allocated each time more and more heavily on the bigger rings until the condition on the minimum number of nodes is satisfied. The following table lists the percentages of the existing traffic allocated on each ring at each step of the iteration.

Table 5.1
Distribution of existing capacity on the rings

	STM 1	STM 4	STM 16	STM 64
Step 1	50%	50%	-	-
Step 2	50%	30%	20%	-
Step 3	20%	50%	30%	-
Step 4	-	50%	40%	10%
Step 5	-	20%	60%	20%
Step 6	-	-	70%	30%
Step 7	-	-	50%	50%
Step 8	-	-	20%	80%
Step 9	-	-	-	100%

If the total capacity to be carried on the network is still to large to allow three nodes per ring (even with all the capacity allocated on STM 64 rings), then the model will still allocate all the capacity on STM 64 rings. As a result, the model will allow for rings with less than three non-host nodes.

5.4.3 Differences in the use of utilisation rates

As with the utilisation rates for the switches, we would expect lower utilisation rates for transmission network elements lower down in the network and where large scale STM has been deployed.

5.4.4 The treatment of leased lines

The provision of transmission requires an investment in infrastructure, much of which is shared between a variety of services. If the entire investment were borne by the PSTN, the charge would be too high.

We achieve this cost sharing in part by dimensioning the network for both PSTN and leased lines. A number of other networks also use the transmission system such as public data networks and special service networks introduced to meet specialised demands from customers. We would expect that PSTN traffic and leased lines will make up the bulk of the capacity required in this part of the network; if users of the model wish to do so they can increase leased line traffic to include traffic by other networks as well as leased lines.

One difficulty that NRAs may have when entering the relevant information into the model is to estimate the routeing factors for leased lines. The model requires an estimate of the intensity with which services, including the leased line network, use the transmission network. However, leased lines use the network in a different way to PSTN traffic. PSTN traffic, for example can be mapped onto the transmission network by considering how many RCU-LS links a local call uses, how many LS-TS links a local call uses etc. A leased line, on the other hand is an end to end connection from one site to another. Operators may not, therefore, collect information in the same way as they collect it for PSTN services and assumptions may need to be made about the intensity with which leased lines use the network.[26]

The sharing of the transmission network by PSTN and leased lines (and increasingly in the future, other services) gives rise to a pool of shared costs which can also be referred to as intra-conveyance common costs. Examples include most of the duct and fibre as well as multiplexing equipment, digital cross connects and regenerators. These shared costs are attributed to each of the services using the transmission network on the basis of their share of capacity. In other words, the total cost of transmission and infrastructure required to offer PSTN and leased lines is divided by the capacity of the two (in Mbit/s which are then converted to minutes). The per-minute charge will then be applied to the transmission components of interconnection, as part of the interconnection charge.

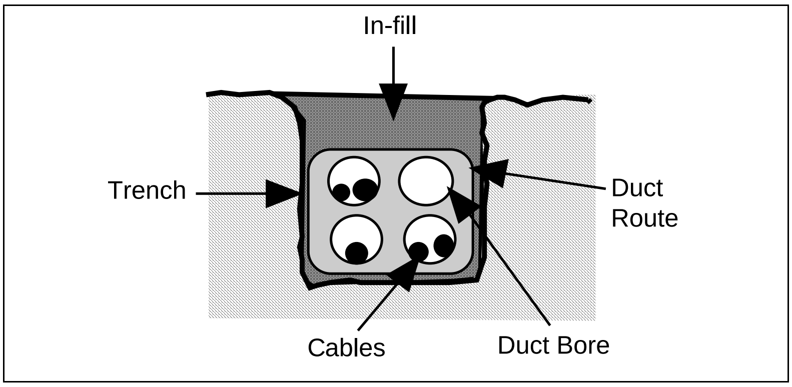
[26] For example, short distance leased lines may be assumed to display similar routeing factors as local calls, while longer distance leased lines may display similar routeing factors to long distance calls.

6 OVERVIEW OF INFRASTRUCTURE ASSUMPTIONS

Infrastructure refers to the equipment in the ground, and typically makes up a large share of the transmission network costs. Another term used to describe infrastructure is underground plant. Infrastructure costs are determined for the same elements as the transmission network and their costs are ultimately included as part of the transmission network elements when unit costs are estimated.

Infrastructure comprises primarily ducts, cables, and the fibre carried in cables as illustrated in Figure 6.1 below. The duct costs in the model include bores, and in a fibre optic network, we are assuming no more than about four bores to be required in a trench. A small component of network management costs is included in the model to cover fault detection in cables.

Figure 6.1
Components of Infrastructure



6.1 Duct

Duct comprises a trench into which a duct route is laid. The duct route comprises a number of bores into which cables are laid. Cables, in turn, have different numbers of fibres.

Infrastructure costs that we have modelled are driven mainly by the actual length of routes in a Member State, but are also influenced by two key factors:

- the extent to which cables are "ducted" as opposed to "buried". Ducting is more costly as it involves digging up and re-instating roads to install a duct route. Duct costs become progressively less in urban and rural areas may have fewer bores. In rural areas, cables may even be directly buried without the need for duct. Cables may also be tunnelled although this option is not considered in the model; and

- the extent to which duct is shared by other services such as the access network, or by other networks (for example, other operators or even other utilities). Sharing reduces the infrastructure costs that can be attributed to conveyance.

The costs of infrastructure are difficult to estimate accurately, largely because few operators are thought to have reliable records of duct lengths in their network, or of the extent of sharing.

Differences in geo-types will affect infrastructure costs more than switching and transmission costs for a number of reasons:

- Differences in terrain will affect duct costs. The type of surface is a factor that greatly affects the costs of duct as reconstruction costs account for a considerable share of overall civil engineering costs. The model provides a duct cost that differs according to whether the duct is in metropolitan areas, urban areas, and rural areas, as a proxy for different terrains.

- Different levels of sharing across geo-types. The extent of duct sharing, particularly with the access network, will vary from network to network. This would be expected to be the case mainly in metropolitan areas and would reduce the costs attributed to the core network.

- Differences in route lengths. In general, distance plays a relatively minor role in interconnection services, but it will affect some infrastructure costs and the need for regenerators.

- Differences in the percentage of cables ducted across geo-types. Buried cables are less costly than ducted cables and are more common in rural areas.

6.2 Cables

The model estimates the cable size used in each network element in the following way:

- first, NRAs insert an assumption on the average number of cables per duct;

- second, the model estimates the total cable length by multiplying the number of cables per duct by the actual duct length;

- third, the total length of fibre is estimated by multiplying the number of transmission routes in the model by two (as each system needs to transmit information in two directions between its ends and uses a fibre for each direction of transmission). We then multiply this number by the average length of transmission routes to get total fibre kilometres; and

- finally, we divide fibre kilometres by total cable length to get the fibres per cable. The model then looks at the size of fibre required and fits a fibre size that can meet the number of cables (with a minimum size used in 12 fibres).

7 MODEL OUTPUTS

The major outputs of the model are estimates of the cost of each of the three relevant interconnection services. These are derived from a second major output of the model, the total costs incurred for each network element and the unit cost of each network element.

Another feature of the model is that it can calculate the LRIC cost with or without an allowance for many of the common costs incurred in the provision of conveyance.

7.1 Totals and Unit Costs

7.1.1 Total costs

The model calculates the following costs for each network element:

- capital costs;
  - network related equipment costs(annualised).
  - non- network capital costs (such as non-operational buildings, vehicles etc).
- operating costs;
  - network related operating costs.
  - non-network operating costs (such as human resources, legal services, etc).

7.1.2 Unit Costs

The total cost of each network element is divided by the existing demand for that element (after adjusting for routeing factors) in order to estimate the unit cost. Existing demand differs from the dimensioned demand in that it does not include an allowance for growth, capacity utilisation, and unsuccessful call attempts. This means that existing users of the conveyance network (including the incumbent) pay all of the costs of a network that is dimensioned for a level of demand which exceeds the existing demand.

The network elements for which a unit cost is estimated are:

- remote concentrator unit;
- local switch;
- tandem switch;
- remote to local transmission link;
- local to tandem to transmission link; and
- tandem to tandem transmission link.

7.1.3 The Cost of Interconnection Services

The unit costs of each network element are then combined in different ways to calculate the costs of the three specified interconnection services, namely local, single transit, and double transit interconnection. The amount of each network element that is attributed to each interconnection service is determined partly by definition and partly by the way in which subscribers are connected to the conveyance network.

- **Local level interconnection**, for example, involves the use of one local switch (by definition) and a proportion of an RCU and RCU-LS transmission link. The share of the RCU and RCU-LS transmission link used for local level interconnection is estimated as follows: if (say) 90 per cent of subscribers are connected to an RCU then 90 per cent of the RCU and RCU-LS unit cost will be included in the cost of that interconnection service.

- **Single transit interconnection**, includes the cost components used for a local level interconnection as well as a tandem switch and a local to tandem transmission link.

- **Double transit interconnection** includes the cost components used for single transit interconnection as well as an additional tandem switch and a tandem to tandem transmission link.

7.2 Common Costs

The model can estimate those costs that are avoided if conveyance were not to be provided by a full-service operator as well as the LRIC of conveyance with an allowance for common costs. The difference between these two cost measures depends on the extent of cost sharing in telecommunications networks.

The common costs included differ depending on the network element being considered, as is illustrated in Table 7.1 below.

Table 7.1
Shared Costs excluded when estimated avoidable costs

Switching	Transmission Infrastructure
Fixed site cost	Fixed site cost
	Cost of buried shared cable
	Cost of shared ducts

These common costs are allocated to the conveyance network on the basis of a percentage inputted by NRAs. The default assumption in the model is set at 50 per cent.

7.3 Total Costs Under Different Increments

The model also produces costs estimates based on different definitions of the increment. These estimates are not used to provide the default results and some of the model features (such as the sensitivities) may not function when this option is selected.

The two additional choices provided in the model are:

- an estimate of the incremental costs of PSTN conveyance on a network providing access and leased lines. This will produce relatively low estimates for the transmission elements as the duct costs will be attributed to leased lines and only the addition cost of fibre and multilexers associated with PSTN would be shown;

- an estimate of the costs of a network without leased lines. In other words a network where the only service provided over the transmission network was PSTN. The cost of interconnection would be relatively high under this option as they would be bearing all of the duct and fibre costs attributed to the conveyance network.

Switching costs are not affected in either of these two options as leased lines do not use the switched network.

8 TOP-DOWN AND BOTTOM-UP RECONCILIATION

The Terms of Reference require that a reconciliation with a top-down and an independent bottom-up model be undertaken stating that:

> "It is on the operational side that we understand bottom-up models are weakest, typically relying on mark-ups to get final cost figures. For this reason and also those raised in the above paragraph, it is imperative that a reconciliation be made with a suitable top-down model."

This chapter will present illustrative results from the adaptable interconnection model and describe BT's top-down model and Oftel's bottom up model — the two models reviewed as part of the reconciliation exercise. It will then assess the areas of difference and highlight those data to which the final results are particularly sensitive.

8.1 The Objectives of the Reconciliation Exercise

The purpose of a reconciliation is to ensure that the model built by Europe Economics can be applied to different Member States and produces robust estimates of the long run incremental costs.

In order to achieve this, we produced results for a Member State in which a suitable top-down model was available, and then compared our results with those produced by the relevant top-down model. The same was done with a bottom-up model.

In general, we expected the results of the top-down model to differ significantly from those of the bottom-up model, and that the key areas of difference would be the following:

- differences in asset valuation and depreciation methods;
- operating costs in a top-down model are likely to be based on actual costs incurred rather than an estimate of the operating costs incurred by an efficient operator;
- the unit costs of the transmission elements may differ as a result of our assumption of a full SDH network.

