ESTIMATING THE LONG RU
INCREMENTAL COS
OF PSTN ACCES

A Draft Report for ACC

Prepared by NER

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TABLE OF CONTENTS

1. INTRODUCTION

National Economic Research Associates (NERA) has been commissioned by the Australian Competition and Consumer Commission (ACCC) to construct a total service long run incremental cost ("TSLRIC") model of the costs to Telstra of call conveyance and of customer access, in order to calculate the costs of originating and terminating interconnection services provided by Telstra.

This report describes the main assumptions made and the modelling approach we have used. Key results are reported for our "base case" assumptions and for a range of sensitivities around this base case.

We would welcome comments from the industry on the assumptions and methodology used. Throughout the report we have highlighted issues where feedback and comment would be particularly useful.

Before describing the details of our analysis in Sections 2 to 6, we review some general aspects of the approach:

- definition of the costs of conveyance and customer access;
- the "bottom-up" modelling approach;
- the network component based approach;
- the treatment of fixed shared and common costs.

1.1. Definition of the Costs of Call Conveyance and Access

The cost definition we are using is that of total service long run incremental cost (TSLRIC). Our approach is outlined below:

- we model a "stand-alone" network capable of providing Telstra's inland PSTN and inland private circuit services, including both traffic related and line related costs;
- we identify the TSLRIC of providing these services;
- all traffic related costs (such as switch processors, multiplexing equipment, cable and trench in the core network) are attributed to the cost of call conveyance;
- all line related costs (such as the cost of the copper local loop and line cards) are attributed to the cost of providing customer access;
- direct network costs which are common to call conveyance and access (eg the site cost for a local switch) are allocated between conveyance and access on the basis of cost drivers within the model;

- to estimate PSTN conveyance costs, leased line conveyance costs are eliminated by dividing transmission costs according to the proportions of capacity used for leased lines and call conveyance respectively;[1]
- indirect costs are modelled as a percentage mark up on either total network costs or total network operating costs as appropriate.

We note that the split of costs between line related and traffic related, does not correspond to our understanding of the definition of "CAN", and "IEN" as used by Telstra - the costs of the links from remote units (IRIMs or RSS / RSUs) are traffic driven and treated as part of the cost of conveyance rather than access.

We also note that we have built in leased line capacity to the model, and PSTN transmission costs will thus be lower than they would otherwise be due to the sharing of trenching, cables and multiplexing equipment.[2] We can quantify the effect of this on interconnection charges by zeroing out this capacity in the model - this is considered as a sensitivity on the base results in Section 6.

It should also be noted that we are modelling the costs of the wholesale provision of call conveyance, since this is what would be purchased by an interconnecting telecommunications operator. In other words, we do not include retail costs that are irrelevant to providing call conveyance for interconnection purposes. Such irrelevant retail costs include sales, advertising, marketing and subscriber billing. Similarly our estimates for the costs of customer access do not include retail costs and this should be borne in mind in any comparison with Telstra retail charges.

1.2. “Bottom-up” Modelling

The approach we have adopted in this analysis is usually described as “bottom-up” modelling. We estimate the cost of re-building Telstra’s current network with the costs for modern equivalent assets, assuming the network must carry Telstra’s current (ie forecast 1997 / 1998) traffic levels at the existing grade of service, and assuming that the network is operated efficiently within its existing architecture and node locations.

Two alternative assumptions exist for the specification of the network to be modelled under the “bottom-up” approach. These are usually described as “scorched node” and “scorched earth”.

As stated above, the “bottom-up” approach we have adopted involves calculating the

[1] Note that switching costs are only relevant to call conveyance.

[2] Telstra have stated that this is not appropriate. However, we note that in practice PSTN and leased line services do share these facilities and that consequently there are fixed costs that are common to the two services. Failure to take this into account will exaggerate the PSTN costs.

(annualised) cost of re-building and operating Telstra's network as it now exists. This is sometimes described as a "scorched node" assumption, since the model is based on the operator's (Telstra 's) existing number of exchange sites and transmission links. By way of contrast, under a "scorched earth" assumption, the network is based on an efficient number of exchange sites and transmission links. If, for example, the number of exchange sites in Australia seemed excessively large, compared to other countries, there may be a case for adopting a scorched earth approach. This would ensure that the costs were not inflated by Telstra's inefficient network design. However, in general, there are quite strong arguments for using the scorched node approach on grounds of:

- practicality - determining an "optimal" Telstra network would be a major task;
- relevance - Telstra's current network nodes are, to an extent, imposed upon it by historical reasons. It is not necessarily reasonable (or even cost effective) to suppose that network nodes can be reorganised in the near future.

In practice, we have essentially adopted a scorched node approach, but based on Telstra's *proposed forward looking* network, which is not currently fully in place (ie the model is based on the Future Mode of Operation, or "FMO"). We have taken as given estimates for the number of remote units, local switch and tandem switch sites in Australia on a *forward looking* basis. With regards the numbers of transmission links, we have made estimates based on our understanding of Telstra's forward looking network plan and planning principles.

1.3. Overview of the "Bottom-up" Modelling Approach

The "bottom-up" modelling approach requires the following tasks:

- specifying the physical quantities of components in the network (eg. the number of local and tandem switches, the numbers and lengths of transmission links, the number of line cards);
- estimating the capacity required by each of these components, based on the demanded traffic levels in the network (eg the numbers of ports required in the switches and the capacity of the different transmission links);
- applying costs to each of these components (both fixed costs for each switch or transmission link (dependent on route length), and variable capacity costs);
- averaging traffic related costs across the actual volume of traffic passed over each component to yield a unit cost for conveyance, and averaging line related costs over the number of access lines to yield a per line cost for access;
- aggregating the component unit costs by the use made of them by different call services (using routing factors). For example, a local switch interconnection segment uses one local switch component plus (in some cases) a transmission link between

the switch and a remote unit (ie remote concentrator or remote switch).

Each of these steps will be described in more detail in the following chapters.

1.4. Network Component Based Approach

In common with other telecommunications cost modelling studies, we use a network component based approach (eg deriving costs for the different components of the network, such as local and tandem switches, and the different types of transmission links in the network). This approach is adopted for two principal reasons.

First, a component based approach is the most practical since costs are relatively easily identified on a component basis in a "bottom-up" model.

However, secondly, and more importantly, the costs imposed on the network by different forms of interconnection usage (eg local exchange interconnection or interconnection at tandem exchanges are strictly related to the components utilised by each of these services. For example, if Telstra provides local exchange interconnection to a competitor, it will be required to provide capacity only in its local exchanges and transmission links between local exchanges and remote units. In this case, the competitor will impose no cost on Telstra's tandem switches. However, if the competitor received single tandem interconnection or double tandem interconnection, then the cost implications for Telstra's tandem switches and associated transmission links should be included, with more costs being incurred in the case of double tandem than in the case of single tandem. A component cost approach will achieve just this.

The linkage between component costs and service costs (whether retail services such as local calls, or interconnection services such as local exchange interconnection segments) is provided by the so-called "routing factors". These simply specify the average number of units of each network component used by a particular type of service and are discussed in more detail in Section 2.2.4. Routing factors are commonly measured from traffic samples by large operators, and are often already used as a means of establishing the cost of retail call services. In the case of interconnection services, many of the routing factors can often be established almost by definition. For example, a single tandem interconnection segment makes use of one tandem switch, one tandem - local transmission link, one local switch, and lastly a proportion of transmission links between the local switch and remote units (less than one due to collocation of some concentrator / remote switching units with local switches).

If costs are calculated correctly on a component basis, distance is only relevant to the extent that transmission links between network nodes vary in length (thus requiring different lengths of duct, cables and numbers of repeaters). The parts of the network where distance is likely to be a significant cost driver are in the longer distance routes for example tandem to tandem routes. Given that modelling of tandem-tandem routes is not required in order to calculate interconnection charges, we have not splt out costs into distance / non-distance related components. However, in view of the fact that different area types (eg urban and rural) have different costs, we have disaggregated the costs of the remote unit to local switch links.

1.5. Fixed Shared and Common Costs

The definition of cost we have been asked to consider is total service long run incremental cost: for a new service TSLRIC measures the increase in costs causally associated with the supply of the new service at the full volume of its likely demand; for an existing service, TSLRIC measures the decrease in costs associated with discontinuing supply of the service in its entirety. Under this definition fixed costs (ie costs that do not vary with output) that are specific to the service being considered are included in the definition of costs. There are, however, two other types of cost that are also relevant to interconnection charges:

- shared fixed costs are the fixed costs associated with the supply of a group of services comprising more than one, but less than all, of a firm's services;
- common fixed costs are fixed costs that are shared by all services produced by the firm.

Examples of shared fixed costs are:

- the cost of the site for a local switch is shared between PSTN and customer access - the site hosts both line related pieces of equipment (such as line cards) and traffic related pieces of equipment (such as the switch processor). The cost of the site itself, however, is fixed and does not depend directly on either on lines or traffic;
- trenches that are shared between the access network and the core network;
- the transmission link costs in the core network are shared between leased line and PSTN services.

Classic examples of common costs are the company's headquarters and the chairman's salary.

In principle applying "TSLRIC" would imply that shared and common costs are not included in our cost estimates for interconnection services. Some kind of "mark up" over the costs estimated using TSLRIC would then be needed to ensure adequate cost recovery.

In practice in building the model we have included all costs relevant to customer access and to PSTN / leased lines. Costs that are shared or common have then been allocated in one of several ways:

- drivers in the model may be used to determine the split of costs (for example the split of switch site costs is done on the basis of estimating the proportion of equipment costs (other than site costs) which are line / traffic sensitive and using this proportion as the basis for splitting site costs;

- a simple "rule" is used - for example the costs of portions of trench that are shared between the access and core network are split 50:50 between TS and NTS services;
- non-network costs (both fixed costs and operating costs) are estimated as a proportion of network costs and included as a mark up on network costs for each part of the network.

In this sense the model is not pure "TSLRIC". The advantages of this approach are that:

- all costs are accounted for within the model;
- costs are allocated on some reasoned basis - the alternative is to estimate some "lump" of cost that lacks any basis for allocation;
- having built in these shared and fixed costs it is then relatively easy to subtract them out again, so "pure" TSLRIC costs can still be estimated.

We can distinguish between shared / common costs which:

- could be attributed if the analysis were sufficiently detailed;
- reflect intrinsic economies of scope in providing more than one service.

The "indirect" costs in our model (eg the costs of accounting services or non-network buildings) generally come into the former category - with the adoption of a proper cost attribution method (such as activity based costing) the shared / common costs of such "overheads" would be small. The shared / common costs of the network itself generally arise from economies of scope between the core network and the access network (for example duct sharing).

In principle, we can also distinguish "intra-core" shared / common costs, for example duct sharing between remote to local switch links and local to tandem switch links. In practice the data we have received does not allow us to distinguish this (eg the estimates of duct length for different types of link provided by Telstra have already taken account of this sharing, but do not show it explicitly).

In Section 6 we discuss the proportion of network costs which are in fact shared / common and we consider the impact on the results for interconnection charges if these costs are separated out.

2. ASSUMPTIONS

We have modelled Telstra's network under the assumptions of full digitalisation of switches and a full SDH network. This is appropriate given that the model is based on Telstra's FMO.

We use the following terminology:

- "IRIM" denotes a remote concentrator;
- "RSS / RSU" denotes a remote switch;
- "RAU" denote a remote access unit, which may be either an IRIM or an RSS / RSU;
- "LAS" denotes a local switch;
- "TS" denotes a tandem switch.

2.1. Network Architecture

It is assumed that customers are located in one of five geographical area types as follows:

- CBD;
- Metropolitan;
- Provincial;
- Rural;
- Remote rural;

which range from "CBD", describing the densest customer inner city areas, to "remote rural" describing areas with very low customer density.

The following sub-sections look in more detail at the assumptions made regarding:

- the access network;
- switching;
- the different parts of the transmission network.

2.1.1. Access network

We have modelled the costs of a line from a customer site up to the first switching unit (which may be a remote concentrator (IRIM), a remote switch (RSS / RSU) or host local switch (LAS)). In principle we can consider two types of access:

- copper local loop;
- radio.

