ANNEXURE C

APPROPRIATENESS OF TELSTRA'S COST MODELLING METHODOLOGY

[NON CONFIDENTIAL VERSION]

ANNEXURE B TO TELSTRA'S DETAILED SUBMISSION IN SUPPORT OF ITS UNDERTAKINGS DATED 9 JANUARY 2003

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APPROPRIATENESS OF TELSTRA'S COST MODELLING METHODOLOGY

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1 PRELIMINARY MATTERS

1.1 Confidentiality and Qualifications

1. The information in this statement is confidential to Telstra Corporation Limited **("Telstra")**. I have prepared this statement on the assumption that this report will remain confidential, subject to disclosure for the purpose of assessing Telstra's undertakings given on 9 January 2003 and to the terms of confidentiality undertakings signed by persons involved in that process.

2. A summary of my qualifications together with my curriculum vitae are attached in Annexure A.

1.2 Scope of statement

3. I have been asked by Telstra to provide a report as to the appropriateness of Telstra's methodology for the estimation of efficient network costs ("**EN costs**") of the services that are the subject of the undertakings. Those services are PSTN originating and terminating access services (**"PSTN OTA")**, local carriage service (**"LCS"**) and unbundled local loop service (**"ULLS"**) -- together the "**UT Services**".

4. In preparing this report I have examined a description of a bottom-up engineering-based cost model – the PSTN Ingress Egress II (**"PIE II"**) model – constructed by Telstra to estimate those efficient network costs. I have assessed the PIE II model's cost estimating methodology from the perspective of economic principles of cost estimation and the practice of TSLRIC modelling in regulatory proceedings in other countries.

5. In reaching my opinion in this report, I have had reference to the HCPM, HM5.0a, and BCPM 3.1 cost models and I have relied on a description of the PIE II model provided to me by Telstra and the documents and data sources that are referenced in the footnotes of this report.

2 EXECUTIVE SUMMARY

6. As a matter of regulatory policy in Australia and in other countries, the prices for UT services should be based on Total Service Long-Run Incremental Cost

("**TSLRIC**"), plus an allocation of common costs. Such efficient network costs (EN costs) are consistent with the Australian legislative criteria for determining access prices.

7. In practice, estimates of EN costs have been calculated by constructing engineering-economic models of a telecommunications network based on individual network elements. These models are called Total Element Long-Run Incremental Cost ("**TELRIC**") models. In TELRIC models each service is well defined by its uses of the network elements. This approach substantially reduces the magnitude of the problem of measuring and allocating common costs.

8. In most countries, the scope of the modelled network includes supplying basic PSTN services to residential and business customers, and access services such as the UT services. The PIE II model includes these services and, in addition, leased lines, ISDN services, and copper-based access services.

9. An efficient network must be provisioned with sufficient capacity both to meet current demand and to provide spare capacity to serve future growth. In international practice, the costs of spare capacity are recovered in the prices of services in both current and future periods.

10. The major requirements for a TELRIC model include efficient production of services, employment of best-in-use technology, and a forward-looking perspective that accounts for current and future prices and technological advances. In international practice, regulators have adopted a "scorched-node" approach that optimises the design of a new network given the existing switching locations. The PIE II model is consistent with these requirements but includes some features that achieve greater efficiency than would be obtained from a strict scorched-node model.

11. The PIE II model dimensions the customer access network using data for each local service area. Copper access cables to remote access units connect subscribers. Local and transit network switches are connected by fibre-optic cables and rings. The major network elements, including distribution and main cables, remote access units, switches, cable trenches, and transport facilities are dimensioned using current best-practice design principles. In line with

international cost modelling practice, operating and maintenance expenses, common support expenses, and indirect capital costs are estimated by adjusting current actual expenses to reflect a forward-looking view.

12. The PIE II model is based on best-practice network technology. It is forward-looking, incorporating subscriber and traffic forecasts for the years 2002/03 – 2004/05. Provisioning of each network element is based on efficient engineering principles that take into account subscriber and traffic density. Asset prices and operating, maintenance, and indirect expenses are estimated based on recent experience with current-technology equipment.