The purpose of the reconciliation exercise conducted as part of this study has not been to determine which set of results are more accurate and therefore which should be used to set interconnection charges. Rather, the purpose was to assess the robustness of the adaptable bottom-up model and to ensure that the reasons for any differences between the results of the two models were understood.

Our reconciliation, therefore focuses on two areas:

- to identify the factors which would result in differences between the models; and
- to examine the significance of each of these factors.

8.2 Populating the Adaptable Bottom-up Model

The project team requested information from NRAs on telecommunications networks in order to populate the model and to test the assumptions made. The information provided by Oftel and BT, which would have enabled the project team to produce results for the UK, was the most comprehensive provided, but was not fully complete and in order to produce illustrative results, assumptions were required to fill in some important gaps.

In some case, the results are sensitive to these assumptions, illustrating the need for robust data to be collected by NRAs and for the need for sensitivity analysis on the results. For that reason, a range of results was determined, one set of which was used for the reconciliation exercise reported in this chapter.

The model presented here was used to produce results for two periods — one for 1998 to compare with the results from BT's top-down model in 1998 and one for 1995 to compare with the results from Oftel's bottom-up model for 1994/95. These results are shown in the table below:

Table 8.1:
Results from the Adaptable Interconnection Model

(euro/100 per minute)

	EER results to compare with BT's 1998 top-down results	EER results for 1994/95 to compare with Oftel's bottom-up results
Remote concentrator unit	0.163	0.195
Local switch	0.210	0.232
Tandem switch	0.091	0.105
Remote to local transmission	0.195	0.254
Local to tandem transmission	0.115	0.155
Tandem to tandem transmission	0.340	0.446

Source: EER estimates

These data sources used to populate the model included:

- Market Information 1993/94 to 1997/98, published by OFTEL;
- the bottom-up network model, version 2.2, released by OFTEL in March 1997;
- Evaluation of the Efficiency of BT's Network Operations, prepared for OFTEL by Strategic Policy Research, Inc and Weber Temin and Co;
- BT's "Current Cost Financial Statements for the Business and Activities 1998 and Restated Current Cost Financial Statements 1997".

8.3 Reconciling with a Top-Down Model

BT has developed a top-down model that can model incremental costs in current cost accounting (CCA) terms. The model can produce costs of LRIC floors and ceilings, as well as fully allocated costs (FAC) and stand alone costs (SAC). Cost floors are calculated on what BT term a distributed long-run incremental cost (DLRIC) basis. Cost ceilings are based on distributed stand-alone costs (DSAC).

DLRIC of the core, for example, is calculated by BT as follows[27]:

- the LRIC of the core is calculated by treating the core as a single increment;
- the LRIC of the network components comprising the core are calculated;
- the difference between the two is the fixed common cost of the core;
- this common cost is allocated proportionally to the components based on the LRICs of the components.

The SAC is the cost of producing an increment without any other increments provided. Clearly, this would give the maximum cost of producing an increment and it is therefore used as the ceiling.

FAC is the allocation of costs including those indirectly associated with the activities such as the support functions. BT use cost drivers to apportion these costs and, where these are not available, the apportionment is based on the value added as judged by management.[28]

The Europe Economics model includes some indirect costs such as site costs, shared duct etc. Therefore, the data from BT's top-down model used in the reconciliation are the costs on a current cost basis that uses FAC. (The use of DLRIC or SAC would be inappropriate as it would not be comparing like with like.) Differences in the approach to the apportionment of indirect costs may, however, be part of the explanation of any difference between the model and BT's results.

8.3.1 Brief overview of BT's Top-Down model

The six key inputs are:

- CCA costs;
- cost/volume relationships;
- cost driver volumes;
- cost category to cost volume dependency linkages;

[27] Source: 'Accounting Documents' dated 16 September 1999.
[28] Source: 'Accounting Documents' dated 16 September 1999.

- increments to be measured; and
- other assumptions.

8.3.2 CCA cost

The costs are separated into categories of similar cost type and identical cost drivers. The calculation of current costs is as follows:

8.3.2.1 Current Cost Adjustments

These were prepared under the financial capital maintenance (FCM) convention. This 'reflects the holding gain or loss to the economic value of the assets through specific price changes (or through value changes arising from technical progress) as well as allowing for the reduction in the real value of shareholders' funds employed in the business as a result of general inflation.'[29]

8.3.2.2 Detailed valuation methods

Tangible fixed assets are valued at the current replacement cost which is based on the value of the modern equivalent asset. Changes in fixed asset values are classified as holding gains or losses. They are attributed between activities on the same basis as the assets themselves.

Depreciation is on a straight line basis. The difference between depreciation based on HCA and CCA valuations of assets (supplementary depreciation) is also attributed on the same basis as the assets themselves.

The following are attributed to the Residual Business (i.e. not included in any other businesses, such as network business):

- realised holding gains or losses;
- foreign exchange translation of overseas investments; and
- goodwill adjustments.

8.3.2.3 Operating costs

CCA adjustments to HCA operating costs are:

- supplementary depreciation; and
- holding gain and other CCA adjustments.

8.3.2.4 Capital cost

Capital cost is calculated by:

[29] From BT 'Long Run Incremental Cost Methodology' (dated 28 November 1997)

- CCA mean capital employed x applicable rate of return (12.5%).

8.3.3 Cost volume relationships

The cost volume relationship shows how costs change as the volume of its cost driver increases. The existence of fixed common and joint costs[30] will result in a non-linear cost volume relationship. This would indicate the existence of economies of scope. Economies of scale may also arise due to declining marginal costs as volume increases.

8.3.4 Cost category to cost volume dependency linkages

Costs drivers can be:

- Independent – i.e. directly related to the external demand and not dependent on any other cost volume relationships.
- Dependent – i.e depend on other cost drivers.

The model is arranged so that changes in a cost category flow though to the dependent costs.

8.3.5 Increments to be measured

The increments in the model relating to the core are:

- the top 9 network components;
- product management, policy and planning;
- inland private circuits; and
- interconnect connections and rentals.

8.3.6 Assumptions

The following assumptions are made in the model:

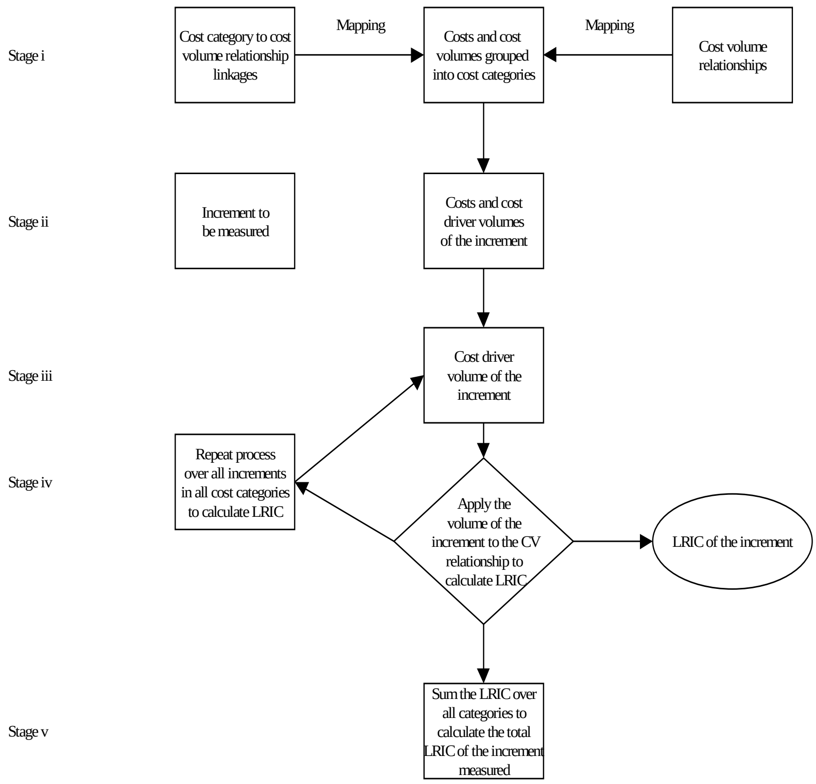
- scorched node;
- thinning – which means that existing transmission routes are assumed to be required to provide connectivity between network nodes independent of the scale of activity. The amount and type of equipment used will alter with the scale of activity;[31]
- service levels are maintained; and
- constant mix of demand characteristics (e.g. average call duration) with respect to scale.

[30] Fixed common costs being fixed and joint costs being variable.
[31] Source: Accounting Documents – 16 September 1999

8.3.7 Summary of BT's modelling approach

The process is summarised in Figure 1.

Figure 1: Flow diagram of inputs through the model to calculate LRIC



Source: BT Long Run Incremental Cost Model – Relationships and Parameters 13 November 1998.

The model maps all cost categories (independent and dependent) to the relevant cost/volume relationships (CVRs). The mapping first takes in independent cost categories and then dependent costs categories. The model calculates the LRIC of the dependent costs using the LRICS from costs higher in the hierarchy (e.g. independent costs) to calculate the cost driver volumes.

Assuming the cost driver volume of the increment can be measured, the LRIC is calculated. The LRIC for the increment is then found by summing the LRICs over all the cost categories.

8.4 Results from the models

The results from the models can be seen on the following pages.

8.4.1 BT's costs on a current cost and FAC basis

Table 8.2

Network components	Total CCA operating costs (euro m)	Capital costs (euro m)	Total (euro m)	Minutes (millions)	Total cost per minute (euro/100)
Remote concentrator	156	191	347	255,420	0.136
Local switch	273	269	542	258,985	0.209
Tandem switch	84	86	170	160,645	0.106
Remote to local transmission	174	216	390	192,584	0.203
Local to tandem transmission	113	132	245	141,819	0.173
Tandem to tandem transmission	46	80	126	47,261	0.266

Source: BT Statement of costs on a current cost basis for the year ended 31 March 1998 in 'Current Cost Financial Statements for the Business and Activities 1998 and Restated Current Cost Financial Statements 1997' (p.20)

For consistency with the assumptions on which Europe Economics' results are based, the following adjustments to the BT terminology and calculations have been made:

- A local exchange concentrator is called a remote concentrator.
- A local exchange processor is called a local switch.
- Main and digital junction switching is called a tandem switch.
- Local to remote transmission is called remote to local transmission.
- BT transmission costs have been converted into a per minute charge (see section 8.4.2.2); and
- The depreciation charge was reallocated from operating expenses to capital costs using an approximation for depreciation of 30 per cent of total operating expenses (see section 8.4.2.2).

8.4.2 Comparing the results of the two models

The results from BT's top down model and EER's adaptable interconnection model are provided in Table 8.3.

Table 8.3

Results from BT and EER

	Results from BT's top down model	Results from EER's adaptable bottom-up model
Remote concentrator	0.136	0.163
Local switch	0.209	0.210
Tandem switch	0.106	0.091
Remote to local transmission	0.203	0.195
Local to tandem transmission	0.173	0.115
Tandem to tandem transmission	0.266	0.340

We explored the general reasons behind the differences between the models and then considered the specific reasons for differences for each network element. The latter task was aided by breaking down the cost of each network element into the capital costs, operating costs, and minutes.

8.4.2.1 General factors

The following should be noted as general factors which affect the reconciliation:

- BT adds a product management, policy and planning charge to its interconnection costs which are not included in the unit costs shown here.

- The exchange rate used to convert sterling to ECU was £1 = ECU 1.5. This rate is based on the average of the rates of the first three quarters in 1999 as given by the European Central Bank.

- The (dis)inflation rate specific to telecoms has not been accounted for in the figures. As the BT figures are for the year ended 31 March 1998 and the EER figures are based on prices in 1999, this is not likely to make a material difference for the purposes of the reconciliation. It could be assumed, however, that the BT costs would be lower for 1999 than for 1998.