Copper access will be by far the most common form of access. However, radio access is relevant for some remote rural areas.

Within each area type, customer connection may be one of several types:

- CBD - customers connect directly to the LAS;[3]
- Metropolitan, provincial and rural - customers connect to a remote unit (IRIM or RSS/RSU);
- Remote rural - customer have a radio connection to an IRIM.

Telstra have provided the following information (see Table 2.1) for each area type:

- typical distance from the customer to the first switching stage;
- for connections direct to an LAS or to an RSS/RSU a pillar is used, and the distance from the customer to the pillar has been given;
- the proportion of lines for each area type and each connection type.

Table 2.1
Proportion of Lines and Typical Distances, by Area and Connection Type

Area type	Connection type	Proportion of lines	Typical distance in m	Distance from customer to pillar in m
CBD	to LAS	4.83%	c-i-c	c-i-c
Metropolitan	to IRIM	20.82%	c-i-c	
	to RSS/RSU	47.39%	c-i-c	c-i-c
Provincial	to IRIM	5.47%	c-i-c	
	to RSS/RSU	10.18%	c-i-c	c-i-c
Rural	to IRIM	5.12%	c-i-c	
	to RSS/RSU	5.94	c-i-c	c-i-c
Remote rural	Radio access	0.26%		

c-i-c- commercial -in-confidence data removed

Source: Telstra

[3] In this case an RSS/RSU unit is co-located with the local switch .

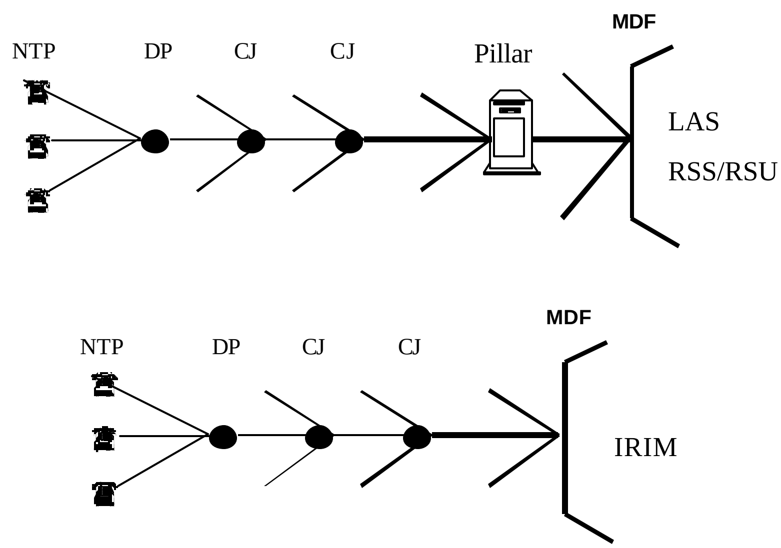
2.1.1.1. Copper access

The architecture that we have modelled is illustrated in Figure 2.1. The network has a "tree and branch" structure, and each section of the network is characterised by cables of different typical sizes.

We have assumed that the link from the customer up to the main distribution frame (MDF) at the first switch site (which may be an IRIM, RSS / RSU or LAS) is made up of the following sub-links:

- the network termination point (NTP) within the customers premises;
- a dedicated single copper pair running from the customer site to the distribution point (DP);
- a multi-pair cable running from the DP to the first cable junction (CJ);
- a number of different sections made up of multi-pair cables running from CJ to CJ;
- for connections that either go directly to the LAS or which use an RSS / RSU, a pillar is used;
- there is a final multi-pair cable running from the last CJ / the pillar to the MDF (there may also be additional cable jointing between the pillar and MDF).

Figure 2.1
Access Network Architecture



An important cost driver is distance, and we have characterised each area type by the "typical distance" listed in Table 2.1.

It is then important to know the proportion of the access network which uses cables of different sizes. One way of doing this is to explicitly sub-divide the "typical distance" to give the proportion of the route using different cable sizes.

Telstra have not provided data to us in this form. Instead they have carried out some analysis that indicates that *on average* the cable size in the "distribution network" (ie that part of the access network running from the customer site to the IRIM or pillar) is 47.5 pairs.

At the time of writing this report we have not received Telstra's estimate of the average cable size in the "feeder" network (ie that part of the network running from the pillar to the LAS or RSS/RSU). However we know that typically 300 copper pairs leave the pillar and that there may be further cable jointing as the cable runs towards the RSS/RSU or LAS. We have assumed an average cable size of 400 pairs in the feeder network.

We have not explicitly modelled the cable junctions or pits. Instead Telstra have provided an estimate for cable costs which roll in the cost of cable junctions and pits and based on averaging over different cable sizes (with an average cable size of 47.5 pairs). This implies an uplift of around 7% on the pure cable cost. We have used the same uplift for cable in the feeder network.

The costs per customer are derived from:

- the cost of the network termination point (NTP) - this cost is customer specific;
- the cost of the "final drop" - this cost is customer specific;
- the cost of copper cables (of varying sizes) leading up to the MDF - these costs are shared;
- the cost of the distribution points and the cable junctions (these are implicit in the "average" cable cost) - these costs are shared;
- the costs of trenching - these costs are shared;
- the cost of the pillar if appropriate - this cost is shared;
- the cost of a line card at the switch/concentrator site - this is a cost per customer (though the cost of "sparing" is shared);
- a proportion of the cost of the switching/concentrator site - these costs are shared.

The number of copper lines installed in the access network is not the same as the number of end user lines , or "services in operation" (SIO). Additional capacity is installed to cover for growth margins, sparing for faults etc. Telstra have indicated that provisioning of copper pairs is as follows:

- in the distribution network (between the customer and the IRIM or pillar) 2 copper pairs are installed for every 1 SIO;
- in the feeder network (between the pillar and the RSS / RSU or LAS) 1.66 copper pairs are installed for every 1 SIO.

Telstra have provided data regarding the size of a pillar as used in their network. Typically a pillar can accommodate up to 5 x 100 pair cables coming in from the distribution network and 3 x 100 pair cables going out to the feeder network (less cables are required on the feeder network side as there is less spare capacity in this part of the network). Pillar utilisation on average is given as 70%.

At the switch or concentrator site, copper lines connect to line cards. The number of line cards is related to the number of SIO with additional cards being provided to allow for growth margins and sparing. The rules used by Telstra in providing line cards are as follows:

- at an IRIM 1.3 line cards are provided for every SIO;
- at an RSS / RSU (either remote or co-located), the average occupancy is 85%, so 1.18 line cards are provided for every SIO.

With regards trenching, as well as costs being shared between the PSTN and private circuit customers using the trench, there are further opportunities for sharing:

- trench may be shared between the access and the core network;
- each trench may hold several access cables;
- trench may be shared with other services (for example cable TV or utility services).

Data provided by Telstra suggests:

- the average number of additional utilities sharing the trench is 0.075;[4]
- the average trench sharing is 10% for the feeder cable;
- the average number of cables in a distribution cable conduit is 1.24 cables;
- there is some sharing of trench with the core network - see section 2.1.3.

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[4] Trench sharing with other utilities only occurs in the distribution network. In new estates the number of additional utility cables sharing the trench is on average 1.5. However, new estates account for only 5% of the distribution network.

We note that where cable is ploughed, there is no trench sharing. We have assumed that in rural areas all cable is ploughed.

A question arises regarding the costs of the "final drop" (including the NTP), ie the customer specific costs incurred when there is a new connection. We would normally expect that the cost of new connections are fully expensed in the year in which they occur, ie they are treated as an operating cost rather than a capital cost. The total annual operating cost that arises as a result of the final drop is then the sum of:

- the capital cost for new connections in the year;
- the annual operating cost for all connections.

We have used a growth figure of 2.2% based on the ratio of the number of lines projected for 1997 / 98 divided by the actual number of lines for 1996 / 97. This is a somewhat conservative estimate of the number of new lines as it gives the net change in connections (ie the difference between new connections and connections that have ceased to be operational), while it is the gross number of new connections which in practice drives this element of cost, but we do not expect this to make a big difference in terms of the end result.

In the base case we have used Telstra's provisioning rules for cable and linecards - we would welcome views from other industry parties on the figures used. We also welcome views on the utilisation rates assumed in these rules.

2.1.1.2. Radio access

In remote rural areas access via radio links is more cost effective than copper wire.

It has not been possible to obtain data in a disaggregated form to allow a proper modelling of these costs, although both Telstra and Optus have provided estimates of typical investment costs.

We have treated rural and remote rural customers as a single category and have taken account of the additional costs of radio access by using a simple multiple of the investment cost per rural customer. In the base case we have used a multiple of 5, implying a total investment cost per remote rural customer of around $11,000. Sensitivities around this are reported in Section 6.

2.1.2. Switching

2.1.2.1. Switch nodes

The assumptions we have made about the number of switch nodes are shown in Table 2.2.

Table 2.2
Number of switch nodes

Type of node	Forward looking number of units	Forward looking number of sites
IRIM	16,863	16,863
MUX*	4,701	4,701
RSS/RSU** (remote)	4,629*	1,020
LAS	191	135
TS	20	20

Source: Telstra

* *Where IRIMs are used, traffic from these feed into a MUX before linking up to the LAS*

** *Telstra's data had a total of 4,980 units and 1,155 sites - this includes co-located RSS/RSUs and hence the number for remote units has been reduced by the ratio of the number of lines using a remote RSS/RSU to the total number of lines using an RSS/RSU, and the number of sites has been reduced by the number of LAS sites.*

The figures are based on analysis carried out by Telstra of the equipment that will be required under the FMO (they do not relate to the number of pieces of equipment currently in the network). We understand that the number of IRIMs and RSS/RSUs is determined with reference to the assumption that customers are connected to an IRIM if they are located more than 2 km away from the location of an RSS/RSU site (or if they are in a small rural exchange service area). Customers are connected to an RSS/RSU if they are within 2 km of an RSS/RSU site.

From the number of IRIM and RSS/RSU units together with the number of customers attached to these equipment types, we can estimate the utilisation ra tes. Using the figures in Table 2.1 we can see that 32% of customers connect to an IRIM, ie a total of 3.2 million customers. An IRIM can accommodate up to 480 line cards, implying a maximum capacity of 8.1 million services - actual utilisation is then around 40% and the ratio of linecards provisioned (assuming 1.3 line cards for every SIO) to maximum capacity is 51%.

The remaining 68% of customers (6.8 million) connect to an RSS/RSU unit (which may be either located remotely or co-located with the LAS). Up to 2,048 line cards can be accommodated at each RSS/RSU unit, implying a maximum capacity of 10.2 million services. The actual utilisation is then around 68%of maximum capacity and the ratio of linecards provisioned (assuming 1.18 linecards for every SIO) to maximum capacity is 80%.

The fact that the ratio of linecards to maximum equipment capacity is in both cases significantly below one, is due to the modularity of the equipment.

We seek comments on the number of IRIMs and RSS/RSUs assumed.

2.1.2.2. Signalling and synchronisation

Associated with the costs of switching are the costs of signalling and synchronisation. These costs are included in the costs of LAS and TS switching.

For the signalling system we have assumed that there a total of 20 Signalling Transfer Points (STP), and the total cost is simply the number of STPs times the unit cost.

For synchronisation we have assumed a total of 4 clocks (or PRCs) are needed. In addition to the cost of these we have included cost elements for:

- synchronisation (SSU) costs;
- synchronisation (SSU) licence.

2.1.3. Transmission network

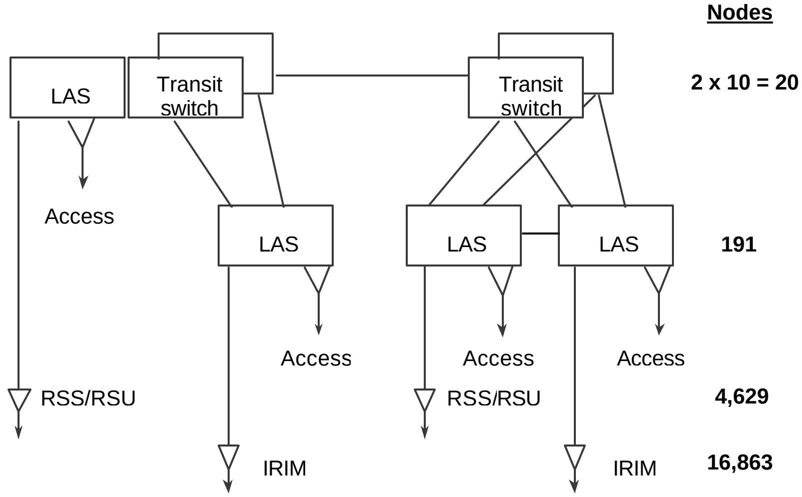
The transmission network includes the following;

- links from an IRIM (via a MUX) to the LAS;
- links from an RSS / RSU to the LAS;
- LAS-LAS links;
- LAS-TS links;
- TS-TS links.