- The depreciation method used by BT is replacement cost based on a modern equivalent asset with straight line depreciation. The investment costs in the EER model may be higher as they are based on replacement cost and do not require an adjustment for the modern equivalent asset as would be the case for BT.[32]

- BT's asset lives and depreciation schedules were in some cases likely to be different to those used by EER. Approximations based on information in BT's accounts were input into the model to attempt to estimate the impact of this. The results were found not to be significantly different from those with EER's asset lives and depreciation schedules.

- The apportionment of indirect costs may differ between EER's and BT's approach. Not enough information was available to assess the impact of this.

8.4.2.2 Specific factors

In order to explore the differences in unit costs per minute, the costs of each network element were disaggregated into capital costs, operating costs, and minutes. However, BT include depreciation as an operating costs while the adaptable interconnection model treats it as a capital cost. Therefore, an adjustment was made to the BT costs to remove depreciation from operating costs and include it as a capital cost.

This adjustment was performed using an approximation for depreciation of 30 per cent of total operating expenses. The estimate was based on the mid-point of the range given for depreciation as a percentage of operating costs for the year ended 31 March 1998 in BT's 'Current Cost Financial Statements for the Business and Activities 1998 and Restated Current Cost Financial Statements 1997' (p.23).

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[32] This would suggest that the EER capital costs, and cost per minute, would be higher than for BT if all other costs were the same. Given the lack of information and difficulty of comparison between the two asset valuations, we are unable to quantify this factor. It is possible that it could be significant.

The disaggregated results are shown and discussed separately for the switching elements and the transmission elements.

Table 8.4

Remote Concentrator Units

	Per BT	***Per EER***	***Variance (%)***
Cost per minute (euro/100)	0.136	0.163	19.9
Minutes (millions)	255,420	255,536	0.0
Total costs including working capital cost (euro millions)	347	416	19.9
Operating costs	156	154	-1.3
Capital costs	191	255	33.5

Table 8.5

Local Switches

	Per BT	***Per EER***	***Variance (%)***
Cost per minute (euro/100)	0.209	0.210	0.5
Minutes (millions)	258,985	260,783	0.7
Total costs including working capital cost (euro millions)	542	548	1.1
Operating costs	273	185	-32.2
Capital costs	269	255	-5.2

Table 8.6

Tandem Switches

	Per BT	***Per EER***	***Variance (%)***
Cost per minute (euro/100)	0.106	0.09	-15.1
Minutes (millions)	160,645	160,671	0.0
Total costs including working capital cost (euro millions)	171	147	-14.0
Operating costs	84	51	-39.3
Capital costs	86	94	9.3

The results for each of the switching elements shows that the number of minutes used in the two models are very similar. The differences in the unit costs are, therefore, due to differences in capital and operating costs. These differences may be due to the following:

- the adjustment performed by EER to remove depreciation from operating costs and include it as a capital cost;
- the different operating cost ratios derived mainly in the US;
- the definition of remote concentrator units which may vary between the two models;
- assumptions regarding capacity utilisation, margins for growth etc, which determine the dimensioned capacity; and/or;
- the treatment of associated costs such as synchronisation, network management, and signalling which have been added to the switching costs thus increasing the capital costs. It is unclear how these costs have been treated in BT's top down model.

The disaggregation of the unit costs for the transmission elements showed one major area of difference between BT's top-down model and EER's adaptable interconnection model. This difference was in the area of leased lines. BT does not include leased lines in the cost of the transmission elements and shows them as a separate entry in their accounts. As a result, extra figures have been included for transmission which give the minutes and total costs if leased lines were not included in the EER model.

Table 8.7

Remote to Local Transmission

	Per BT	***Per EER***	***Variance (%)***
Cost per minute (euro/100)	0.203	0.195	-3.9
Minutes (millions)	192,584	355,781	84.7
Minutes excl. leased lines (millions)	*192,584*	*198,141*	2.9
Total costs including working capital cost (euro millions)	390	694	77.9
Total costs excl. leased lines (euro millions)	*390*	*678*	73.8
Operating costs excl. leased lines (euro millions)	*174*	*280*	60.9
Capital costs excl leased lines (euro millions)	*216*	*387*	79.2

Table 8.8

Local to Tandem Transmission

	Per BT	***Per EER***	***Variance (%)***
Cost per minute (euro/100)	0.173	0.115	-33.5
Minutes (millions)	141,819	277,456	95.6
Minutes excl. leased lines (millions)	*141,819*	*151,344*	6.7
Total costs including working capital cost (euro millions)	245	319	30.2
Total costs excl. leased lines (euro millions)	*245*	*316*	29.0
Operating costs excl. leased lines (euro millions)	*113*	*135*	19.5
Capital costs excl leased lines (euro millions)	*132*	*176*	33.3

Table 8.9

Tandem to Tandem Transmission

	Per BT	***Per EER***	***Variance (%)***
Cost per minute (euro/100)	0.266	0.34	27.8
Minutes (millions)	47,261	125,509	165.6
Minutes excl. leased lines (millions)	*47,261*	*51,944*	9.9
Total costs including working capital cost (euro millions)	126	471	273.8
Total costs excl. leased lines (euro millions)	*126*	*366*	190.5
Operating costs excl. leased lines (euro millions)	*46*	*150*	226.1
Capital costs excl leased lines (euro millions)	*80*	*209*	161.3

The exclusion of the leased lines produces figures which still higher than BT's. One explanation may be that the costs of infrastructure are all attributed to the PSTN when leased lines are set to zero in the model. In addition, when looking at the split between operating and capital costs, it should also be remembered that the split of the BT figures may not be accurate due to the aforementioned estimation used for allocating depreciation from operating costs to capital costs.

These differences between the two models may be due to the following:

- the use of efficient operating cost ratios derived mainly in the US;
- SDH is only considered to be MEA at the higher levels of the transmission network in BT's model;
- the assumption used in the adaptable interconnection model regarding duct length and its allocation across transmission links is likely to be incorrect; the results are quite sensitive to duct;
- assumptions made by EER regarding capacity utilisation, margin for growth etc, which determine the dimensioned capacity; and/or;
- as the remote to local, local to tandem and tandem to tandem transmission costs are split into link and length costs in the BT report, the figures had to be converted to a per minute charge. This was achieved by taking the total transmission costs for each type (i.e link plus length costs) and dividing this by the link minutes to give a per minute cost.

8.5 Reconciling with an Independent Bottom-up Model

The UK results of the adaptable interconnection model were also compared with the results of the bottom-up model developed by OFTEL. Oftel's model was used as one of the tools to help them determine interconnection charges in the UK.

8.5.1 Brief overview of Oftel's bottom-up model

Oftel's model determines the unit cost of switching and transmission elements. The costs of these network elements are derived by applying annualisation factors to the investment costs. The two annualisation factors are:

- economic depreciation rate, which converts the investment cost into an annual capital charge; and
- operating cost factors, which use the level of investment costs to derive the annual operating expenditure.

The factors used for the major cost elements are shown in the table below.

Table 8.10
Annualisation factors used in the Oftel model

Network element	Annual capital cost (percentage)	Operating cost (percentage)	Total cost (percentage)
Local switching	16.2	10	26.2
Tandem switching	16.2	10	26.2
Transmission: fibre	14.6	7.0	21.6
Transmission: electronics	16.6	7.0	23.6
Transmission: duct	10.7	7.0	17.7

Source: Oftel Bottom Up Network Model, Version 2.2 March 1997.

8.5.1.1 Switching

The three switching elements modelled by Oftel are remote concentrator units, local switches, and tandem switches. There are two types of concentrators in Oftel's network — host concentrators which are co-located with the local switch and remote concentrators which are located remotely from the local switch.[33]

The costs of the three switching elements are broken down into port costs, processing costs, line driven costs, and common costs. The line driven costs, which are only relevant for concentrators and local switches, are fed into Oftel's bottom-up access model. Common costs are relevant for the calculation of ceilings.

The cost of the switch depends upon its port and processing capacity, and upon indirect capital costs (such as capitalised planning, power, accommodation assets, computing, materials awaiting installation, miscellaneous capital etc). The cost drivers of each of these are as follows:

- port costs are driven by the traffic demand in busy hour erlangs and relate to elements of the switch that support call duration;
- processing costs are driven by busy hour call attempts and relate to elements that support the call set-up function of the switch such as the processor cluster;
- unattributable costs are not specifically driven by either busy hour erlangs or busy hour call attempts, but are nevertheless incremental to conveyance. They are, therefore, included when developing the cost of network component.

An example of the steps used to derive the cost per minute for port costs is provided below:

- first, the investment per unit is determined for different parts of the switch, with the unattributable costs attributed to ports. This cost is then divided by dimensioned capacity;

[33] The model shows the cost of each type of concentrator separately although the results are reported as a weighted average.

- the investment per unit is then used to calculate the investment per busy hour erlang;[34]
- third, the investment per average busy hour minute is estimated from the investment per busy hour erlang;
- fourth, the investment per busy hour minute is then annualised by applying the economic depreciation factor and operating cost factor;
- finally, the working capital surcharge is estimated and added to the cost.

8.5.1.2 Transmission

The transmission network on Oftel's model is structured on a point to point basis, largely as its modelling is more tractable than modelling a multiplexed network. The transmission technology is assumed to be Plesiochronous Digital Hierarchy (PDH) which in 1997 formed the basis of BT's and Mercury's networks even though new entrants were installing Synchronous Digital Hierarchy (SDH) systems. Consequently, PDH was regarded as the modern equivalent technology.

All transmission capacity is assumed to be carried along fibres inside ducts. There is assumed to be no use of the radio spectrum in the transmission network.

The investment cost of each line system size is specified for end equipment and for repeaters. End equipment costs comprise the cost of line terminating equipment and associated indirect costs (such as power, accommodation assets, computing and motor transport). The cost of end equipment is stated as the investment required for electronics at both ends of the link.

The line system mix, the capacity mix and the equipment utilisation are derived in the model for each component. The line system mix gives the proportion of the total number of line systems installed for the transmission component of each line system size. The capacity mix is the proportion of total 2Mbit/s capacity for the transmission component that is served by each of the line system sizes. Equipment utilisation is defined as the proportion of the maximum capacity that is used in dimensioning busy hour. The end equipment cost per 2Mbit/s for a line system is given by the investment cost of the equipment, divided by the maximum capacity of the system and the equipment utilisation.

The cost of repeaters per 2Mbit/s is derived in a similar way to the cost of end equipment but is multiplied by the number of repeaters needed on average for each transmission component.

The cost of duct is expressed per 2Mbit/s per kilometre for each transmission component. It is built up from the cost of duct per metre, the length of transmission routes and the amount of duct shared between routes. The cost of duct includes the cost of planning and installing a number of bores (typically one to three), other direct costs such as jointing chambers, and associated indirect costs.

[34] Investment per unit is divided by erlangs per circuit and this is then divided by the number of circuits per port (30).

The cost of fibre is built up from the cost of an individual fibre per metre, the number of line systems per route and the length of the transmission routes. Besides the cost of optical fibre and cable sheath, the fibre cost per metre includes the cost of planning and installation as well as associated indirect costs.

The transmission investment per logical voice circuit (64 Kbit/s) for each transmission component is calculated from equipment costs per 2Mbit/s, repeater cost per 2Mbit/s, duct cost per 2Mbit/s per kilometre and fibre per 2Mbit/s per kilometre. The transmission investment cost per logical voice circuit for each transmission component is calculated from these elements by applying the average route length of each transmission component to the length related costs (duct and fibre) and adding on the cost of end equipment and repeaters. It is then converted in into a pence per minute cost.

The total investment in transmission is found by multiplying the investment cost per logical 64Kbit/s circuit for each transmission component by the number of logical circuits. The number of logical circuits depends upon the number of logical routes in each transmission component and the dimensioned traffic demands on those routes.

8.5.2 Comparing the results of the two models

The results from Oftel's model and from the Adaptable Interconnection model configured with (our estimate of) data from 1994/95 are shown in the table below.

Table 8.11
Results from Oftel's bottom-up model and EER's Adaptable Model

	Oftel cost per minute (1994 Euros)	Oftel cost per minute (1998 Euros)	EER cost per minute
Concentrator	0.15428	0.19684	0.19524
Local Switch	0.12876	0.16428	0.23249
Tandem Switch	0.10440	0.13320	0.10587
RCU local transmission	0.26912	0.34336	0.25444
Local- tandem Transmission	0.04524	0.05772	0.15534
Inter-tandem transmission	0.20996	0.26788	0.44676

The results of these two models show some variances. The reasons behind these variances are explored below by considering both general and specific factors.

8.5.2.1 General factors

The general factors between the two models which could account for some of differences in results could include:

- The costs requested for and used by the adaptable interconnection model were 1999 costs. These may differ from those used in the Oftel model, although the direction and magnitude of that difference will not always be clear. For instance, the cost of switches and some transmission equipment is likely to have fallen while the cost of infrastructure is likely to have remained very broadly constant.

- The cost of capital used in the two models may have been different. Oftel may have used 9 per cent, while the adaptable interconnection model used 12.5 per cent. (This difference would account for less than 10 per cent of the difference.)

- Oftel's model excludes some types of calls which have been included by the adaptable interconnection model (such as calls to and from mobiles).

8.5.2.2 Specific factors

The switching costs produced by the two models are difficult to compare as different definitions may be used. For example, concentrators in the Oftel model may include the cost of host concentrators which are not included in the EER Adaptable Interconnection model. The results for each switching element are shown below.

Remote Concentrator Units

	Per OFTEL	***Per EER***	***Variance (%)***
Cost per minute (euro/100)	0.196	0.195	-0.5
Minutes (millions)	201,104	201,071	0.0

Local Switches

	Per OFTEL	***Per EER***	***Variance (%)***
Cost per minute (euro/100)	0.164	0.232	41.5
Minutes (millions)	182,543	202,656	11.0

Tandem Switches

	Per OFTEL	***Per EER***	***Variance (%)***
Cost per minute (euro/100)	0.133	0.105	-21.1
Minutes (millions)	116,516	108,217	-7.1

The major variances are in the costs of local switches and tandem switches. There are a number of possible reasons for these:

- the component minutes in the EER adaptable interconnection model should be higher as the model includes some calls that were not included in Oftel's bottom-up model (such as calls to and from mobiles);

- the number of busy hour call attempts and ports is higher in the adaptable interconnection model than in Oftel's model. This, however, only accounts for a relatively small amount of the difference between the models; and

- operating expenditure is on average 6 per cent lower in the Oftel model due to lower operating cost ratios.

Transmission costs are less easy to reconcile largely because the methodology used to estimate costs in the two models is very different. Oftel models the transmission network using a point to point assumption whereas we model multiplexing to a greater extent through the use of rings at the RCU and LS level and a virtual ladder incorporating a partial mesh for transmission between tandem switches.

Other areas of difference in the transmission costs between the two models are likely to be:

- SDH versus PDH. The adaptable interconnection model assumes a full SDH architecture whereas Oftel modelled a PDH network, which was considered to be a modern equivalent asset in 1994/95;

- The intensity of leased line usage. The Oftel model takes explicit account of the intensity of leased line usage in different parts of the transmission network whereas the adaptable interconnection model assumes that the capacity is distributed in the same way as switched traffic.

- Price trends. The cost of transmission equipment will have fallen between 1994/95 although the cost of ducts may have remained constant or even risen.

The two most important of these are likely to be the extent of SDH in the network and the way that the network is configured. We have not been able to quantify the impact of these differences although we would expect them to be very important to transmission costs and to account for most of the variance in costs between the two models.

8.6 A Checklist for NRAs

The reconciliation exercise identified a number of factors that are likely to be important when comparing the outputs of different models. The areas that were either most sensitive or where robust data are critical include the following:

- the choice of depreciation methods;

- whether leased lines are included in a model;

- routeing factors, particularly for leased lines;

- the total length of duct for the conveyance network;

- the allocation of that duct over each of the transmission links;

- the number of nodes;
- the types of call included in each model;
- the nature of the transmission network; and
- the extent of SDH in the transmission network.

9 USING THE MODEL FOR POLICY PURPOSES

In conclusion, we summarise some of the factors which are likely to be important in using the model for policy purposes. These concern the determination of interconnection charges, call origination, call termination and internet services.

9.1 Determining Interconnection Charges

The model is intended to assist NRAs to calculate interconnection charges on the LRAIC basis which would represent a competitive and efficient level of charges, meeting the requirements of the Interconnection Directive.

Charges calculated on this basis should be more relevant than the "best practice" charges currently published by the Commission, on the basis of the three lowest current charges in EU Member States.

The importance of interconnection charges to incumbent operators and to their competitors is so great that many NRAs will no doubt expect controversy over their determinations. We have emphasised the desirability of inputting data to the model relevant to the particular circumstances of each Member State, where such data are available.

Incumbents wishing to resist a possible reduction in interconnection rates may propose the use of a 'top-down' approach, based on their accounting data. By definition, 'top-down' calculations reflect recent levels of cost, which may not be efficient. Reconciliation of top-down and bottom-up calculations is therefore likely to involve significant adjustments to the cost levels and asset values recorded in the accounts, to make them more relevant to the costs which would be incurred by an efficient operation.

The facility to calculate sensitively analysis will allow NRAs to judge which assumptions are most important.

The model presented here, like previous bottom-up models, estimates LRAIC on the basis of current efficient technology, and costs, and computes the appropriate current interconnection charges.

NRAs will also wish to consider whether the charges are likely to remain appropriate in future years, if their policy is to favour relatively stable or predictable interconnection charges. This raises two questions:

(1) Is the level of operating costs per unit of output likely to change significantly in the next few years (for example, because rapid improvements in productivity, or reductions in input prices, can be foreseen)?

(2) Does the method used to estimate the first year costs of capital equipment imply significant changes in the next few years? The user is offered a choice of methods within this model; aggressive depreciation methods resulting in a high cost in year 1 will also imply correspondingly reduced costs (and hence interconnection charges) in the future.

By comparison, a straight line or annuity method would imply lower charges in the Year 1, and less reason to expect significant charges in the following years.

9.2 Call Origination and Call Termination

The European Commission 1999 Communications Review discussed the potential for different markets to emerge within the broader market for interconnection services;

> "The Commission anticipates the development of differentiated markets such as (a) call origination services (b) the provision of transit capacity and (c) the provision of call termination services, with the competitive position in each of these markets evolving differently. The future regulatory framework should therefore allow for progressive relaxation of ex ante obligations in specific markets, once it could be shown that competition was sufficiently strong to guarantee equivalent outcomes."

One possibility is that call origination may develop as an increasingly competitive service, and so may not need to be subjected to the same charging rules as less competitive services, such as call termination. This would affect the regulatory limits applied by NRAs, rather than the estimation of bottom-up LRAIC, or interconnection charges for call termination.

9.3 Internet Services

Other changes in telecommunication markets are expected to derive from the development of the Internet.

Some NRAs are considering changing the way that certain interconnection charges are set. In the UK, for example, OFTEL has recently begun a consultation exercise on the most appropriate way to charge for interconnection of Internet calls.[35] OFTEL argues that the introduction of two-part charging for interconnection of Internet calls should end the current situation whereby calls of longer than average duration are "over-charged". The effect of this should be to reduce the cost of Internet access.

To the extent that some costs can be attributed to call set-up and other costs to call duration, a two part charging structure would help to make charges more cost reflective. The model provides the functionality to show the set-up costs separately to the usage-related costs and calculate unit costs for both. There are a significant amount of costs that relate to switching which would need to be allocated to either call set-up or call duration. These include site costs, and the costs of synchronisation which need to be allocated to set-up or duration.

Consideration would also have to be given to how transmission costs would be recovered under a two-part charging structure. The model, by identifying the costs of transmission electronic equipment separately to the costs of infrastructure, lends itself to the development of a more flexible arrangement to recover transmission costs.

[35] OFTEL. Pricing of calls to the Internet:: Possible initiatives to bring about more appropriate and flexible tariffs. November 1999.

APPENDICES

A1 OPTIMISATION

A bottom-up LRIC model inevitably involves a measure of compromise between what it is sensible to model and the realities of a national network evolving over a long period. The nodes which any optimisation is notionally re-equipping were probably laid out in the days of copper core networks supplemented by microwave routes and using electro-mechanical switches. Given probable replacement dates, a national operator might choose to avoid replacement of a particular modem switch with a concentrator ahead of wholesale changes in network topography. The links between them are, in practice, dimensioned from a detailed knowledge of the existing demand both for switched traffic and for other services such as leased lines.

Changes in technology are being taken into account as a national network evolves, as patterns of demand change and as new services come on stream or are envisaged. The boundary between core and access network is shifting and is likely to continue to shift. The advent of IP and of ATM is causing network planners to reconsider their topography and the possibilities of xDSL and other non-call switched services sharing the network with ongoing PSTN/ISDN services is complicating the planner's life.

A1.1 Optimisation A

The objective of this approach is to assess whether the equipment currently located at each switching node (remote concentrator unit or local switch) is optimal (i.e. minimises costs). It requires NRAs to have access to the node database of the incumbent operator. Such a database is likely to contain, at a minimum, information on the number of lines at each switching node (PSTN and ISDN).[36]

The objective of optimisation for the purposes of this study is not to redesign the network in specific detail, but to determine the optimal mix of remote concentrators and local switches, constrained by the scorched node assumption. We have therefore developed a way of estimating the equipment which would be needed by an efficient operator at switching nodes which we believe gives reasonable “ball-park” estimates of the optimal mix.

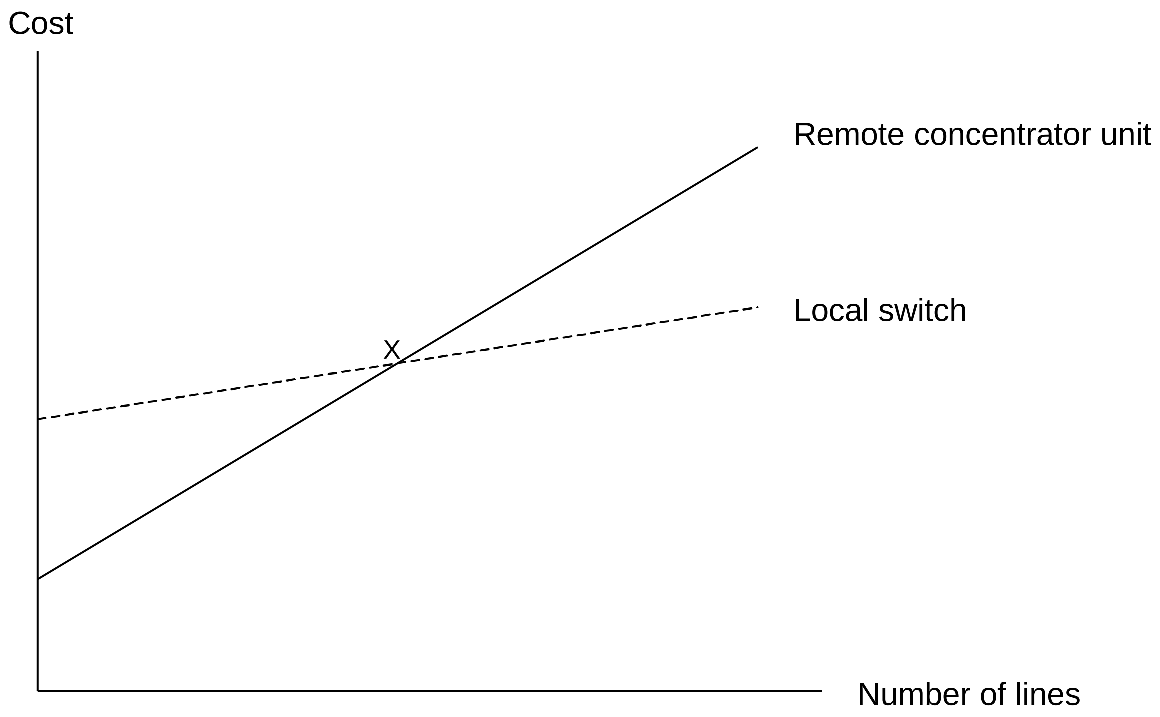
This approach may be summarised as follows:

- identify from the node database whether each node houses a remote concentrator unit or a local switch;
- estimate the demand for lines at each node, measured in PSTN line equivalents; and
- define the maximum number of lines that should be connected to a remote concentrator.