We have assumed that SDH is used throughout the network.

A schematic of the network is given in Figure 2.2.

Figure 2.2
Schematic of Telstra Core Network



The transmission network costs consist of the following:

- the trench costs, which will be driven by trench length and areas types. There will also be some sharing of trench costs between different sections of the network, which will reduce overall costs;
- cable costs, which will be driven by cable size and cable length;
- the numbers of units of, and costs of, the electronic equipment required for multiplexing, cross connects, repeaters etc.

The information we have from Telstra relates to the drivers for duct costs - as a significant proportion of fibre is "ploughed" and not in ducts this does not give us the total trench length. We have been given a figure of 68,400 km for the total core network duct distance, which is split 96% RAU to LAS, 3% LAS-LAS and 1% LAS-TS. For TS-TS links the duct distance is close to zero (though the ploughed trench will clearly be significant).

We have been given the information shown in Table 2.3 on trench sharing between CAN and transmission fibre by area.

Table 2.3
Duct and Trench Sharing

Area	% of fibre ring in ducts	% of ducts in shared trenching
CBD	100%	100%
Metro	90%	40%
Provincial	40%	10%
Rural	10%	

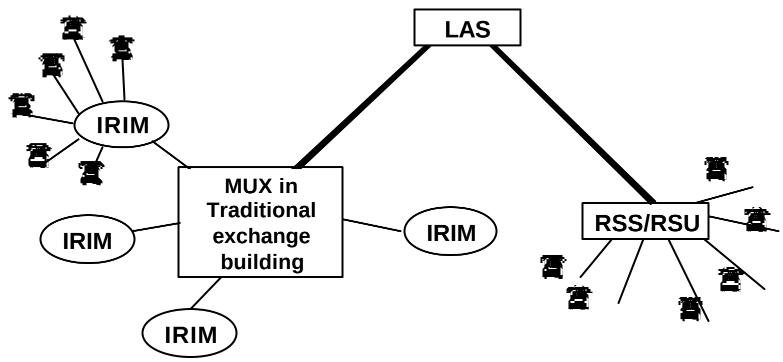
Fibre that is not in ducts is assumed to be ploughed in

We discuss each part of the network (and how we use Telstra's data) in more detail in the following sections.

2.1.3.1. Remote to LAS links

In all areas apart from CBD, customers link first to a remote unit, and we have modelled the transmission links from this remote unit up to the LAS (see Figure 2.3).

Figure 2.3
Schematic of Telstra Network - Remote to LAS links



For this modelling the following are required:

- estimates of trench length - Telstra have provided a figure for total duct length for remote units to LAS - this needs to be allocated by connection type and area, the length for ploughed trench needs to be deduced and trench sharing with the CAN needs to be taken into account;
- estimates of cable length - Telstra have not provided data on this and we have modelled cable length by assuming there are 2 cables per trench;
- number and size of multiplexers.

For each area and connection type, the duct and trench lengths for RAU-LAS have been approximated using the following steps:

- calculate the total number of "logical" routes for each connection type (for IRIM-LAS this is equal to the number of IRIMs etc);
- calculate total logical route length by area and connection type using the number of logical routes split by area type according to the proportion of customers by area and the typical route length by area and connection;
- calculate the total logical duct route length by area and connection type using the % of fibre ring in ducts figures provided by Telstra;
- allocate the total actual duct length for RAU-LAS by connection type according to logical duct route lengths;
- calculate a trench sharing factor for ducted routes as the ratio of logical duct length over actual duct length;
- it is assumed that this "trench sharing" factor can also be used for buried trench and total trench length is calculated as logical route length / trench sharing factor;
- trench sharing with the access network is calculated using the % of ducts in shared trenching figures provided by Telstra (it is assumed that where duct / trench is shared 50% of the costs are allocated to access and 50% to conveyance);[5]
- finally this gives estimates of trench (split into duct and ploughed) by area and connection type, taking account of trench sharing with the access network.

Clearly this involves a fair degree of approximation and simplification, both in deducing the ploughed trench length and in allocating the duct and ploughed trench lengths between areas and connection types.

We have assumed that at each IRIM there is an STM1 MUX - this assumption has been checked against the average route capacity and the results indicate that STM1 is in fact more than adequate.

We have modelled the capacity distribution for routes from the MUX to LAS (for an IRIM-LAS link) and for routes from an RSS / RSU to LAS. These distributions have been estimated using data provided by Telstra. The data provided by Telstra gives the number of lines per MUX site and per RSS / RSU site. Using an average figure for minutes of conversation per line, and a typical figure for number of minutes per 2Mbit / s we can estimate the number of 2Mbits / s per route. The information for each individual MUX site and RSS / RSU site can then by turned into a "distribution" by calculating the number of routes with capacity

5 Note there is no trench sharing with the access network for ploughed trench.

between given limits.[6]

2.1.3.2. LAS-LAS and LAS-TS links

For calls that go outside a customer's "own exchange" area, calls will be routed from the first LAS to a second switch, which may be either an LAS or TS.

For the modelling of LAS-LAS and LAS-TS links we require:

- an estimates of trench length - Telstra have provided an estimate of the total duct length for LAS - LAS and LAS-TS, but not of the ploughed trench length;
- Telstra have not provided any estimates for total cable length - we have modelled this by assuming there are 2 cables per trench and multiplying trench length by number of cables per trench;
- number and size of multiplexers.

The total duct length needs to be broken down according to the type of area that is crossed. We do not have estimates of this from Telstra and have had to put in assumptions - these can be varied as a sensitivity on the base case results. For the base case we have assumed that the proportion of duct length by area types are as shown in Table 2.4.

Table 2.4
Proportion of Duct Length by Area Type

Area type	LAS-LAS	LAS-TS
CBD	5%	0%
Metropolitan	10%	0%
Provincial	10%	0%
Rural	75%	100%

Source: NERA assumptions

These figures are based on the assumption that we would not expect that much of the trench for these types of link will actually cross dense urban areas.[7] Using these assumptions we can follow similar steps in allocating duct lengths by area types, and in deducing ploughed trench lengths, as for the RAU-LAS links.

[6] This calculation is used to determine the shape of the distribution only - the actual capacity requirements are determined in the main model and the capacity figures in the distribution are rescaled to ensure the correct total amount of capacity is provided for.

[7] We can contrast short distance links (eg the link from the customer to the first switching stage) where the area type for the duct will generally be the same area type as the location of the customer, to long distance links (such as TS-TS) where virtually none of the trench length is across urban areas (reflecting the fact that urban areas cover only a very small proportion of total area). LAS-LAS and LAS-TS links are intermediate between these two extremes.

The capacity distribution of traffic from an LAS is estimated using the number of lines per LAS, in a similar way as for the remote to LAS links. In addition we have assumed:

- each LAS connects to 2 TSs;
- each LAS has a direct connection to 5 other LASs.

2.1.3.3. TS-TS links

The final part of the network is the TS-TS links. It is our understanding that this type of link does not form part of any interconnection service, and hence in principle need not be part of the model.

Nonetheless, we have included this type of link for the following reasons:

- it adds flexibility to the model should this be needed at a later stage;
- it ensures that any cost sharing is taken into account (eg trenching sharing[8]) and allows us to compare with Telstra's aggregate cost figures (eg for optical fibre).

We have adopted the following procedure:

- in the absence of trench figures from Telstra we have made some crude estimates based on a map of the long distance network - this would need to be reconsidered if these figures were to be used in earnest (note that it is assumed that 100% of trench is ploughed);
- we assume that there are 3 cables per trench and calculate total cable length as trench length times 3;
- multiplexing equipment is determined by the average capacity per route;[9]
- the number of routes is calculated assuming complete intermeshing of 10 TS pairs.

2.2. Traffic and Lines

Once the network architecture has been established, it is then necessary to analyse the number of lines in the access network and traffic flows in the core network.

The number of lines in the access network is based on:

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[8] In practice as we have not had detailed trench km figures from Telstra, it is difficult to say anything about trench sharing.

[9] This is a simplification - ideally we would have estimated a distribution based on traffic data. In view of the fact that this section of the modelling is not as crucial we have not pursued obtaining the data we would require to do this from Telstra, however the functionality is there to improve this at a later stage.

- the number of PSTN access lines;
- the number of ISDN access;
- the number of leased lines.

To ensure that all access lines are counted consistently, "routing" factors are defined that take account of the fact that:

- PSTN and ISDN lines have a single end (at the customer's premises);
- leased lines have two ends - one at each of the sites that are connected.

Traffic flows are needed in order to be able to determine the capacity requirements. This involves three stages:

- estimates of numbers of originating calls of different types;
- estimates of leased line capacity
- application of routing factors to each call type to estimate network component usage.

2.2.1. Number of lines

For 1997/98 we have estimates for the number of lines from Telstra as follows:

- PSTN = 9,954,800;
- ISDN = 152,604;

The total number of 64Kbit equivalent access line ends for leased lines is given by Telstra as c-i-c[10].

Routing factors in the access network are based on the proportion of customers with different connection types for different areas (ie direct to LAS, to RSS/RSU and to IRIM). The sum over all connection types is 1 for PSTN and ISDN lines (which have one end only) and 2 for all leased lines (which have two ends).

The above figures all refer to end to end lines.

2.2.2. Originating calls of different types

Figures for Telstra's conversation minutes and successful calls are shown in Table 2.5 and

[10] c-i-c denotes the figure is commercial-in-confidence.

Table 2.6. These figures represent annual figures for the year 1 July 1997 to 30 June 1998.

Table 2.5
Conversation Minutes for 1997/98

Type of call	Number of minutes
Local call minutes	c-i-c
Trunk call (STD) minutes	c-i-c
International call minutes - outgoing & incoming	c-i-c
Call to mobile minutes	c-i-c
Call from mobile minutes	c-i-c
Toll Free Local minutes	c-i-c
Toll Free Long distance minutes	c-i-c
ISDN Local call minutes	c-i-c
ISDN Long Distance call minutes	c-i-c
Interconnect: local call minutes	c-i-c
Interconnect: Long Distance call minutes	c-i-c
Total all minutes	**c-i-c**

c-i-c- commercial -in-confidence data removed

Table 2.6
Successful Calls for 1997/98

Type of call	Number of successful calls
Local call attempts	c-i-c
Trunk (STD) call attempts	c-i-c
International call attempts - incoming & outgoing	c-i-c
Call to mobile attempts	c-i-c
Call from mobile attempts	c-i-c
Toll Free Local call attempts	c-i-c
Toll Free Long distance call attempts	c-i-c
ISDN Local call attempts	c-i-c
ISDN Long Distance call attempts	c-i-c
Interconnect: local call attempts	c-i-c
Interconnect: Long Distance call attempts	c-i-c
Total call attempts	**c-i-c**

c-i-c- commercial -in-confidence data removed

2.2.3. Leased line capacity

The estimate of the amount of leased line capacity is important in that it is assumed that costs which are common to switched traffic and private circuits are shared in proportion to the amount of capacity for each service.