[36] It may also have information on the volume of traffic at each node.

Such studies will, by definition, incorporate the traffic patterns, and provide a robust estimate of the maximum economic number of lines that a concentrator should have. This maximum size may be illustrated by point X in Fig A1.1 below. This shows the plot of such studies: the local switch has higher fixed costs, but lower variable costs compared to a remote concentrator unit. Hence, for nodes with fewer lines, it is more economic for that node to be equipped by a remote concentrator unit. But as more and more lines are added to the concentrator, which in turn requires more processing capacity at the local switch serving as the host, the costs of the remote concentrator increase. At some critical level of lines, it would be more economic for the node to be equipped by a local switch.

Figure A1.1



A1.2 Optimisation B

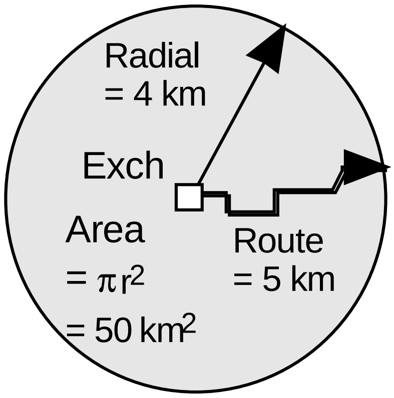
The objective of this approach is to estimate the optimised mix of nodes using a series of “best practice” ratios. This approach may be used if NRAs do not have access to a node database or are unsure whether the existing configuration in their Member State is likely to be appropriate.

The final step in this approach is to determine the number of remote concentrator sites that will house RCU to which customers are connected. The difference between RCU sites and nodes is important, and although the number of sites is derived initially, it is subsequently adjusted to reflect the number of nodes.

A1.2.1 Deriving the number of RCU sites

Assume that, due to the technical constraints of the copper local loop, the maximum reach is 5 km with a route: radial ratio of 5:4. Therefore, the maximum area served by a remote concentrator unit is $\pi r^2 = 50\ km^2$.

Figure A1.2



Some Member States may have a radial distance of 5 kilometres in which case the route distance will be longer, and area served by the remote concentrator unit will be almost 80 km^2.

The total area of the Member State (measured in terms of km^2) is then divided by the maximum area served by an RCU (50 km^2 for a Member State with a population density greater than 100 or 80 km^2 for a Member State with a more dispersed population).

A1.2.2 Deriving the number of local and tandem switches

The number of local switches and the number of tandem switches is then derived using a series of best practice ratios. These ratios, which summarise the relationship between local switches and remote concentrator sites and between local switches and tandem switches may differ from one Member State to another.

In the absence of detailed local information we assume the appropriate ratio of remote concentrators to every local switch is as presented in table A1.1. (Note that the applicability of these ratios has not been tested for each Member State due to the lack of data provided by NRAs, and as a result, further work may be needed on the appropriateness of each ratio in each Member State.)

Table A1.1:
Efficient ratio of concentrator to local switch

Population density (population/surface area, Km squared)	Efficient ratio of concentrators to local switches (national average) illustrative
0-99	above 15
100-149	10 to 15
150-199	7 to 10
200-249	4 to 7
above 250	up to 4

Once the "efficient" number of local switches has been determined, another ratio can be applied to derive the number of tandem switches. We would expect digitalisation in the telecommunications industry to be reducing the number of tandem switches and the OFTEL bottom-up network model stated that they would expect there to be about 10 local switches to each tandem switch. Unless NRAs have better information, this is the ratio we suggest should be adopted under this approach.

A1.2.3 Estimating the number of RCU nodes

The formula derived in A1.2.1 estimates the number of RCU sites. This provides the basis for estimating the total number of RCU nodes.[37]

This is achieved by multiplying the number of RCU sites by a "density factor". This factor will be at least one and may be just over one for dense areas. The factor will be higher when a Member State has a large number of dense areas. The larger the number of major conurbations, for example, the more we would expect the factor to be above unity. The model assumes a default value of 1.2 (which can be modified by the user).

A1.2.4 Constraining the results for the scorched node assumption

The number of nodes that result from this approach may not equal the existing number of nodes in the Member State, thus breaching the scorched node assumption underlying the model (see Chapter 2). This final step therefore aligns the existing number of nodes in the network to the "efficient" number of nodes derived from this approach by either subtracting from or adding to the total existing number of nodes. In both cases, nodes are subtracted from or added to the efficient number in proportion to the share of the node type to the total number of nodes.

[37] We do not have to derive LS and TS nodes as the relationships in the formulae above assumed the relationship between RCU sites and LS and hence TS.

A2 DEMAND FOR NETWORK ELEMENTS

The objective of this section is to provide details of our modelling approach and assumptions for establishing the demand for network elements. This can be summarised as follows:

- establish demand for the network by narrow-band and leased line services; and
- use routeing factors to establish demand at each network element:
  - *switching*: demand is established in terms of busy hour call attempts (BHCA) and busy hour erlangs (BHE)
  - *transmission*: for switched traffic, demand is established in terms of busy hour erlangs (BHE) converted to Mbit, and for leased lines demand is measured directly in Mbit.

An explanation of how to derive unit costs of switching elements (per minute for call termination and origination services) is provided in Chapter 7 (Outputs of the Model).

A2.1 Establishing Demand for Narrow-band and Leased Line Services

Demand represents the demand for which the conveyance network should cater. It refers to call attempts, waiting time, call minutes and capacity required for leased lines as these are the factors used to estimate the dimension needed in the switching and transmission network.

Total capacity required to handle current volumes of billed traffic is the starting point. Other features of traffic needed to dimension the network include capacity required for:

- average holding time;
- unsuccessful calls;
- traffic growth; and
- traffic in the conventional “busiest hour” of the year.

A description of each of these features was provided in Chapter 3.

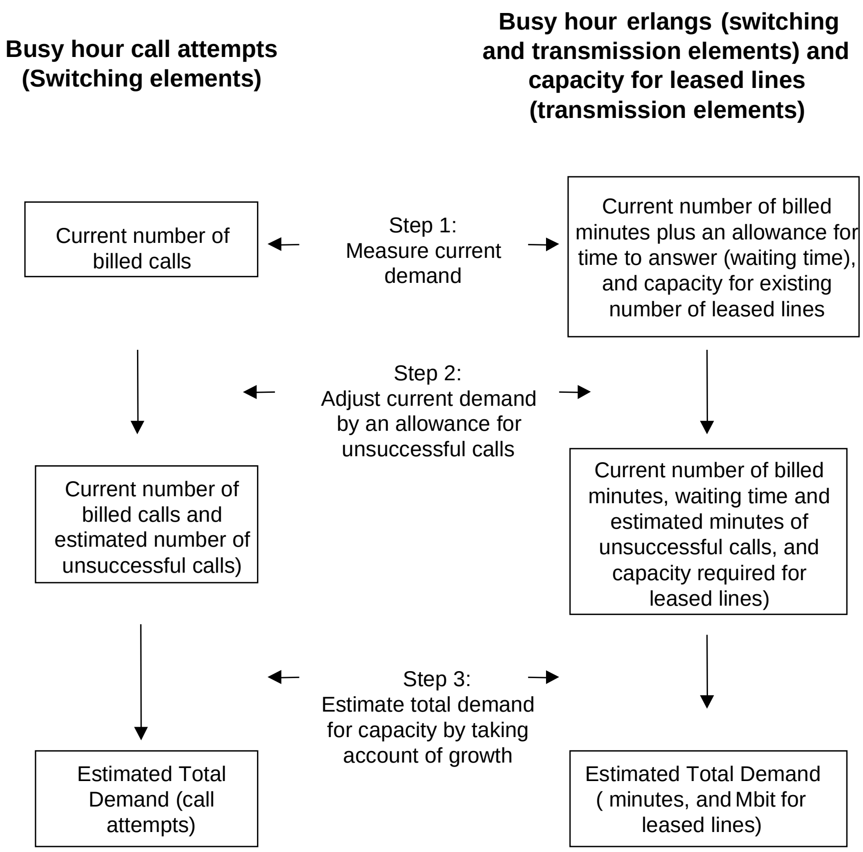
Our approach to determining the demand (or capacity required) for a network element is to separate demand into:

- demand driven by the number of busy hour call attempts (which determines the dimensioning of the event-sensitive part of switches, the processor); and
- demand driven by:
  - number of minutes (which determines demand for the volume sensitive part of switching and transmission elements)

– Mbit of capacity required for leased lines (which also determines demand principally for transmission elements).

An illustration of this approach is provided in Figure A2.1

Figure A2.1
Establishing Demand for Narrow-band and Leased Line Services



Each of these steps is explained below.

A2.1.1 Step 1: Measure of current demand

The first step is to estimate current demand for narrow-band and leased services, by using measured (or billed) calls and minutes, as well as leased lines that make use of network elements.

Billed calls

Current demand in terms of calls is the number of all narrow-band calls that have been successful and billed for. Each call attempt is a cost driver of processing costs.

Demand generated by the current number of billed calls can be expressed as:

$$D_c \equiv \sum^{n} B_c \qquad \textit{(Equation A2.1)}$$

where:

D_c = current demand measured in number of calls

n = number of PSTN services

B_c = number of billed calls

<u>*Billed minutes adjusted for time to answer*</u>

Current demand in terms of minutes is the sum of all narrow-band minutes that have been successful and billed for, and of the time taken to answer the call (holding time). Each minute of traffic using switching elements drives the costs of switchblocks and ports. The same number of minutes is also used to dimension the transmission network.

Current measured demand underestimates the capacity required because it does not reflect the time taken to answer the call.

Demand generated by current number of billed calls can therefore be expressed as:

$$D_m \equiv \sum^{n} B_m + (B_c \ x \ T_h) \qquad \textit{(Equation A2.2)}$$

where:

D_m = current demand measured in minutes

n = number of PSTN services

B_m = number of billed minutes

B_c = number of billed calls

T_h = holding time in minutes

<u>*Leased lines (Mbit)*</u>

Demand for leased lines is expressed in 64bit/s equivalents and is converted into Mbit for dimensioning transmission electronics. This can be expressed as:

$$D_L \equiv (n \ / \psi) \ x \ 2 \qquad \textit{(Equation A2.3)}$$

where:

D_L = existing demand for leased lines in Mbit

n = number of 64kbit equivalent leased lines

ψ = number of 64 kbit channels in a 2 Mbit

The denominator is divided by two to convert 2Mbit into Mbit.

A2.1.2 Step 2: Adjust current demand for an allowance for unsuccessful calls

The second step is to ensure that the demand for narrow-band services as currently measured also includes demand for the capacity required for unsuccessful calls (these are not measured or billed).

Both the current demand for calls and minutes is, therefore, adjusted by a margin for unsuccessful calls, that can be expressed as follows:

$$U_c \equiv (1 / \alpha) - 1 \qquad \text{(Equation A2.4)}$$

where

U_c = margin for unsuccessful calls

α = proportion of calls that are successful

Calls

Demand for processing at switches is determined by the demand generated by the current number of billed calls and demand created by unsuccessful calls. It can be expressed as:

$$E_{dc} \equiv D_c \; x \; (1 + U_c) \qquad \text{(Equation A2.5)}$$

where

E_{dc} = estimated current demand in calls

D_c = current demand for calls

U_c = margin for unsuccessful calls

Minutes

In addition to the demand generated by current number of billed minutes, estimated demand for ports and switchblocks needs to account for the fact that successful calls are not answered immediately, but require switching capacity during waiting time.

Estimated demand for minutes can then be expressed as:

$$E_{dm} \equiv D_m + (D_c \; x \; U_c \; x \; T_h) \qquad \text{(Equation A2.6)}$$

where

E_{dm} = estimated demand in minutes

D_m = current demand measured in minutes

D_c = current demand for calls

U_c = margin for unsuccessful calls

T_h = holding time in minutes

It should be noted that this step is not required for leased lines as they are assumed not to be affected by unsuccessful calls.

A2.1.3 Step 3: Estimate total demand by adjusting for allowance for growth

The switching element being modelled must be dimensioned not just to cater to current demand but also for growth.

Calls

The total demand for narrow-band services over the network measured in calls, including anticipated growth, can be expressed as:

$$T_{dc} = E_{dc} \ x \ (1 + M) \quad \text{(Equation A2.7)}$$

where

T_{dc} = total demand for PSTN services measured in calls

E_{dc} = estimated total demand in calls

M = margin for growth

Minutes

The total demand for narrow-band services over the network measured in minutes, including anticipated growth, can be expressed as:

$$T_{dm} = E_{dm} \ x \ (1 + M) \quad \text{(Equation A2.8)}$$

where

T_{dm} = total demand for narrow-band services measured in minutes

E_{dm} = estimated total demand in minutes

M = margin for growth

Leased Lines

The total demand for leased line services is also adjusted by a margin for growth, and can be expressed as:

$$TDL \equiv D_L \ x \ (1 + M) \qquad \text{(Equation A2.9)}$$

where

T_{DL} *= total demand for leased line services in Mbit*

D_L *= existing demand for leased lines in Mbit*

M = margin for growth

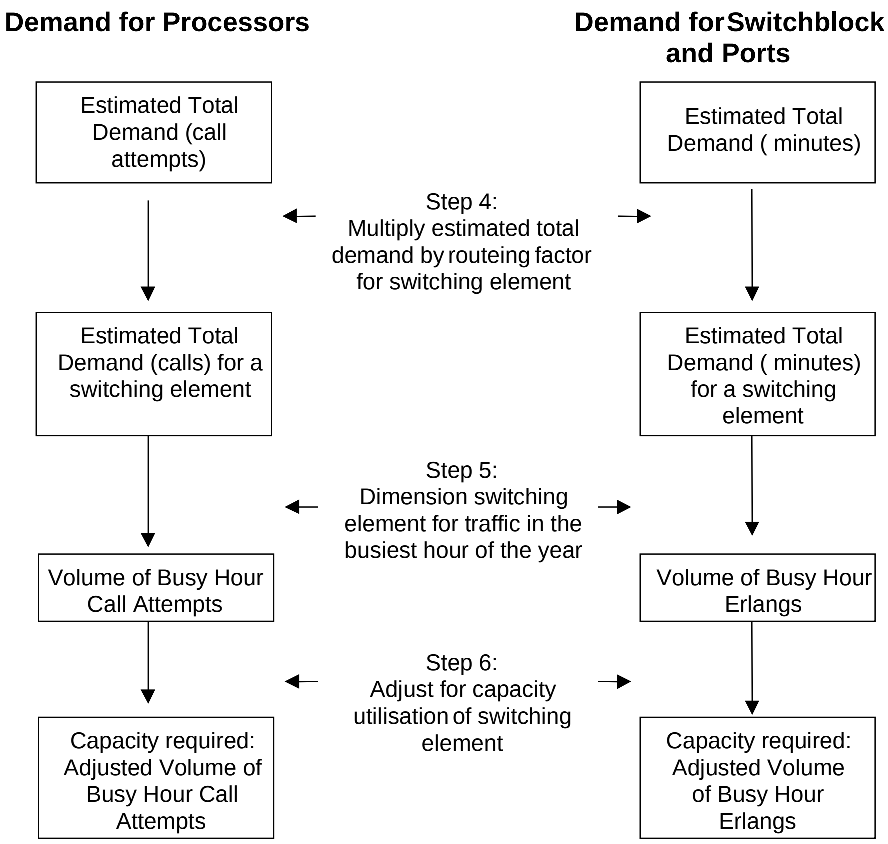
A2.2 Establishing Demand for Switching Elements

Demand (or capacity required) for switching elements is determined by:

- the number of busy hour call attempts (which determines the dimensioning of the processing capacity for switching elements); and
- number of minutes (which determines demand for switchblocks and digital line termination units (ports).

Our approach to estimating demand for switching element is summarised in the figure A2.2 below.

Figure A2.2
Establishing Demand for a Switching Element



Each of these steps is explained below.

A2.2.1 Step 4: Apply routeing factors to establish demand for each switching element

The next step is to establish the demand for switching elements, based on total demand for narrow-band services and the use made of the switching element for different PSTN services (i.e. the routeing factor). For example, if there are a total of 100 minutes of local calls, and local calls use, on average, 1.5 switches i.e. the routeing factor is 1.5, and then the usage of the local switch by local calls is 150 minutes. The same example can also be applied to call attempts.

Calls

The total demand for the switching element measured in number of calls is expressed as:

$$T_{dcE} = \sum^{n} (T_{dci} \ x \ R_{i}) \qquad \textit{(Equation A2.10)}$$

where:

T_{dcE} = total demand for the switching element for all narrow band calls

n = all narrow-band services

R = routeing factor for switching element

i = narrow band call service

T_{dc} = total demand (in calls) for narrow-band service

<u>Minutes</u>

The total demand for the switching element measured in minutes can be expressed as:

$$T_{dmE} = \sum^{n} (T_{dmi} \ x \ R_{i}) \qquad \textit{(Equation A2.11)}$$

where

T_{dmE} = total demand for the switching element for all narrow band minutes

n = all narrow-band services

R = routeing factor for switching element

i = narrow band call service

T_{dm} = total demand (in minutes) for narrow-band service

A2.2.2 Step 5: Convert demand into volumes of cost-drivers

Networks (and network equipment in turn) are dimensioned to handle traffic in the busy hour. The costs of the switching elements in our model are therefore driven by the number of BHCA that determines the amount of processing required and the number of BHE that determines the number of digital line termination units and switchblocks required.

As a penultimate step, total demand for a switching element must be converted from calls and minutes to BHCA and BHE.

This conversion is based on an estimate of the traffic in the conventional "busiest hour" of the year as a fraction of annual traffic.[38] This has the advantage that dimensioning the demand for a switching element based on a value higher than the average daily peak load ensures that weekly and monthly peak loads can also be handled.

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38 The network is not dimensioned to carry an unrepresentative surge.

Calls

The total demand for the switching element expressed in BHCA is:

$$BHCA = T_{dcE} \ x \ \delta \qquad \text{(Equation A2.12)}$$

where

BHCA = total number of busy hour call attempts at a switching element

T_{dcE} = total demand for the switching element in calls

δ = ratio of traffic in the busiest hour of the year to total annual traffic

Minutes

The total demand for the switching element measured in minutes is first converted to erlangs (by dividing by 60) and then to busy hour erlangs (BHE).[39] This can be expressed as:

$$BHE = (T_{dmE}) / 60) \ x \ \delta \qquad \text{(Equation A2.13)}$$

where

BHE = total number of busy hour erlangs at a switching element

T_{dmE} = total demand for the switching element in minutes

δ = ratio of traffic in the busiest hour of the year to total annual traffic

A2.2.3 Step 3: Adjusting for capacity utilisation

The final step is to take account of capacity utilisation. Utilisation is total capacity that is used (actual or forecast) as a fraction of installed capacity. If the capacity utilisation is too high, the equipment will have insufficient capacity to accommodate increases in demand. In contrast, if capacity utilisation is set too low, excess capacity increases the cost estimates to above those of an efficient operator.

Calls

The adjusted total demand for the switching element expressed in BHCA is:

$$TBHCA = BHCA \ / \ \phi \qquad \text{(Equation A2.14)}$$

where

TBHCA = total (adjusted) number of busy hour call attempts at a switching element

39 An erlang is one hour of traffic.

BHCA = total number of busy hour call attempts

ϕ = *proportion of capacity utilised*

Minutes

The total demand for the switching element expressed in BHE is:

$$TBHE = BHE \;/\; \phi$$ *(Equation A2.15)*

where

TBHE = Total (adjusted) number of busy hour erlangs at a switching element

BHE = total number of busy hour erlangs

ϕ = *proportion of capacity utilised.*

A2.3 Establishing Demand for Transmission Elements

Having determined the cost-driver of the transmission network (Mbit), there are two further steps needed to establish demand for each transmission element:

- convert traffic in minutes to BHE and then to Mbit;
- add the demand for transmission elements from switched traffic and leased lines;
- apply routeing factors that describe usage of each transmission element; and
- adjust for capacity utilisation.

A2.3.1 Step 7: Convert switched traffic into Mbit

Traffic (in minutes) making use of the transmission network is converted to BHE that are used to dimension the transmission network. The total demand for the transmission element is converted to BHE using a step similar to Step 5 for switching.

Making use of the transmission network, BHEs are then converted to Mbit as follows:

$$D_{SW} \equiv \text{BHE} \;/\left(\gamma * \psi / 2\right)$$ *(Equation A2.16)*

where:

D_{SW} *= existing demand for switched traffic in Mbit*

BHE = total switched traffic in BHE

γ *= circuit efficiency (or erlangs per circuit)*

ψ = number of 64 kbit/s channels in a 2Mbit

The denominator is multiplied by two to convert 2Mbit into Mbit.

A2.3.2 Step 8: Add demand from switched and non-switched traffic

Total demand for transmission elements is thus the sum of total switched (narrow-band services) traffic and non-switched traffic (leased lines), expressed as:

$$DT \equiv D_{SW} + T_{DL} \qquad \text{(Equation A2.17)}$$

where:

D_T = total demand for transmission elements in Mbit

D_{SW} = existing demand for switched traffic in Mbit

T_{DL} = total demand for leased line services in Mbit

A2.3.3 Step 9: Apply routeing factors to establish demand for each transmission element

The next step is to establish the demand for transmission elements, based on total demand for transmission elements and the use made of the transmission elements by each service.

The total demand for a transmission element measured in Mbit is expressed as:

$$TD_{TE} = \sum^{n} (D_{T_i} \ x \ R_{i)} \qquad \text{(Equation A2.18)}$$

where:

TD_{TE} = total demand for the transmission element in Mbit

R = routeing factor for transmission element

i = the service

n = all services (narrow-band and leased line)

D_T = total demand for transmission elements in Mbit

A2.3.4 Step 10: Adjusting for capacity utilisation

The final step is to take account of capacity utilisation. Capacity utilisation is the percentage of total capacity that is to be used (rather than the amount available in reserve). If the capacity utilisation is too high, the equipment will have insufficient capacity to accommodate increases in demand. In contrast, if capacity utilisation is set too low, excess capacity increases the model's cost estimates higher than that of an efficient operator.

The adjusted total demand for the transmission element expressed in Mbit is:

$$ATD_{TE} = TD_{TE} \; / \; \phi \qquad \textit{(Equation A2.19)}$$

where

ATD_{TE} = *total (adjusted) Mbit at a transmission element*

TD_{TE} = *total demand for the transmission element in Mbit*

ϕ = *percentage of capacity utilised*

A3 ESTIMATING NON-NETWORK COSTS

A3.1 Introduction

This section provides our methodology for estimating non-network costs of which there are two types — non-network capital costs and non-network operating costs. Our approach to estimating these costs is to use "best practice" ratios, such that:

- non-network capital costs are estimated as a percentage of (annualised) network investment costs; and
- non-network operating costs are estimated as a percentage of network operating costs.