To estimate the amount of capacity, we need estimates of the number of and average capacity of leased lines for each line type. Figures from Telstra indicate that the number of leased lines of different types are as follows:

- 2Mbit/s links: c-i-c[11] -retail, c-i-c-carriers, c-i-c mobile and c-i-c own use;
- Network Connected Leased Lines: c -i-c
- Private Lines: c-i-c
- Tie Lines: c-i-c

The total number of 2Mbit/s links including figures for retail, carriers and mobile, but excluding Telstra own use is c-i-c. If the leased lines used by Telstra for the mobiles network are excluded then the number of 2Mbit/s links becomes c-i-c. Where leased lines share duct and cable with PSTN services it appears appropriate to allocate these shared costs across the two services, and in the base case of the model the shared costs are allocated on the basis of the relative amount of capacity provided. An important question is to understand to what extent the mobile leased line links (which are used to connect a mobile base station to a mobile switch) also share duct and cable with the PSTN network. Telstra have indicated that these links would not usually share duct with IRIM-LAS links, but have been unable to provide information on the degree of sharing with other link types. In the base case we have included the mobile links but consider removing these as a sensitivity.

We have assumed:

- 2Mbit/s links have capacity of 2Mbit/s (true by definition);
- all the other lines have 32 KBit/s (information provided by Telstra indicates that the capacity of these lines is less than 64 Kbit/s).

We note that leased line capacity is dominated by the 2Mbit/s links, and hence that the assumption for capacity/line for the other lines is less important than it might otherwise be.

2.2.4. Network component usage

The analysis requires the estimation of traffic passing over different components of Telstra's network. This depends on routing factors for each call type.

Starting with the links from remote units to the LAS network, data from Telstra (Table 2.1) indicates that 32% of lines connect to an IRIM and 64% of lines connect to a remote

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[11] c-i-c denotes commercial-in-confidence data removed.

RSS / RSU. This implies, for example, that the average domestic call will pass over 0.64 transmission links between an IRIM and an LAS (0.32 at each end). International calls, on the other hand (with only one domestic end), will pass over an average of 0.32 such links. Similar considerations lead to the routing factors for RSS / RSU to LAS links and for the IRIM and RSS / RSU themselves.[12]

Routing factors for other components can be built up from a description of the possible routes a call using a particular service may take, and the relative frequency of each route. For each route the number of components used by the call can be listed and routing factors are calculated as the average number of components used, weighted by the frequency of the route.

For most routes the number of components used can be defined very simply, and this is illustrated in Table 2.7.

Table 2.7
Component Usage for Different Routes

Route	LAS - LAS	LAS - TS	TS - TS	LAS	TS
End to end calls					
A - LAS - B	0	0	0	1	0
A - LAS - LAS - B	1	0	0	2	0
A - LAS - TS - LAS - B	0	2	0	2	1
A - LAS - TS - TS - LAS - B	0	2	1	2	2
Single end calls*					
A - LAS	0	0	0	1	0
A - LAS - LAS	1	0	0	2	0
A - LAS - TS	0	1	0	1	1
A - LAS - TS - TS	0	1	1	1	2

* *for mobile calls there is an additional link to the gateway - this is assumed to be equivalent to an additional LAS-TS link, ie the routes are A - LAS - gateway (using 1 "LAS-TS"), and A - LAS - TS - gateway (using 2 "LAS-TS").*

We have taken Telstra estimates for routing factors and have checked that these are consistent with a breakdown into the kinds of routes in table 2.4 - we have checked for internal consistency as well as efficient routing (ie there are no more than 2 switches per call). In Table 2.8 we have listed the assumptions implicit in the routing factors provided by Telstra.

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[12] These routing factors are based on national traffic. For interconnection we also consider routing factors by area type, where the routing factors relate to the proportion of lines within a given area, using a given type of connection (eg routing factors for IRIM - LAS = 0 for CBD, 0.31for Metro, 0.35 for Provincial and 0.48 for Rural).

Table 2.8
Assumptions Implicit in Routing Factors

Route	Proportion of calls using this route			
	Local	National	International	Mobile
End to end calls				
A - LAS - B	8%	10%		
A - LAS - LAS - B	46%	45%		
A - LAS - TS - LAS - B	46%	23%		
A - LAS - TS - TS - LAS - B		23%		
Single end calls				
A - LAS (-gateway)				50%
A - LAS - LAS				
A - LAS - TS (-gateway)			90%	50%
A - LAS - TS - TS			10%	

Source: NERA analysis of Telstra data

We need to make assumptions about the routings used by leased lines. One way of approximating routing factors for leased lines is to use the information we have on routings for local and national calls - ie we assume that on average leased lines have the same routing factors as PSTN traffic.[13] The routing factors implied by this approach are shown in Table 2.9.

Table 2.9
Leased Line Routing Factors

Route	Proportion for local calls	Proportion for national calls	Proportion for leased lines	LAS-LAS	LAS-TS	TS-TS
A-LAS-B	7.5%	10%	7.9%	0	0	0
A-LAS-LAS-B	46.25%	45%	46.1%	1	0	0
A-LAS-TS-LAS-B	46.25%	22.5%	42.7%	0	2	0
A-LAS-TS-TS-LAS-B	0	22.5%	3.3%	0	2	1
Routing factor				**0.461**	**0.92**	**0.033**

The "proportion for leased lines" has been calculated as the weighted average of the figures for local and national calls, with the weights given by the relative numbers of local and national call minutes.

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13 Data for the UK, for example, suggests that leased line capacity as a percentage of PSTN capacity is approximately the same for different types of link - our assumption ensures that this applies (approximately) in the Telstra network (apart from the IRIM-LAS links, due to the difference in routing assumed for mobile network links).

For the RAU to LAS links the routing factors are just as for any end to end call, apart from for mobile links where no IRIM-LAS links are assumed.

Using these figures we get results for leased line capacity as a percentage of total capacity in each level of the network as shown in Table 2.10. Figures are presented both for the case where we include the mobile network links and when we exclude them.

Table 2.10
Leased Line Capacity as a Proportion of the Total Network Capacity

Part of network	Leased line capacity/total capacity	
	Include mobile links	Exclude mobile links
IRIM-LAS	25%	25%
RSS/RSU-LAS	44%	25%
LAS-LAS	46%	27%
LAS-TS	40%	22%
TS-TS	41%	23%
Average	**38%**	**24%**

We note that if we include mobile links then leased line capacity accounts for around 38% of all capacity while if mobile leased line links are excluded, then leased line capacity accounts for around 24% of all capacity. The issue of whether or not to share costs with leased lines is important.

Views on the treatment of leased lines would be welcome.

2.3. Network Design Assumptions

Assumptions need to be made in order to deduce the level of capacity required to carry a certain expected volume of traffic at an acceptable grade of service. We have already commented in Section 2.1.1.1 and Section 2.1.2 on the provisioning rules used in our modelling of the access network (for cable and linecards) and on the impact of modularity in determining the usage of IRIM and RSS/RSU units.

Assumptions used elsewhere in the network are as follows:

- switching capacity for unsuccessful calls. International experience indicates that typically around 65% of call attempts are successful, and that a typical "holding time" per call is around 15s;
- the amount of traffic in the average working day busy hour as a percentage of the total traffic in the week, and the "uplift" factor to go from the average busy hour to the annual busiest busy hour. In line with the experience of operators in other countries, these figures are assumed to be 1.5%, and 1.15 respectively, giving the

ratio of traffic in the busiest busy hour to annual traffic as 0.033%(=1.5%*1.15 / 52);[14]

- design margins to cope with daily fluctuations in busy hour traffic levels and planning margins based on lead times for ordering and installing new equipment. In line with the experience of most operators, target fills are generally assumed to be 85%;
- finally, a blocking margin is needed to achieve a certain grade of service (assumed to be a congestion level of less than 1% in the busy hour) taking account of the random arrival of traffic during the busy hour. This blocking % is used together with erlang tables to derive the actual number of channels required, given an initial estimate based on the assumption of uniform traffic.

Assumptions also need to be made regarding the level of resilience and diversity provided for in the network. We have assumed that:

- multiplexing equipment is sized to be able to cope with double the amount of capacity actually required;
- to the extent that diverse *routing* is required it is assumed that this is already implicit in the total duct length figures provided by Telstra;
- TSs are taken to be located in pairs to provide diversity - but these are sized to deal with 50% (not 100%) of the traffic in the peak busy hour. A transit switch failure in the peak busy hour would cause some traffic to be blocked (though the proportion blocked would be less than 50% due to the fact we have incorporated: a 15% design margin, a 10% margin for growth, the modularity of equipment).

We would welcome views on these assumptions.

2.4. Equipment Costs

We have categorised costs under three headings:

- equipment costs (capital expenditure), including installation;
- equipment maintenance and operating expenses;
- other capital costs and expenses.

2.4.1. Equipment costs

The capital equipment cost assumptions together with assumptions about expected annual

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[14] The model has the functionality to distinguish the remote to LAS links from the rest of the network, as this is what Telstra have stated that they do. At present however, the same figure is used for all links.

price changes are needed for each type of equipment. These figures (based on 1998 costs) are based on data provided by Telstra and OPTUS as well as NERA's experience of working with telecommunications operators around the world. The figures for "equipment cost" include both the capital investment and the installation cost.

We have put together two tables of costs:

- the first is based on an average across data provided by Telstra and OPTUS and also NERA's international benchmarks;[15]
- the second is based on Telstra data to the extent this has been provided - NERA / OPTUS data is used where Telstra have not provided estimates of equipment costs.

These tables are shown in Appendix A.

There are some important issues that arise for IRIM and RSS / RSU's and these are discussed in Appendix B.

Telstra have in some cases provided data either:

- on an historical cost basis;
- in an aggregated form (eg for network site costs).

In these cases we have not used Telstra's data directly.

A similar approach has been used for data on:

- price trends;
- asset lives;
- operating costs as a percentage of investment cost.

Based on the capital expenditure costs for 1998, it is necessary to calculate an annualised cost, taking account of:

- the depreciation of the asset over an appropriate time period, ie the asset life;
- an appropriate depreciation method - options included in the model are:
  - tilted straight line depreciation which takes into account the anticipated

[15] Note that the amount of data varies - for some equipment we have 3 estimates, but for others only Telstra or NERA data is available.

changes in the price of the asset over its lifetime - if the asset price is falling, depreciation of the asset is accelerated to compensate for its declining economic value;[16]

- "sum of the years digits" depreciation (front or back loaded) - this is a method that gives some form of crude approximation to "economic" depreciation by tilting the depreciation schedule towards the early years if the price trend is downwards, and towards the end of the asset life, if the price trend is upwards;[17]
- geometric (front or back loaded);[18]
- straight line deprecation with no tilt;[19]

- the cost of capital (CoC), ie. the return that Telstra can expect to earn on its investment. We have assumed this to be 12% on a nominal basis.

We note that in the "base case" of the model we take the depreciation method to be straight line. Telstra have suggested that we use different depreciation methods for different types of asset, and this can be run as a sensitivity.

To use the "geometric" depreciation profile, some estimate is needed of the scrapvalue of the asset as a percentage of the initial investment. We have used a notional figure of 10%, but better estimates may be required if this option is to be used in a serious way.

It is important to be clear about the time at which the assets are to be costed and the time over which prices are to be estimated. We are using traffic data relating to the period July 1997 to June 98, so implicitly we are "building" our new network in July 97 and sizing it to deal with the average traffic level over 1997/98 (to the extent that there is growth in traffic over the year, and investment is continuous rather than discrete, this is a simplification). To be consistent, the equipment prices we use should relate to July 97. We have assumed that the cost data provided by Telstra and Optus relates to the period April 97-March 98, so on average can be thought to be Oct 97 prices. We have "rolled" back these equipment prices to July 97 using the nominal price trends.

To estimate prices for July 1997 to June 98 we have:

- calculated all costs in real terms;

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16 The formula used for the annual charge as a percentage of the capital investment is: 1/asset life + CoC - price trend.

17 The formula used for the annual charge as a percentage of the capital investment is, for eg an asset life of 10 years: 10/55 + CoC, for front loaded, and 1/55 + CoC, for back loaded, where 55 = 10+9+8+7+6+5+4+3+2+1.

18 The formula used for the annual charge as a percentage of the capital investment is: 1-exp(log(scrapvalue/investment)/asset life) + CoC for front loaded and 0 +CoC for backloaded.

- translated these costs to nominal terms using a value for inflation of 2.5%.

Further details of this approach are given in Appendix C.

Views on appropriate cost figures, asset lives and price trend figures for the types of equipment listed in Appendix A would be welcomed. We would also invite comment on the appropriate depreciation profiles to be used.