The benchmark ratios provided in the model as default values relate to the US network operators' cost accounting data published by the FCC in the Statistics of Communications Common Carriers (SOCC). As the default ratios are developed from US data and for years in the past, NRAs will doubtless wish to review whether more recent national data are available.

The estimates included as defaults in the model were used in the NERA study to estimate the long run incremental costs of PSTN access for the ACCC in Australia (Final Report, January 1999). These, of course, should not be treated as final and the model allows NRAs wishing to use a different ratio, informed perhaps by discussions with their incumbent operator, to do so.

A3.2 Non-network Related Capital Costs

Investment in non-network capital is essential for network operation and is modelled for each network element. The ratio used to estimate non-network costs in the model is a single number which is likely to include the following types of costs:

- **Land**: this is all land other than that used for the purpose of laying cable and duct or any external network equipment.
- **Non-operational buildings**: this includes all permanent fixtures, machinery and appliances installed as a part thereof. It also includes costs incident to the construction or purchase of a building and to securing possession and title.
- **Motor vehicles**: this includes motor vehicles of the type that are designed and routinely licensed to operate on public streets and highways.
- **General-purpose computers**: this includes computers and peripheral devices that are designed to perform general administrative information processing activities. Administrative information processing includes, but is not limited to, activities such as the preparation of financial, statistical, or other business analytical reports; preparation of payroll, customer bills, and cash management reports and other records and reports not specifically designed for testing, diagnosis, maintenance or control of the telecommunications network facilities. It also includes the operating system software for

computers. It does not include computers associated with switching, network signalling and other network operations.

- **Other equipment**: this includes power-operated equipment, general-purpose tools, office equipment in offices, shops and other buildings, and furniture in offices, storerooms, shops and other buildings.

These investments are needed to provide conveyance services as a whole but they are not easily allocated to individual network elements. As a result, bottom-up models have hitherto usually estimated the amount of non-network investment required, for each network element, using ratios of non-network investments to network investments.

However, it should be noted that not all of these costs may be related to conveyance and an adjustment needs to be made to capture the conveyance-specific costs. The model for the ACCC made adjustment to these benchmarks by making an assessment on the relevance of the cost item for interconnection. Given that the increment is defined more broadly than just interconnection, we have treated this adjustment as applying to conveyance-related costs rather than just interconnection-related costs. To the extent that this is not the case, NRAs may need to adjust this factor in the model. The “adjusted” ratio is applied to the annualised capital costs and a share of operating costs added.

A3.3 Non-network operating costs

It is also possible to estimate the non-network operating costs for each network element. This is done in a similar way with a single number drawn from the 1999 ACCC study. The non-network operating costs that will be included in this total include:

- **Sales and Marketing**: this includes costs incurred in selling products and services, including determination of individual consumer needs, development and presentation of customer proposals, sales orders and handling; costs incurred in developing and implementing promotional strategies to stimulate the purchase of products and services. It also includes costs incurred in performing administrative activities related to marketing products and services.

- **Executive**: this includes costs incurred in formulating corporate policy and in providing overall administration and management.

- **Planning**: this includes the costs of developing and evaluating long-term courses of action for the future operations of the company, including performing corporate organisation and integrated long-term planning (management studies, options and contingency plans and economic strategic analysis).

- **Accounting and finance**: this includes the costs of providing accounting and financial services. Accounting services include payroll and disbursements, property accounting, capital recovery, regulatory accounting, non-customer billing, internal and external auditing, capital and operating budget analysis and control. Financial services include banking operations, cash management, benefit investment and fund management, securities management, corporate financial planning and analysis, and internal cashier services.

- **External relations**: this includes the cost of maintaining relations with government, regulators, other companies and the general public. Such activities may involve reviewing existing or pending legislation, preparing and presenting information for regulatory purposes, obtaining licences, performing public relations and non-product related corporate image advertising, administrative relations with other operators, and investor relations.

- **Human resources**: this includes the cost of performing personnel administration activities, such as equal employment opportunities programmes, employee data for forecasting, general employment services, occupational medical services, job analysis and salary programs, labour related activities, personnel development and staffing services (career planning, counselling etc), employee communications, benefit administration, employee activity programs, employee safety programs and non-technical training course development and presentation.

- **Information management**: this includes the cost incurred in planning, developing, testing, implementing and maintaining databases and application systems for general purpose computers.

- **Legal**: this includes the costs of providing legal services such as conducting and co-ordinating litigation, guidance on regulatory and labour matters, preparing, reviewing patent matters, contracts and interpreting legislation.

- **Procurement**: this includes the cost of procuring materials and supplies, including office supplies. This includes analysing and evaluating suppliers' products, selecting appropriate suppliers, negotiating supply contracts, placing purchase orders.

- **Research and Development**: this includes the cost of making planned search or critical investigation aimed at discovery of new knowledge. It also includes translating research findings into a plan or design for a new product or process or for significant improvements to an existing product or process.

- **Other**: this includes the cost of performing general administrative activities not directly charged to the user. This includes providing general reference libraries, food services, archives, general security, operating private exchanges, and telecommunications and mail services. Also included are settlements of accident and damage claims, insurance premiums.

Similar to adjustments made to non-network capital costs, relevant operating costs are considered for non-network operating costs.

A4 WORKING CAPITAL

In order to gain a realistic estimate of the cost of the operations of the interconnection network, an allowance for working capital should be included.

In order to maintain tractability, the surcharge per unit is given in a single cell in the model.

There are two possibilities for calculating the surcharge. One is a method used by Oftel[40] in a 1997 study; the other is an adaptation of the Oftel model which, whilst requiring slightly more information[41], should provide a more robust result.

A4.1 Definition

Working capital is:

Current assets less current liabilities

Or in more detail

	Stock
Plus	Debtors
Plus	Cash
Less	Creditors

Debtors would primarily include debtors from sales, but also prepayments such as rent and rates.

Cash would comprise quick access cash (e.g. current account) and short-term investments.

Creditors arising from operating activities and the purchase of capital equipment would be included.

A4.2 The Cost of Working Capital

It is the nature of telecoms that there is a delay between paying for inputs and receiving payment for outputs. In other words, there is a period of time during which cash is tied up in the business.

An injection of cash (working capital) is required at the beginning of trading to be able cope with this delay which arises from the normal activities.[42] Once the investment is made, this cash is tied up in the running of the business until trading ceases. There is therefore an opportunity cost as this cash could otherwise be invested.

40 In 'Long run Incremental Costs: The Bottom-up Network Model' Version 2.2 March 1997
41 This information will be provided by the model.
42 Of course, extra injections may be required due to changes in the cashflow cycle and to other factors such as growth and inflation.

The cost of working capital is therefore:

Working capital x financing cost

A4.3 Calculating Working Capital

There is clearly scope for debate in calculating working capital for an efficient operator. The estimate could, however, be tackled in a way similar to that used in the Oftel model.

A4.3.1 The Oftel model

The approach used in the Oftel model first estimates the payment periods for debtors and creditors. The components are:

- Income debtors
- Creditors (including suppliers of capital equipment)
- Prepayments

For example, if wages were paid monthly in arrears the average payment period would be 15 days.

The weighted average of creditor days is then calculated based on the size of each cost as a proportion of the total costs relevant to the creditors analysed. That is, if capital equipment creditors, wages creditors and rent and rates debtors[43] are being estimated, the total cost would be the total of capital equipment, wages, rent and rates expenditure.

A4.3.1.1 Net debtor days

The net debtor days are then calculated by debtor days less creditor days.

A contingency requirement is also included for uncertainty in the level of working capital requirements. The Oftel model suggests accounting for this with a percentage increase in net debtor days.

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[43] Assuming rent and rates are paid in advance.

A4.3.1.2 Working capital cost

The working capital cost is then calculated by applying a surcharge to the cost per unit. The surcharge is calculated as follows:

$$\frac{\text{Net debtor days}}{365} \times \text{cost of capital}$$

A4.3.1.3 Result for BT

Oftel calculated the working capital surcharge to be 1.5% in their LRIC model.[44]

A4.3.2 Adjustment to the Oftel model

The same methodology could be used with an adjustment which could lead to a potentially more robust result. The extra information required is given by the model.

The adjustment relates to the part of working capital cost relating to creditors. In order to calculate this, the Oftel model implicitly uses:

$$\frac{\text{Creditor days}}{365} \times \text{cost of capital} \times \text{charge per unit}$$

The relevant cost for creditors, however, is the cost per unit relating to operating and capital equipment expenditure rather than the economic cost.[45]

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[44] 'Long run Incremental Costs: The Bottom-up Network Model' Version 2.2 March 1997

[45] A more detailed analysis is as follows.

The cost of working capital is essentially:

$$w = (d + s + £ – k) \times r \qquad (1)$$

Where w is working capital cost, d is debtors, s stock, £ cash, k creditors and r the cost of capital

A simplification for analysis of the Oftel model would be:

$$w = (d – k) \times r \qquad (2)$$

The contingency requirement in the Oftel model described in section 1.3.1.1 would represent the stock and cash held for such matters. For simplification, the contingency requirement has not been included.

Oftel calculates the total cost of working capital using the following methodology:

$$w = \frac{(\text{Debtor days} – \text{Creditor days})}{365} \times r \times c \qquad (3)$$

where c is the economic cost of the output, which includes rate of return and capital expenditure.

Now, the standard calculations of debtor and creditor days are:

Debtor days = (d/T) x 365

To adjust for this, the final step in calculating the surcharge should be:

$$\frac{\underline{\text{Debtor days} - (\text{Creditor days} \times (a/b))}}{365} \times r$$

where **"a"** is the total cost relating to the creditors and **"b"** is the total economic cost. The cost **"a"** is likely to be the operating expenses plus depreciation.[46]

Given that the model calculates the annualised cost as whole rather than depreciation and the cost of capital separately, the cost of capital needs to be taken out of the total cost to give a figure for **"a"** .

To calculate capital cost use:

Total capital equipment cost x r

From this, **"a"** is found and the working capital surcharge can be produced.[47]

This surcharge would be applied to the total cost excluding working capital to produce a total cost including working capital. This percentage surcharge would be applied to each category – that is, RCU, LS, TS and so on.[48]

Creditors days = (k/C) x 365

Where T is turnover and C costs relating to the creditors.

Therefore equation 1 can be written as:

$$w = (d/T - k/C) \times r \times c \qquad (4)$$

So, for equation 4 to be the equivalent of equation 2, the following must be true:

$$T = C = c$$

Now, as c is the economic cost,

$$T = c$$

This ignores the complication of the cost of working capital being included in T. This should, however, give a close enough approximation as the impact of the cost of working capital as the difference is unlikely to be large enough to affect the result significantly and, in turn, the final costs produced by the model

But, as C is the cost that relates to creditors, it does not include the cost of capital. So,

$$C \neq c$$

Therefore, the Oftel model may not produce a robust figure.

46 Depreciation being a measure of annual capital expenditure in a steady state.

47 This is suitable for all annualised cost methods except for the annuity method. But, as the annuity rate is unlikely to be used extensively, if at all, this approach would seem reasonable.

A4.4 Information Requirements

The information requirements for the adjusted Oftel approach are:

- The weighted average debtor and creditor days – provided by the NRA.
- Rate of return – provided by the NRA.
- Total costs – the sum of all total costs for RCU, LS, TS, RCU-LS, LS-TS, TS-TS found in the 'Total costs' sheet in the model.
- Total capital equipment costs - the sum of all capital equipment costs for RCU, LS, TS, RCU-LS, LS-TS, TS-TS found in the 'Total costs' sheet in the model.

These figures can then be used to calculate the surcharge which is then input into the 'Cost input assumptions' sheet in the model. The results produced by this model will then include the working capital costs.

[48] Note that applying the same percentage to each category is unlikely to give a true reflection of how working capital cost should be apportioned as the level of working capital would probably vary across each category. For the purposes of this model, however, this approach should be adequate given that the extra detail would probably result in immaterial differences in the costs.

A5 DEPRECIATION OPTIONS

The different methods for calculating the annualisation factor for Year 1 (based on depreciation profiles) which are available in our model are:

- Straight-line: The annualisation factor is:

  [(1/*asset life*) *+ cost of capital*] ** asset value*

- Adjusted Straight-line: This takes into account expected changes in the real price of the asset. The annualisation factor in this case is:

  [(1/*asset life*) *- price trend* + *cost of capital*] ** asset value*

- Annuities which consist of constant payments that cover both depreciation and cost of capital in each year of the asset's life. (The balance between depreciation and the cost of capital within the constant payment would vary: depreciation charges would be low at the start of the asset life, a higher proportion being used to cover the return on capital employed; depreciation charges would be correspondingly higher towards the end of the asset life, a lower proportion being used to cover interest on debt). The annualisation factor is:

  cost of capital/{1-[1/(1+cost of capital)]^asset life}

- Sum of digits. The formula is the following:

  2/(asset life + 1) + cost of capital

For an asset life with ten years, sum of digits is 1+2+3+…10 which is equal to 55. The annualisation factor for the capital charge, as a percentage of investment costs, for the first year is thus 10/55 + cost of capital.

A6 SOURCE OF COST DATA

LRIC models are, by nature, data intensive. We have attempted to reduce the burden on users by providing estimates of the investment costs of different types of equipment, which can be used as default values in running the model. This appendix presents sources and magnitude of the data that were collected, as well as the estimates used in the model.

Our approach to collecting this information was to review the assumption in existing bottom-up models such as those developed by Oftel, Hatfield Associates and the ACCC. A list of our cost information requirements was circulated by NRAs to network operators in their Member State; our request was met with limited response. In addition, we also contacted equipment vendors; here the response to our request was negative.

Therefore, it should be noted that given the limited response from operators and vendors alike, the cost estimates used in the model are indicative and should be supplemented by data collection at a Member State level. This is particularly the case where cost estimates were not provided to the project team (for instance, switchblocks, synchronisation related costs etc.) or when inconsistent estimates were provided (such as digital cross connects).

A6.1 Equipment Investment Costs

	Equipment investment cost (euros)	Source
Switching		
Remote Concentrator		
Fixed cost of processor	87,000	Industry: c-i-c
Site costs	240,000	Hatfield model
Processing cost per BHCA (variable costs)	8	Europe Economics
Cost per BHE for switchblock	5.0	Europe Economics
Digital line termination unit (2mbit/s port)	1,500	Industry: c-i-c
Local Switches		
Fixed cost of processor	345,000	Industry: c-i-c
Site costs	750,000	Hatfield model
Processing cost per BHCA (variable costs)	8	Europe Economics
Cost per BHE for switchblock	5.0	Europe Economics
Digital line termination unit (2mbit/s port)	1,500	Industry: c-i-c
Tandem Switch:		
Fixed cost of processor	610,000	Industry: c-i-c
Site costs	1,950,000	Hatfield model
Processing cost per BHCA (variable costs)	2.0	Europe Economics
Cost per BHE for switchblock	5	Europe Economics
Digital line termination unit (2mbit/s port)	1,210	Hatfield model
Other costs:		
Synchronisation related cost	65,000	Europe Economics
Signalling Transfer Points	500,000	Hatfield model
Network management: switching *	5%	Europe Economics
Network management: transmission	2%	Europe Economics
Network Management: infrastructure	0.5%	Europe Economics

	Equipment investment cost (euros)	Source
Transmission		
Electronics:		
STM 1	20,000	Industry and Hatfield model: c-i-c
STM 4	40,000	Industry and Hatfield model: c-i-c
STM 16	58,000	Industry and Hatfield model: c-i-c
STM 64	78,000	Europe Economics
Regenerators STM	26,500	Industry and Hatfield model: c-i-c
Digital cross connects	500,000	Industry and Europe Economics
Line termination system STM-1	30,000	Europe Economics
Line termination system STM-4	50,000	Europe Economics
Line termination system STM-16	75,000	Europe Economics
Line termination system STM-64	90,000	Europe Economics
Infrastructure		
Cable/metre:		
12 fibre cable	10.0	Industry, Oftel and Hatfield models
24 fibre cable	12.0	Industry, Oftel and Hatfield models
48 fibre cable	14.0	Industry, Oftel and Hatfield models
96 fibre cable	18.0	Industry, Oftel and Hatfield models
Duct/metre		
Metropolitan	92.0	Industry and Hatfield model
Urban	56.0	Industry and Hatfield model
Rural	38.0	Industry and Hatfield model
Buried cable	6.0	Industry and Hatfield model: c-i-c

Notes:

c-i-c = commercial-in-confidence

* *Network management costs are expressed as a percentage of total network costs.*

A6.2 Equipment Asset Lives

	Asset Lives (years)	Source
Switching		
Remote Concentrator		
Fixed cost of processor	11	Industry sources, Oftel, Hatfield and ACCC models
Site costs	38	Industry sources, Oftel, Hatfield and ACCC models
Processing cost per BHCA (variable costs)	12	Industry sources, Oftel, Hatfield and ACCC models
Cost per BHE for switchblock	13	Industry sources, Oftel, Hatfield and ACCC models
Digital line termination unit (2mbit/s port)	12	Industry sources, Oftel, Hatfield and ACCC models
Local Switches		Industry sources, Oftel, Hatfield and ACCC models
Fixed cost of processor	11	Industry sources, Oftel, Hatfield and ACCC models
Site costs	37	Industry sources, Oftel, Hatfield and ACCC models
Processing cost per BHCA (variable costs)	12	Industry sources, Oftel, Hatfield and ACCC models
Cost per BHE for switchblock	13	Industry sources, Oftel, Hatfield and ACCC models
Digital line termination unit (2mbit/s port)	12	Industry sources, Oftel, Hatfield and ACCC models
Tandem Switch:		
Fixed cost of processor	10	Industry sources, Oftel, Hatfield and ACCC models
Site costs	37	Industry sources, Oftel, Hatfield and ACCC models
Processing cost per BHCA (variable costs)	12	Industry sources, Oftel, Hatfield and ACCC models
Cost per BHE for switchblock	13	Industry sources, Oftel, Hatfield and ACCC models
Digital line termination unit (2mbit/s port)	11	Industry sources, Oftel, Hatfield and ACCC models
Other costs:		
Synchronisation related cost	16	Hatfield
Signalling Transfer Points	16	Hatfield
Network management: switching *	9	Europe Economics
Network management: transmission	9	Europe Economics
Network Management: infrastructure	9	Europe Economics

	Equipment investment cost (euros)	Source
Transmission		
Electronics:		
STM 1	10	Industry sources, Oftel, Hatfield and ACCC models
STM 4	10	Industry sources, Oftel, Hatfield and ACCC models
STM 16	10	Industry sources, Oftel, Hatfield and ACCC models
STM 64	10	Industry sources, Oftel, Hatfield and ACCC models
Regenerators STM	10	Industry sources, Oftel, Hatfield and ACCC models
Digital cross connects	10	Industry sources, Oftel, Hatfield and ACCC models
Line termination system STM-1	10	Industry sources, Oftel, Hatfield and ACCC models
Line termination system STM-4	10	Industry sources, Oftel, Hatfield and ACCC models
Line termination system STM-16	10	Industry sources, Oftel, Hatfield and ACCC models
Line termination system STM-64	10	Industry sources, Oftel, Hatfield and ACCC models
Infrastructure		
Cable/metre:		
12 fibre cable	23	Industry sources, Oftel, Hatfield and ACCC models
24 fibre cable	23	Industry sources, Oftel, Hatfield and ACCC models
48 fibre cable	23	Industry sources, Oftel, Hatfield and ACCC models
96 fibre cable	23	Industry sources, Oftel, Hatfield and ACCC models
Duct/metre		
Metropolitan	38	Industry sources, Oftel, Hatfield and ACCC models
Urban	38	Industry sources, Oftel, Hatfield and ACCC models
Rural	38	Industry sources, Oftel, Hatfield and ACCC models
Buried cable	38	Industry sources, Oftel, Hatfield and ACCC models

Notes:

c-i-c = commercial-in-confidence

A7 SOURCE OF DEFAULT VALUES INCLUDED IN THE ADAPTABLE INTERCONNECTION MODEL

A7.1 Network Assumptions (Demand)

Variable	Default Value in Model		Source
Average call set-up time (time to answer)	Successful	15 seconds	EER estimate based on engineering advice
	Unsuccessful	30 seconds	
Percentage of successful calls	90 per cent		EER estimate based on engineering advice
Traffic in busiest hour of the year (as a percentage of the total)	0.000320		EER estimate based on engineering advice

A7.2 Network Assumptions (Technical)

Variable	Default Value in Model	Source
Erlangs per circuit	RCU - LS 0.5 LS – TS 0.6 TS – TS 0.7	EER estimate based on the assumption that even though a larger group of trunks is more efficient that a smaller group, trunk occupancy will approach 0.7
Percentage of tandem switches co-located with local switches	50 per cent	EER estimate but will vary across networks and could be as low as 0% or as high as 100%
Maximum number of nodes on a ring	16	HAI estimate based on advice from Fujutsu
Utilisation level of switching nodes	• 60% for RCU (RCU-LS) • 70% for LS (LS to TS) • 80% for TS (TS to TS)	EER estimate based on the view that utilisation will increase for equipment higher up in the network
Percentage of own switch calls for concentrators	5 per cent	EER estimate
Number of channels per 2 Mbit/s	30	EER estimate based on maximum number of channels that are technically feasible. It is also consistent with ITU recommendations
Utilisation level of transmission elements	RCU - LS 60 per cent LS – TS 70 per cent TS – TS 80per cent	EER estimate based on maximum number of channels that are technically feasible. It is also consistent with ITU recommendations
Utilisation level of leased lines	100 per cent	EER estimate which could be adjusted if NRAs would prefer to dimension the transmission network assuming that leased lines are not dedicated.
Distance between regenerators	64,000 meters	HAI estimate based on field experience
Distance between repeaters	75,000 meters	EER estimates
Diversity for STM multiplexers and LTES	15 per cent	EER default based on engineering advice to take account of additional capacity required
Transmission cross connects per tandem	2	EER estimate to allow for digital cross connects and diversity thereof
Diversity for regenerators	2	EER estimate to allow for diversity of regenerators

Variable	Default Value in Model	Source
Maximum capacity of SDH equipment (Mbit/s)	• 140 for STM –1 • 565 for STM –4 • 2295 for STM –16 • 8400 for STM - 64	Technical constraints based on the need to allowing for the overhead of control and surveillance
Percentage of shared trench attributable to conveyance	50 per cent	EER estimate based on relative importance of conveyance network vis a vis other networks
Percentage of RCU site attributed to service	Access 50 per cent Core 50 per cent Other 0 per cent	EER estimate based on relative importance of conveyance network vis a vis other networks
Percentage of LS site attributed to service	Access 50 per cent Core 50 per cent Other 0 per cent	EER estimate based on an assumption that transmission equipment is located at switching nodes
Percentage of site costs allocated to transmission (as opposed to switching)	50 per cent	EER estimates

Interconnection service routeing factor:

	Local level	Single transit	Double transit
RCU	0.90	0.90	0.90
LS	1	1	1
TS	0	1	2
RCU-LS	0.90	0.90	0.90
LS-TS	0	1	1
TS-TS	0	0	1