2.4.2. Maintenance and operating costs

For each equipment type we have estimated the annual operating / maintenance cost as a percentage of the capital cost in 1998. These figures are based on estimates provided by OPTUS together with NERA experience elsewhere. We note that Telstra have provided data on the basis of total costs by equipment category group for historic assets - this cannot be used directly in the model.

Views on appropriate operating cost percentages for the types of equipment listed in Appendix A would be welcomed.

2.4.3. Other "indirect" costs

There are a number of other capital costs and operating costs which are relevant to call conveyance and access but which do not form part of the direct "network" costs.

To model these costs we have used data for the US LECs and AT&T reported to the FCC, as well as data for BT. The data for the LECs is a relevant comparator for costs associated with the access network and the "local" network (in which we include the remote to LAS links, the remote units and the LASs). The data for AT&T is a relevant comparator for costs associated with the longer distance networks (the LAS-LAS, LAS-TS and TS-TS links and the TSs).

For each capital cost item that we identify as being relevant to call conveyance and access we carry out the following procedure:

- the "indirect" capital cost is expressed as a percentage of the total direct network cost for each LEC / AT&T;
- for the LECs, the median percentages are calculated;
- an adjustment to take into account any differences in environment between Australia and the US is made;
- the relevance of the cost item to interconnection charges is estimated, and the figures

[19] The formula used for the annual charge as a percentage of the capital investment is: 1 / asset life + CoC

adjusted to make sure only relevant costs are included.

A similar procedure is followed for indirect operating costs, where here the LEC / AT&T costs are expressed as a percentage of total direct network operating costs.

For capital costs the cost items we consider relevant, together with the adjustments we have made are shown in Table 2.11.

Table 2.11
Indirect Capital Costs as a Percentage of Direct Network Capital Costs

Expense category	Benchmark (median) Local	Benchmark (median) Trunk	Environment adjustment	Relevance to IC	Local	Trunk
Land	0.20%	0.28%		50%	0.10%	0.14%
Vehicles	1.00%	0.03%		90%	0.90%	0.03%
Other equipment	0.87%	1.31%		90%	0.79%	1.18%
Buildings	3.59%	7.45%		50%	1.79%	3.73%
Furniture	0.29%	0.07%		50%	0.15%	0.03%
Office equipment	0.74%	0.03%		50%	0.37%	0.02%
General computers	2.00%	0.78%		40%	0.80%	0.31%
TOTAL	**8.69%**	**9.95%**			**4.89%**	**5.43%**

For operating costs the cost items we consider relevant, together with the adjustments we have made are shown in Table 2.12.

Table 2.12
Indirect Operating Costs as a Percentage of Direct Network Operating Costs

Expense category	Benchmark (median) Local	Benchmark (median) Trunk	Environment adjustment	Relevance to IC	Local	Trunk
Wholesale sales and marketing	6.00%	6.00%		100%	6.00%	6.00%
Executive	1.70%	3.56%		40%	0.68%	1.42%
Planning	0.28%	0.28%		60%	0.17%	0.17%
Accounting and finance	4.08%	8.90%		60%	2.45%	5.34%
External relations	3.20%	2.71%		60%	1.92%	1.63%
Human resources	3.17%	2.85%		50%	1.58%	1.43%
Information management	12.93%	17.25%		40%	5.17%	6.90%
Legal	1.06%	4.86%	50%	50%	0.26%	1.21%
Procurement	0.69%	0.16%		80%	0.55%	0.13%
Other	11.98%	38.59%		50%	5.99%	19.30%
TOTAL	**45.09%**	**85.17%**			**24.78%**	**43.53%**

On average these figures suggest just over 50% of these non-network costs are related to network activities. The estimation of the proportion of costs that is relevant to interconnection involves a degree of judgement. However, we note, that non-network expenses account for around 10%-20% of total interconnection charges. Misjudging the overall proportions of cost that are relevant to interconnection by say 10% (ie adjusting the average allocation to interconnection to around 40% rather than around 50%), would result in over estimating interconnection charges by around 2-4%. This implies that our results are relatively robust to these estimates.

We would welcome views on this approach.

3. MODELLING ACCESS COSTS

The following steps summarise our modelling of the copper access network for each area type:

- figures for the various cable "end" points are calculated as follows:[20]
  - number of NTP = number of subscriber lines;
  - number of pillars = number of lines connecting to a pillar (ie lines to LAS or to RSS/RSU) (including margins for growth and sparing)/ no of lines per pillar/average utilisation;
  - number of MDF = number of IRIM plus RSS/RSU plus LAS;
- cable lengths are calculated as typical customer distance times number of lines provided/cable size (split into distribution/feeder network where appropriate);
- trench length is based on cable length adjusted for trench sharing within the access network with further adjustments to take account of sharing with other services and also trench sharing with the core network (the cost of trench that is shared is assumed to be allocated on a basis of 50% to access and 50% to conveyance);
- an additional cost element is added into the cost for rural customers to take account of the additional cost of serving remote rural customers (in the base case it is assumed that the investment cost for a remote rural customer is 5 times that for a rural customer);
- the number of line cards at IRIMs is the number of lines (with allowances for growth and sparing) times the proportion of lines that go to an IRIM; the number of line cards at RSS/RSUs is the number of lines (with allowances for growth and sparing) times the proportion of lines that go to an RSS/RSU; the number of line cards at LASs is the number of lines (with allowances for growth and sparing) times the proportion of lines that go directly to a LAS;
- site costs for IRIM, RSS/RSU and LAS are allocated between access and transport using the percentage of other costs that are non-traffic sensitive/traffic sensitive;
- a split of the switch equipment costs according to whether they are traffic or line related can be applied - see Appendix B;
- unit equipment costs are then applied to estimate total equipment investment;

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[20] These are the only items modelled explicitly - distribution points, cable junctions, pits are all incorporated in the estimates for cable costs.

- investment costs are annualised, taking account of depreciation periods, anticipated price changes and the cost of capital;
- maintenance / operating costs are estimated and added in;
- finally other support investments (annualised) and expenses are added.

This gives a total cost for access by area type, which can then be divided by the number of lines to give a per line cost. Results are shown in Table 3.1.[21]

Table 3.1
Annual per Line Costs for the Access Network for 1997/98

Area type	Annual cost per line
CBD	$536
Metropolitan	$471
Provincial	$369
Rural / remote rural	$801
Average	**$495**

Source: NERA analysis

We note that costs are highest in rural areas where the long distance and low line density make the cost per line high, even though the trenching costs are relatively low. High cost remote rural customers are also included in this category. The costs in CBD areas are the next highest - although distances are relatively short, the trenching costs are high.

The breakdown of overall costs by cost category is given in Table 3.2.

Table 3.2
Breakdown of Investment Costs in the Access Network

Type of cost	Investment (Aus$ million)	% of total
Pillars	$ 338	2%
Copper cable	$ 3,996	24%
Trench	$ 8,302	51%
Line cards	$ 2,392	15%
Other NTS part of switch	$ 1,047	6%
Additional costs for remote rural customers	$ 241	1%
Total	**$ 16,316**	

[21] Implicit in these number is a split of site costs between traffic and lines - see footnote 23.

The key parameters calculated in the model which underpin these investment costs are summarised in Table 3.3.

Table 3.3
Key Parameters Calculated in the Model

	CBD	Metro	Provincial	Rural	Total
Total trench length (km)*	4,366	73,175	18,097	82,382	178,020
Total cable length distribution (km)	4,211	98,471	22,896	81,334	206,911
Total cable length feeder (km)	1,328	8,364	1,797	1,048	12,538
Number of pillars	2,858	28,092	6,035	3,522	40,507

** For rural this is ploughed trench. Note that the length reported is after taking account of any trench sharing.*

The key parameters summarising the degree of "spare" capacity in the access network are listed in Table 3.4.

Table 3.4
Extent of "Spare" Capacity in the Access Network

Ratio of pairs installed to SIO in distribution network	2.0
Ratio of pairs installed to SIO in feeder network	1.66
Ratio of pairs installed in the distribution network to pillar capacity	0.7
Ratio line cards to SIO for IRIM	1.3
Ratio line cards to SIO for RSS/RSU	1.18

We would welcome views on whether this 'spare capacity' is consistent with efficient network operation.

4. MODELLING SWITCH COSTS

The following steps summarise our modelling of IRIM, RSS / RSU, LAS and TS costs:

- the cost of a switch is assumed to consist of:
  - a proportion of the cost of the site (including power and air conditioning);[22]
  - the cost of an N line unit (for IRIM, RSS / RSU and LAS) - see discussion in Appendix B;
  - the costs of ports (where the number of ports is calculated as a function of the traffic through the switch);[23]
  - the fixed cost of the switch(including the cost of the processor) for LAS and TS;
  - a cost per BHCA for LAS and TS - this is designed to reflect the fact that for an increase in traffic, there may be a need to add additional processing modules to the switch or to upgrade the switch to a switch with a higher processing capacity;
  - other costs related to switching (the cost of the 20 STPs forming the SS7 signalling system and of synchronisation, ie clocks and SSU equipment and licences) are also estimated and the costs allocated across LAS and TSs;[24]
- unit equipment costs are then applied to estimate total equipment investment;
- investment costs are annualised, taking account of depreciation periods, anticipated price changes and the cost of capital
- maintenance / operating costs are estimated and added in;
- finally other support investments (annualised) and expenses are added.

We note that Telstra's costs for an IRIM included the cost of the MUX at the IRIM site, but in

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22 For TSs this is the whole site cost, for LASs, RSS / RSUs and IRIMs the site costs is allocated between the access network and the core network on the basis of the split of traffic sensitive to non -traffic sensitive costs of LAS, RSS / RSU and IRIM components.

23 The number of ports for a IRIM or RSS / RSU is equal to the number of (whole) 2Mbit / s of traffic through an average IRIM or RSS / RSU times the number of IRIM or RSS / RSUs; the number of ports for LASs is equal to the number of (whole) 2Mbit / s of traffic through an average LAS times the number of LASs and plus the number of ports on remote units (to take account of traffic from remote units); the number of ports TSs is equal to the number of (whole) 2Mbit / s of traffic through an average TS times the number of TSs times 2 (to take account of ports on both sides of the switch).

24 The cost of synchronisation is spread over the TSs and the cost of signalling across all TS and LASs.

the model we have treated this by subtracting the cost of an STM1 from the IRIM cost and treating the cost of the STM1 as part of the transmission cost for the IRIM - LAS link.

Our approach gives a total cost for switching. The estimated conveyance costs are then divided by the number of minutes of use of IRIM, RSS / RSU, LAS and TS respectively to give network component unit costs. The results are shown in Table 4.1.[25]

Table 4.1
Calculation of Switching Costs for 1997/98 - base case

	IRIMs (call related only)	RSS/RSUs (call related only)	LASs (call related only)	TSs
Total annual cost ($ million)	$94.5	$302.0	$377.5	$60.6
Minutes of use (million)	46,377	93,003	141,226	45,127
Cost per minute	$0.0020	$0.0032	$0.0027	$0.0013

Source: NERA analysis

We can contrast there results with those we obtain using Telstra cost data - see Table 4.2. Note that because no split has been given between line related and traffic related cost the whole cost for IRIM or RSS / RSU (apart from the line cards) has been allocated to traffic.[26]

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[25] Implicit in the numbers in Table 4.1 and also in Table 3.1 are the following split of costs between TS and NTS:

- IRIM: 72% line related;
- RSS / RSU: 72% line related;
- LAS: 10% line related.

The modelling approach requires two steps: 1) we calculate the proportion of equipment costs (excluding site costs) that are line related; 2) we use this proportion to split the site costs between line related and traffic related to give the final cost estimates.

[26] Implicit in the numbers in Table 4.2 are the following split of costs between TS and NTS:

- IRIM: 37% line related;
- RSS / RSU: 37% line related;
- LAS: 4% line related.

Table 4.2
Calculation of Switching Costs for 1999 - Telstra costs and price trends (the whole of the cost of the N line unit is attributed to traffic in this case)

	IRIMs (call related only)	RSS/RSUs (call related only)	LASs (call related only)	TSs
Total annual cost ($ million)	$257.6	$587.8	$365.7	$60.6
Minutes of use (million)	46,377	93,003	141,226	45,127
Cost per minute	$0.0056	$0.0063	$0.0026	$0.0013

Source: NERA analysis

There is clearly a big difference in the results with the unit costs for remote units (both IRIMs and RSS/RSUs) more than doubling.

A key issue arises in identifying how much of the cost for an "N line" unit remote concentrator or remote switch is related to traffic and how much is line related. Telstra's cost data was not provided in a form that identified this. NERA has put forward some alternative data, though it is possible that this goes too far the other way in allocating too little of the cost to conveyance. See also Appendix B for a discussion of this.

Views on how to treat this cost allocation issue are invited.

5. MODELLING TRANSMISSION COSTS

The following steps summarise our modelling of transmission costs for the different link types in the transmission network:

- the total traffic passed over each part of the network is estimated from the originating traffic, routing factors and design margins;
- design capacity is calculated using the percentage of traffic in the busy hour, and aggregating PSTN and leased line capacity;
- using the assumptions about capacity distribution and number of routes, numbers for different types of multiplexers and repeaters are calculated;
- total duct length has been provided by Telstra - this is allocated by area type and also used to deduce total trench length;
- the total "logical" length is calculated by multiplying the typical distances per link by the number of links - this figure is divided by the route length to give the trench sharing within a network (we do not have proper estimates of "typical" distances for LAS-LAS, LAS-TS and TS-TS this calculation is very crude - however the impact on any final results is not big);
- total cable length is calculated from trench length times NERA's assumption for the number of cables per trench;
- the required fibres per cable is calculated by dividing the total logical route distance by the total cable length - a minimum size of 24 fibres per cable is used (this is where poor estimates of "typical" route distance may have some limited impact);
- unit equipment costs are then applied to estimate total equipment investment;
- investment costs are annualised, taking account of depreciation periods, anticipated price changes and the cost of capital;
- maintenance / operating costs are estimated and added in;
- finally other support investments (annualised) and expenses are added.

This gives a total cost for each type of transmission link. This cost is then divided by the number of minutes of use of the different transmission link types to give a network component unit cost for each type of transmission link. The results are shown in Table 5.1. We have not presented the results for TS-TS links in this report due to the uncertainty of the data.

Table 5.1
Calculation of Transmission Costs for 1997/98 in Base Case

	IRIM-LAS	RSS/RSU-LAS	LAS-LAS	LAS-TS
Total annual cost ($ million)	$1,751.2	$ 632.5	$ 93.8	$71.6
Minutes of use (million)	62,902	171,093	58,611	134,794
Cost per minute	$ 0.028	$0.0037	$0.0016	$0.0005

Source: NERA analysis

We have also split the total cost for the remote unit to LAS links by area type. The results are shown in Table 5.2 below.

Table 5.2
Remote to LAS Link Costs per Min by Area Type

Area type	IRIM - LAS	RSS/RSU - LAS
CBD	n/a	n/a
Metropolitan	$0.022	$0.0034
Provincial	$0.029	$0.0041
Rural	$0.050	$0.0056

Source: NERA analysis

Costs are highest in rural areas due to the longer route lengths, despite the lower trenching costs per metre.

The key parameters calculated in the model which underlie these numbers are shown in Table 5.3.

Table 5.3
Key Parameters Calculated for the Transmission Network

	IRIM-LAS	RSS/RSU-LAS	LAS-LAS	LAS-TS	Total
Duct length (km)*	39,938	16,713	1,690	684	**59,024**
Ploughed trench (km)	87,052	28,100	5,995	6,156	**127,303**
Optic fibre cable (km)	266,408	95,223	16,094	13,680	**391,405**
Number of STM1	26,265	8,585	1,910	28	**36,788**
Number of STM2	0	673	0	736	**1,409**
Number of STM3	0	0	0	0	**0**
Total number of links	16,863	4,629	955	382	**22,829**

**Note that the duct length is the total length after adjustments for sharing with the access network.*

6. RESULTS FOR INTERCONNECTION CHARGES AND ACCESS

6.1. Base Case

The base case results for customer access charges are as shown in Table 3.1.

The results that have been listed in Sections 4 and 5, can now be combined with the routing factors discussed in Section 2 to give unit costs for interconnection charges for different services.

It is possible to derive the costs of originating and terminating access from different levels in the network, ie:

- interconnection at an LAS, with no use of LAS-LAS links, "Local exchange";
- interconnection at an LAS, with use of an LAS-LAS link, "Inter-LAS";
- interconnection at a single TS (with no TS - TS link), "Single Trunk";
- interconnection using two TSs (with one TS - TS link), "Double Trunk".

We note that for the purposes of assessing Telstra's charges for originating and terminating access it is the single trunk charges that we are concerned with.[27] However, we present results not only for single trunk but also "local exchange" and "inter LAS" for completeness.[28] The results are shown in Table 6.1.

[27] Any interconnect call in the Telstra network always travels via remote (if applicable) to LAS to TS/POI. A call that involves the use of Telstra's trunk network has an additional separate charge for the equivalent of the TS-TS segment (an overlay network is used for this section).

[28] Results for "double trunk" are not shown in this report due to the fact that our estimation of these charges is crude given the lack of data.

Table 6.1
Results for interconnection charges for 1997/98

Cost per minute	Unit cost	Routing factors for interconnection service Local exchange	Inter-LAS	Single trunk
IRIM - LAS	$ 0.028	0.32	0.32	0.32
RSS / RSU - LAS	$ 0.0037	0.64	0.64	0.64
LAS - LAS	$ 0.0016	0	1	0
LAS - TS	$ 0.0005	0	0	1
IRIM	$ 0.0020	0.32	0.32	0.32
RSS / RSU	$ 0.0032	0.64	0.64	0.64
LAS	$ 0.0027	1	2	1
TS	$ 0.0013	0	0	1
Cost of interconnection service		**$ 0.017**	**$ 0.021**	**$ 0.018**

Source: NERA analysis

Results by area type are shown in Table 6.2.

Table 6.2
Results for interconnection charges for 1997/98 by Area Type

Area type	Local exchange	Inter - LAS	Single trunk
CBD	$ 0.003	$ 0.007	$ 0.005
Metropolitan	$ 0.015	$ 0.019	$ 0.016
Provincial	$ 0.018	$ 0.022	$ 0.020
Rural	$ 0.032	$ 0.036	$ 0.034

Source: NERA analysis

The results differ due to the different use made of remote units and, remote to LAS links, as well as the different costs of these links, according to area type. CBD costs are lower as there are no remote units in these areas.

6.2. Sensitivity Analysis

The model inputs contain a number of assumptions, some of which there is a relatively high degree of uncertainty over. In this section we consider some variations on the "base case" assumptions, and consider the impact on the model results.

We consider sensitivities in the following areas:

1. varying the allocation of switch costs between traffic and access;
2. varying the depreciation profile;
3. varying the cost of capital;
4. the treatment of leased lines;
5. excluding shared / common costs;
6. the treatment of remote rural customers.

6.2.1. Allocation of switch costs between access and transport

We consider the following scenarios:

- Base case;
- Case 1 - Telstra costs for IRIM, RSS / RSU and LAS with all fixed costs allocated to traffic;
- Case 2 - Telstra costs for IRIM, RSS / RSU and LAS with 60% of fixed costs allocated to traffic;
- Case 3 - Telstra costs for IRIM, RSS / RSU and LAS with 30% of fixed costs allocated to traffic.

In all cases site costs are allocated in proportion to line related / traffic related costs. A further sensitivity (Case 4) is carried out starting from the base case but allocating site costs on a 50:50 basis.

The different cases are characterised by the parameters shown in Table 6.3, and the results are shown in Table 6.4 and Table 6.5.

Table 6.3
Allocation of fixed costs and resulting figures for line related costs as a percentage of total costs

		Base case	Case 1	Case 2	Case 3	Case 4
Allocation of fixed costs to traffic:	**IRIM**	n / a*	100%	60%	30%	n / a
	RSS/RSU	n / a*	100%	60%	30%	n / a
	LAS	n / a*	100%	60%	30%	n / a
Results for line related costs as % of total	**IRIM**	72%	37%	60%	78%	72%
	RSS/RSU	72%	37%	59%	76%	63%
	LAS	10%	4%	7%	10%	19%
	in total	59%	32%	50%	63%	56%

** in the base case the allocation of fixed costs is implicit in the cost figures used*

Table 6.4
Component costs - allocation of switch costs sensitivities

	Cost per minute				
	Base case	**Case 1**	**Case 2**	**Case 3**	**Case 4**
IRIM - LAS	$ 0.028	$ 0.028	$ 0.028	$ 0.028	$ 0.028
RSS/RSU - LAS	$ 0.0037	$ 0.0037	$ 0.0037	$ 0.0037	$ 0.0037
LAS - LAS	$ 0.0016	$ 0.0016	$ 0.0016	$ 0.0016	$ 0.0016
LAS - TS	$ 0.0005	$ 0.0005	$ 0.0005	$ 0.0005	$ 0.0005
IRIM	$ 0.0020	$ 0.0056	$ 0.0033	$ 0.0018	$ 0.0020
RSS/RSU	$ 0.0032	$ 0.0063	$ 0.0041	$ 0.0024	$ 0.0043
LAS	$ 0.0027	$ 0.0026	$ 0.0024	$ 0.0023	$ 0.0024
TS	$ 0.0013	$ 0.0013	$ 0.0013	$ 0.0013	$ 0.0013
Average access cost (annual cost per line)	$495	$441	$470	$493	$489

Table 6.5
Interconnection service costs - allocation of switch costs sensitivities

	Cost per minute				
	Base case	**Case 1**	**Case 2**	**Case 3**	**Case 4**
Local exchange	$ 0.017	$ 0.020	$ 0.017	$ 0.016	$ 0.017
Inter LAS	$ 0.021	$ 0.024	$ 0.021	$ 0.020	$ 0.021
Single trunk	$ 0.018	$ 0.021	$ 0.019	$ 0.017	$ 0.019

The allocation of costs has a big impact on the costs for IRIMs and RSS/RSUs, but a relatively small impact on the cost for LASs. The impact on interconnection service costs is up to 17% for single trunk.

6.2.2. Different depreciation profiles

Base case results have been run with straight line depreciation. Other profiles are considered as follows:

- Case 1: tilted straight line;
- Case 2: sum of digits: front loaded if price tilts down and backloaded if price tilts up.

Results are as shown in Table 6.6 and Table 6.7.

Table 6.6
Component costs - depreciation sensitivities

	Cost per minute		
	Base case	**Case 1**	**Case 2**
IRIM - LAS	$ 0.028	$ 0.030	$ 0.0028
RSS/RSU - LAS	$ 0.0037	$ 0.0040	$ 0.0038
LAS - LAS	$ 0.0016	$ 0.0018	$ 0.0017
LAS - TS	$ 0.0005	$ 0.0006	$ 0.0006
IRIM	$ 0.0020	$ 0.0023	$ 0.0026
RSS/RSU	$ 0.0032	$ 0.0035	$ 0.0034
LAS	$ 0.0027	$ 0.0031	$ 0.0033
TS	$ 0.0013	$ 0.0015	$ 0.0016
Average access cost (annual cost per line)	$495	$495	$495

Table 6.7
Interconnection service costs - depreciation sensitivities

	Cost per minute		
	Base case	**Case 1**	**Case 2**
Local exchange	$ 0.017	$ 0.018	$ 0.018
Inter LAS	$ 0.021	$ 0.023	$ 0.023
Single trunk	$ 0.018	$ 0.020	$ 0.020

The results are relatively robust to the choice of depreciation method, with a difference of around 0.2 cents per minute.

6.2.3. Cost of capital

The base case is run with a nominal pre-tax cost of capital of 12%. we run alternatives as follows:

- Case 1: 10%
- Case 2: 14%
- Case 3: 16%

Results are as shown in Table 6.8 and Table 6.9.

Table 6.8
Component costs - cost of capital sensitivities

	Cost per minute			
	Base case	Case 1	Case 2	Case 3
IRIM - LAS	$ 0.028	$ 0.026	$ 0.030	$ 0.032
RSS/RSU - LAS	$ 0.0037	$ 0.0034	$ 0.0040	$ 0.0043
LAS - LAS	$ 0.0016	$ 0.0015	$ 0.0017	$ 0.0018
LAS - TS	$ 0.0005	$ 0.0005	$ 0.0006	$ 0.0006
IRIM	$ 0.0020	$ 0.0019	$ 0.0022	$ 0.0023
RSS/RSU	$ 0.0032	$ 0.0030	$ 0.0035	$ 0.0037
LAS	$ 0.0027	$ 0.0025	$ 0.0028	$ 0.0030
TS	$ 0.0013	$ 0.0013	$ 0.0014	$ 0.0015
Average access cost (annual cost per line)	$495	$463	$528	$560

Table 6.9
Interconnection service costs - cost of capital sensitivities

	Cost per minute			
	Base case	Case 1	Case 2	Case 3
Local exchange	$ 0.017	$ 0.015	$ 0.018	$ 0.019
Inter LAS	$ 0.021	$ 0.019	$ 0.022	$ 0.024
Single trunk	$ 0.018	$ 0.017	$ 0.020	$ 0.021

The return on capital is one element of the total annual charge, the others being depreciation and operating costs. A 2% change in the cost of capital results in a 0.1-0.2 cents per minute change to interconnection charges.

6.2.4. Leased line capacity

We have looked at sensitivities where we vary the amount of leased line capacity in Telstra's network as follows:

- Base case: include all leased line links (including all mobile);
- Case 1: exclude mobile leased lines;
- Case 2: exclude all leased lines.

Results are reported both for individual components and for interconnection services in Table 6.10 and Table 6.11.

Table 6.10
Component costs - leased line sensitivities

	Cost per minute		
	Base case	Case 1	Case 2
IRIM - LAS	$ 0.028	$ 0.028	$ 0.038
RSS/RSU - LAS	$ 0.0037	$ 0.0050	$ 0.0066
LAS - LAS	$ 0.0016	$ 0.0022	$ 0.0031
LAS - TS	$ 0.0005	$ 0.0007	$ 0.0009
IRIM	$ 0.0020	$ 0.0020	$ 0.0020
RSS/RSU	$ 0.0032	$ 0.0032	$ 0.0032
LAS	$ 0.0027	$ 0.0027	$ 0.0027
TS	$ 0.0013	$ 0.0013	$ 0.0013

Table 6.11
Interconnection service costs - leased line sensitivities

	Cost per minute		
	Base case	Case 1	Case 2
Local exchange	$ 0.017	$ 0.017	$ 0.022
Inter LAS	$ 0.021	$ 0.022	$ 0.027
Single trunk	$ 0.018	$ 0.019	$ 0.024

This is clearly an area where the assumptions are important in determining the result. We note that there is relatively little difference between Case 1 and the base case. This is because the IRIM-LAS link is relatively expensive compared to other network components, and the cost of this link does not vary between the two cases (we assume that mobile links to not share trench or cable with IRIM-LAS links).

6.2.5. Excluding shared/common costs

As discussed in Section 1.5, we have allocated all shared / common costs in the base case. We can calculate within the model the amount of cost due to:

- switch sites for remote units and LASs
- shared duct between the access network and the core network.

This analysis of costs is shown in Table 6.12.

Table 6.12
Shared/Common Network Costs

	Total capital investment (Aus$ m)	As proportion of total network cost excluding shared/common costs
RSS / RSU and LAS site costs	$1,522	5.4%
Cost of trench shared between access and core networks	$752	2.7%
Total network cost excluding shared / common costs	$30,291	

In total then, shared / common costs represent a 8% mark-up on network costs. We can calculate component costs and interconnection charges with shared / common network costs excluded. The results are shown in Table 6.13 and Table 6.14.

Table 6.13
Component costs - shared/common cost sensitivities

	Cost per minute	
	Base case	Case 1
IRIM - LAS	$ 0.028	$ 0.026
RSS/RSU - LAS	$ 0.0037	$ 0.0033
LAS - LAS	$ 0.0016	$ 0.0014
LAS - TS	$ 0.0005	$ 0.0005
IRIM	$ 0.0020	$ 0.0020
RSS/RSU	$ 0.0032	$ 0.0019
LAS	$ 0.0027	$ 0.0021
TS	$ 0.0013	$ 0.0013
Average access cost (annual cost per line)	$495	$442

Table 6.14
Interconnection service costs - shared/common cost sensitivities

	Cost per minute	
	Base case	Case 1
Local exchange	$ 0.017	$ 0.014
Inter LAS	$ 0.021	$ 0.018
Single trunk	$ 0.018	$ 0.016

We can also consider the relative importance of indirect costs in our results. In Table 6.15 and Table 6.16 we show the mark up on network costs estimated in the model to take account of indirect costs.[29]

Table 6.15
Mark-up on Component Costs to Cover Indirect Costs

	Mark up
IRIM - LAS	16%
RSS/RSU - LAS	16%
LAS - LAS	22%
LAS - TS	21%
IRIM	12%
RSS/RSU	12%
LAS	13%
TS	18%
Average access cost	18%

Table 6.16
Mark-up on Interconnection Service Costs to Cover Indirect Costs

	Mark up
Local exchange	15%
Inter LAS	15%
Single trunk	15%

6.2.6. Treatment of the costs of serving remote rural customers

In the base case we assume a multiple of 5 for the investment cost of treating remote rural customers compared to rural customers. We have run sensitivities as follows:

[29] The "network" costs we use here include shared / common network costs.

- Case 1: investment multiple of 10;
- Case 2: investment multiple of 15.

The result s for access cost by area type for these different sensitivities are shown in Table 6.17.

Table 6.17
Access costs - remote rural sensitivities

	Cost per line		
	Base case	**Case 1**	**Case 2**
CBD	$536	$ 536	$ 536
Metro	$471	$ 471	$ 471
Provincial	$369	$ 369	$ 369
Rural/remote rural	$801	$ 885	$ 969
Average	**$495**	**$ 505**	**$ 514**

APPENDIX A. COST DATA

We would welcome data to verify the costs of the equipment detailed in the tables below.

Table A.1
Base case assumptions for equipment costs for access network

	Capital investment AUS $	Asset life	Price trend	Operational costs as a % of capital cost	Scrap value as a % of equipment capital cost	Deprec method code*
NTP	$ c-i-c	17	2%	8%	10%	1
DP		17	1%	9%	10%	1
Pillar (900 pair)	$ c-i-c	17	1%	9%	10%	1
Customer radio equipment	n/a	5	-13%		10%	1
Radio repeater station	n/a	14	-18%		10%	1
Radio base station	n/a	14	-8%		10%	1
MDF	$ c-i-c	12	-3%	13%	10%	1
Copper drop / metre	$ c-i-c	22	-1%	13%	10%	1
Copper cable 10 pair / metre	$ c-i-c	22	-1%	13%	10%	1
Copper cable 50 pair / metre	$ c-i-c	22	0%	13%	10%	1
Copper cable 100 pair / metre	$ c-i-c	22	0%	13%	10%	1
Copper cable 400 pair / metre	$ c-i-c	22	-1%	13%	10%	1
Copper cable 800 pair / metre	$ c-i-c	22	-1%	13%	10%	1
Copper cable including pits and cable joints	$ c-i-c	22	-1%	13%	10%	1
Trench / metre - CBD	$ c-i-c	29	1%	12%	10%	1
Trench / metre - Metro	$ c-i-c	29	1%	12%	10%	1
Trench / metre - Provincial	$ c-i-c	29	1%	12%	10%	1
Trench / metre - Rural (ploughed)	$ c-i-c	29	1%	12%	10%	1
Line card in IRIM (per line)	$ c-i-c	10	-4%	7%	10%	1
Line card in RSS/RSU (per line)	$ c-i-c	10	-5%	7%	10%	1
Line card in LAS (per line)	$ c-i-c	10	-5%	7%	10%	1
Access network management centre per access line	$ c-i-c	9	-7%	20%	10%	1

c-i-c- commercial -in-confidence data removed

** Note that the depreciation method codes are as follows:*

- *Straight line:* 1
- *Sum of digits front loaded:* 2
- *Sum of digits back loaded:* 3
- *Geometric front loaded:* 4
- *Geometric back loaded:* 5
- *Tilted straight line:* 6

Table A.2
Base case assumptions for equipment costs for transport network

	Capital investment AUS $	Asset life	Price trend	Operational costs as a % of capital cost	Scrap value as a % of equipment capital cost	Deprec method code
IRIM (per 480 line unit, excl MUX))	$ c-i-c	10	-4%	7%	10%	1
IRIM - port	$ c-i-c	10	-4%	7%	10%	1
IRIM - site		24	1%	12%	10%	1
RSS/RSU (per 2048 line unit)	$ c-i-c	10	-4%	7%	10%	1
RSS/RSU - port	$ c-i-c	10	-4%	7%	10%	1
RSS/RSU - site	$ c-i-c	8	0%	11%	10%	1
LAS (per 2048 line unit)	$ c-i-c	10	-5%	7%	10%	1
LAS - port	$ c-i-c	10	-5%	7%	10%	1
LAS - fixed (processor)	$ c-i-c	10	-8%	7%	10%	1
LAS - per BHCA (processor)	$ c-i-c	10	-8%	7%	10%	1
LAS - site	$ c-i-c	20	-1%	11%	10%	1
TNS - port	$ c-i-c	9	-6%	7%	10%	1
TNS - fixed (processor)	$ c-i-c	9	-6%	7%	10%	1
TNS - per BHCA (processor)	$ c-i-c	9	-6%	7%	10%	1
TNS - site	$ c-i-c	17	-1%	10%	10%	1
Synchronisation PRC	$ c-i-c	4	0%	13%	10%	1
Synchronisation SSU equipment per tandem switch	$ c-i-c	9	0%	13%	10%	1
Synchronisation SSU licence per tandem switch	$ c-i-c	9	0%	13%	10%	1
SDH MUX STM1	$ c-i-c	10	-10%	6%	10%	1
SDH MUX STM4	$ c-i-c	10	-10%	6%	10%	1
SDH MUX STM16	$ c-i-c	10	-10%	6%	10%	1
Digital cross connect	$ c-i-c	10	-9%	7%	10%	1
Line termination system	$ c-i-c	10	-9%	6%	10%	1
STM - 1 Regenerator	$ c-i-c	9	-10%	5%	10%	1
STM - 4 Regenerator	$ c-i-c	9	-10%	5%	10%	1
STM - 16 Regenerator	$ c-i-c	9	-10%	5%	10%	1
Repeater Site Cost	$ c-i-c	23	1%	12%	10%	1
12 fibre cable / metre	$ c-i-c	24	-5%	10%	10%	1
24 fibre cable / metre	$ c-i-c	24	-5%	10%	10%	1
48 fibre cable / metre	$ c-i-c	24	-5%	10%	10%	1
96 fibre cable / metre	$ c-i-c	24	-5%	10%	10%	1
Trench / metre - CBD	$ c-i-c	34	1%	11%	10%	1
Trench / metre - Metro	$ c-i-c	34	1%	11%	10%	1
Trench / metre - Provincial	$ c-i-c	34	1%	11%	10%	1
Trench / metre - Rural (ploughed)	$ c-i-c	34	1%	11%	10%	1
Trench / metre - Rural (ploughed - no duct)	$ c-i-c	34	1%	11%	10%	1
Signalling transfer point	$ c-i-c	9	-5%	8%	10%	1
Core network management centre per switch node	$ c-i-c	9	-7%	62%	10%	1

c-i-c- commercial -in-confidence data removed

Table A.3
Telstra equipment costs for access network*

	Capital investment AUS $	Asset life	Price trend	Operational costs as a % of capital cost	Scrap value as a % of equipment capital cost	Deprec method code
NTP	$ c-i-c	17	4%	8%	10%	1
DP		17	1%	9%	10%	1
Pillar (900 pair)	$ c-i-c	17	1%	9%	10%	1
Customer radio equipment		10	-13%		10%	3
Radio repeater station		16	-18%		10%	4
Radio base station		16	-8%		10%	4
MDF	$ c-i-c	11	-3%	13%	10%	3
Copper drop / metre	$ c-i-c	15	-1%	13%	10%	2
Copper cable 10 pair / metre	$ c-i-c	15	-1%	13%	10%	2
Copper cable 50 pair / metre	$ c-i-c	15	2%	13%	10%	2
Copper cable 100 pair / metre	$ c-i-c	15	2%	13%	10%	2
Copper cable 400 pair / metre	$ c-i-c	15	1%	13%	10%	2
Copper cable 800 pair / metre	$ c-i-c	15	0%	13%	10%	2
Copper cable including pits and cable joints	$ c-i-c	15	-1%	13%	10%	2
Trench / metre - CBD	$ c-i-c	25	4%	12%	10%	1
Trench / metre - Metro	$ c-i-c	25	4%	12%	10%	1
Trench / metre - Provincial	$ c-i-c	25	4%	12%	10%	1
Trench / metre - Rural (ploughed)	$ c-i-c	25	4%	12%	10%	1
Line card in IRIM (per line)	$ c-i-c	9	5%	7%	10%	3
Line card in RSS/RSU (per line)	$ c-i-c	9	3%	7%	10%	3
Line card in LAS (per line)	$ c-i-c	9	3%	7%	10%	3
Access network management centre per access line	$ c-i-c	9	-7%	20%	10%	1

c-i-c- commercial -in-confidence data removed Note that not all of this data is Telstra cost data - where no cost data has been provided by Telstra, base case figures are used.

Table A.4
Telstra equipment costs for transport network*

	Capital investment AUS $	Asset life	Price trend	Operational costs as a % of capital cost	Scrap value as a % of equipment capital cost	Deprec method code
IRIM (per 480 line unit, excl MUX))	$ c-i-c	9	5%	7%	10%	3
IRIM - port	$ c-i-c	9	5%	7%	10%	3
IRIM - site		24	1%	12%	10%	1
RSS / RSU (per 2048 line unit)	$ c-i-c	9	3%	7%	10%	3
RSS / RSU - port	$ c-i-c	9	3%	7%	10%	3
RSS / RSU - site	$ c-i-c	21	0%	11%	10%	1
LAS (per 2048 line unit)	$ c-i-c	9	3%	7%	10%	3
LAS - port	$ c-i-c	9	3%	7%	10%	3
LAS - fixed (processor)	$ c-i-c	9	-8%	7%	10%	3
LAS - per BHCA (processor)	$ c-i-c	9	-8%	7%	10%	3
LAS - site	$ c-i-c	20	-1%	11%	10%	1
TNS - port	$ c-i-c	6	-6%	7%	10%	3
TNS - fixed (processor)	$ c-i-c	6	-6%	7%	10%	3
TNS - per BHCA (processor)	$ c-i-c	6	-6%	7%	10%	3
TNS - site	$ c-i-c	17	-1%	10%	10%	1
Synchronisation PRC	$ c-i-c	4	0%	13%	10%	2
Synchronisation SSU equipment per tandem switch	$ c-i-c	9	0%	13%	10%	2
Synchronisation SSU licence per tandem switch	$ c-i-c	9	0%	13%	10%	2
SDH MUX STM1	$ c-i-c	15	-8%	6%	10%	2
SDH MUX STM4	$ c-i-c	15	-8%	6%	10%	2
SDH MUX STM16	$ c-i-c	15	-8%	6%	10%	2
Digital cross connect	$ c-i-c	15	-8%	7%	10%	1
Line termination system	$ c-i-c	15	-6%	6%	10%	1
STM - 1 Regenerator	$ c-i-c	15	-9%	5%	10%	1
STM - 4 Regenerator	$ c-i-c	15	-9%	5%	10%	1
STM - 16 Regenerator	$ c-i-c	15	-9%	5%	10%	1
Repeater Site Cost	$ c-i-c	23	1%	12%	10%	1
12 fibre cable / metre	$ c-i-c	25	2%	10%	10%	5
24 fibre cable / metre	$ c-i-c	25	1%	10%	10%	5
48 fibre cable / metre	$ c-i-c	25	1%	10%	10%	5
96 fibre cable / metre	$ c-i-c	25	0%	10%	10%	5
Trench / metre - CBD	$ c-i-c	40	4%	11%	10%	1
Trench / metre - Metro	$ c-i-c	40	4%	11%	10%	1
Trench / metre - Provincial	$ c-i-c	40	4%	11%	10%	1
Trench / metre - Rural (ploughed)	$ c-i-c	40	4%	11%	10%	1
Trench / metre - Rural (ploughed - no duct)	$ c-i-c	40	4%	11%	10%	1
Signalling transfer point	$ c-i-c	9	-5%	8%	10%	1
Core network management centre per switch node	$ c-i-c	9	-7%	62%	10%	2

c-i-c- commercial -in-confidence data removed Note that not all of this data is Telstra cost data - where *no cost data has been provided by Telstra, base case figures are used.*

APPENDIX B. COST ALLOCATION ISSUES FOR SWITCHING

The costs of remote units and local switches need to be split into those that are line related and can be allocated to access, and those that are traffic related and can be allocated to transport.

For certain costs categories the appropriate allocation is clear cut:

- the cost of line cards (assuming this is just the cost of the card) is a per line card and should be attributed to access;
- the cost of ports is a traffic related cost and should be attributed to traffic.

The other principal cost categories for IRIM and RSS/RSU are:[30]

- the site cost/housing cost;
- the cost of an N line unit.

The costs of both of these can both largely be allocated, if a sufficiently detailed cost break down is provided.

For example the site cost could be allocated on the basis of floor space. Where the site cost includes the cost of power and air conditioning, these costs can be allocated on the basis of the relative power/cooling needs of different pieces of equipment.

The cost of an N line unit should be split according the functionality of the unit (ie an analysis needs to be carried out of what exactly the unit does in terms of a series of stages taking the traffic from the line card to the port; how each stage best fits with a description of "line related" vs "traffic related" and the relative costs of each stage can then be considered).

Unfortunately this kind of detailed break down is difficult to achieve.

In comparing Telstra data with data NERA has obtained elsewhere, there appear to be some clear differences (see Table B.1) for remote switches.

[30] Since an LAS is assumed to contain co-located RSS/RSUs, the same principles apply for the RSS/RSU part of the LAS.

Table B.1
Comparison of remote switching costs

Component	Telstra	NERA*
Line card	$c-i-c	$c-i-c
2048 line unit	$ c-i-c	$ c-i-c
Total	$c-i-c	$c-i c-

c-i-c- commercial -in-confidence data removed.

**Note these figures are averages over data provided by a number of different operators*

What we see is a very different cost *structure* - although the total cost is also different. We note the following:

- the Telstra figure for the line card is much lower. The fixed cost includes all of the functionality (as well as eg the cabinet) of the RSS / RSU to take traffic from the line card to the port and some of this cost should potentially be allocated to access;
- in the NERA figures the cost per line card includes more than just the line card - the cost of the line card controller is implicitly included (possibly a portion of this cost should in fact be allocated to transport).

These figures represent different extremes for allocating costs - and we will get different end results. Given that the figures do not seem to have been provided on a comparable basis, it is not appropriate to average over them for the purposes of arriving at a "base case" figure.

For the IRIM we have not used independent NERA data, as the figures we have do not seem to be directly comparable - hence we have relied on Telstra data. This still leaves the same issues as above. We would normally expect that the cost of a line card is about the same irrespective of where it is used. Our 2 cost scenarios are then built from:

- Telstra data;
- Telstra data reallocated to give a line card cost equivalent to that for an RSS / RSU.

Results are shown in Table B.2.

Table B.2
Comparison of IRIM costs

Component	Telstra	NERA*
Line card	$ c-i-c	$ c-i-c
480 line unit (excluding MUX)	$c-i-c	$ c-i-c
Total	$c-i-c	$c-i-c

*c-i-c- commercial -in-confidence data removed. *The total cost has been taken to be the same - but the costs have been reallocated between line and traffic*

LAS sites are assumed to include RSS / RSU units and the same fixed and per line card costs are used.

In both cases we can compare the proportion of line card costs to traffic related costs - this ratio can then be compared with what we expect to find based on international comparison.

Site costs are allocated in the model on the basis of the ratio of line to traffic related costs - this is clearly a simplification.

APPENDIX C. REAL VS NOMINAL COST OF CAPITAL AND DEPRECIATION

This Appendix looks at the issue of how to treat the required annual revenue in terms of real vs nominal figures.

The procedure we are currently using is as follows:

- all components of "required revenue" are estimated in real terms (in money of the day at the beginning of the year);
- nominal required revenue (and subsequently nominal charges) is estimated by inflating the real figures by an estimate of inflation over the year.

The following traces through the real terms calculation and shows how the end result can be restated in terms of nominal figures.

Real required revenue is calculated as follows. All the following parameters are defined in "money of the day" at the beginning of the year, ie time t_0.

Value of assets at time t_0	$= V_0$
Real rate of return	$= r$
Return on capital required	$= r \cdot V_0$
Value of assets at end of year (time t_1)	$= V_1$
Depreciation[31]	$= V_0 - V_1$
Operating costs as % of initial investment	$= Op$
Operating costs	$= Op \cdot V_0$
Required real revenue	$= V_0 \cdot [r + (V_0 - V_1) / V_0 + Op]$

Making the simplifying assumption that all transactions (including consumption of capital) take place at the end of year, we can translate real revenue into nominal revenue by multiplying by (1+I), where I= inflation over the year.

Nominal revenue required $= (1 + I) \cdot V_0 \cdot [r + (V_0 - V_1)/V_0 + Op]$

[31] Note that real depreciation measures the change in real value of the asset by comparing the value of the asset at two points in time using the same currency terms or "unit of measurement", eg March 1997 dollars.

It is possible to re-express this using nominal parameters (so that, for example, the nominal rate of return appears explicitly).

Nominal rate of return = R

Where the relationship between R and r is: $1 + R = (1 + r) . (1 + I)$

Or: $(1 + I) . r = R - I$

Using this we have:

Required nominal revenue $= V_0 R - V_0 I + (1 + I) V_0 - V_1 (1 + I) + Op V_0 (1 + I)$

$\mathbf{= V_0 R + (V_0 - V_1{}^1) + Opex^1}$

where V_1 = value of asset at time t_1 in t_0 prices, $V_1{}^1$ = value of asset at time t_1 in t_1 prices; $Opex^1$ = operating costs over year in t_1 prices.

In this form of expressing the result, all parameters are nominal. However the "depreciation" term incorporates both the real change in the value of the assets and the effect of inflation. This has the effect that, in principle, the "depreciation" term could be negative. This result is not in a form that accountants would normally recognise.[32]

To give a numerical example, we need to define a depreciation profile. If we simply use straight line depreciation then we have the following relationships.

Asset life = AL

$V_0 - V_1$ = 1 / AL

$V_0 - V_1{}^1$ $= V_0 - V_0 (1 - 1 / AL) . (1 + I) = (1 + I) . V_0 / AL - IV_0$

Using some simple numbers we can illustrate the two approaches as shown in the following two tables. We take I=3% and AL=10 years in these examples.

32 Note that from an accounting point of view, the nominal gain on assets is put through the total gains account, rather than being used to reduce the depreciation charge in the P&L.

Table C.1
Example 1: Start with everything in real terms and convert end result to nominal terms

Parameter	Value
V_0	100
V_1	90
Depreciation (= V_0 / 10)	10
Rate of return	9%
Allowed return	9
Total real capital charge	19
Total nominal capital charge	**19.57**

Table C.2
Example 2: Use nominal terms throughout

Parameter	Value
V_0	100
$V_1{}^1$ [= V0 (1 - 1 / AL) (1 + I)]	92.7
"Depreciation"	7.3
Rate of return	12.27%
Allowed return	12.27
Total nominal capital charge	**19.57**

We note that in example 1 the nominal total capital charge is only 3% higher than the real total capital charge, even though the nominal cost of capital is approximately 3 percentage points higher than the real cost of capital. This is because as we see in example 2, increases in the asset value due to a rise in the general price level reduce the "depreciation" charge by the holding gain.

Theoretically the two approaches are identical. In practical terms the first approach is marginally easier to apply as the depreciation term is simpler. Note that even with the second approach we do not avoid a need to identify the level of inflation - this is needed to estimate the change in asset value in nominal terms.