13. In my opinion, the cost-estimation methodology and the PIE II model appropriately incorporate the principles for TELRIC modelling that have been developed and applied in international practice.

3 EFFICIENT COSTS AND PRICING

3.1 TSLRIC

14. The ACCC has, in the past, stated that prices for declared services should, in general, be based on the Total Service Long-Run Incremental Cost **("TSLRIC")** of providing the relevant declared service[1] and has used a cost model to calculate an estimate of the TSLRIC of various declared services[2].

15. As applied to services provided over the PSTN **("PSTN Services")**, TSLRIC embodies the following concepts:

- *Total service* requires that the cost of producing the entire output of the service be evaluated. The total output is the sum of the quantity of output used by the incumbent network supplier plus all output required for services used by other operators.
- *Long-run* incremental costs permit all inputs to be considered variable, so that all fixed costs and capital costs are included. The technology of

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[1] ACCC, "Access Pricing Principles: Telecommunications," July 1997, p. 21 ("Access Pricing Principles").

[2] ACCC, "A report on the assessment of Telstra's undertaking for the Domestic PSTN Originating and Terminating Access services," July 2000 ("Assessment of Telstra's Undertaking").

production should be best in use, one that is most cost-effective in current networks.

- *Incremental costs* measure the increase in total costs of providing PSTN Services from a *baseline* in which the services in question are not produced, but other services may be produced. The incremental costs are the difference between the total costs of producing both the baseline services and the increment, and the total costs of producing only the baseline services.

16. A *common cost* is one that the access provider must incur in order to produce the relevant service, another service, or both of those services together[3]. For example, a common cost would be the cost of a local area switch with the minimum capacity necessary to provide either the relevant service or another service. Such costs would be incurred even if only the other service, but not the relevant service, were produced. As a consequence, common costs are not incremental to producing the relevant service. In its *pure* form, the TSLRIC of a PSTN Service therefore excludes any common costs that are shared with other services.

17. However, it is recognized both in Australia and internationally that, in addition to pure TSLRIC, prices should include some recovery of costs that are common to both other services and the relevant service[4]. In this report, I will refer to TSLRIC

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[3] Some costs are likely to be common to *all* services produced by the firm. These may include such things as the costs of general corporate management and network planning.

Other costs can be common to a *subset* of two or more services, but not common to the remaining services. For example, local, long distance and fixed-to-mobile services all use PSTN switching; therefore, some investment and maintenance costs of switching equipment, and their supporting buildings and land, are likely to be common to those services. However, those costs are not common to leased line services, which make no use of PSTN switching.

The TSLRIC of a service includes not only the costs directly associated with that service but also any changes (increases or decreases) that occur in any costs of shared resources when that service is produced with the other baseline services. Increases in the costs of shared resources could, for example, be due to investment in a larger capacity network element that is required because total demand increases due to including the relevant service. The costs of shared resources could also change if efficiently producing that service in conjunction with the other services involves shifting to a different technology. For example, if the service to be evaluated were a high-bandwidth data service, the efficient method of production could result in shifting from a distribution network based on twisted-pair copper cables to one using coaxial or fibre-optic cables. In this case, it is likely that the magnitude of costs shared by the relevant service would change.

[4] (A) The FCC concluded that “the prices that new entrants pay for interconnection and unbundled elements should be based on the local telephone companies [*sic*] Total Service Long Run Incremental Cost of a particular network element … plus a reasonable share of forward-looking joint and common costs.” See FCC, “In the Matter of Implementation of the Local Competition Provisions in the Telecommunications Act of 1996,” CC Docket No. 96-98, First Report and Order, Released: August 8, 1996, ¶ 29 (“FCC Local Competition Order”).

plus an allocation of common costs as “Efficient Network Costs” or “**EN costs**”. If prices include the recovery of common costs for all products and services produced by the access provider, then prices based on those costs should allow the access provider to just recover the full cost of all its products. In my opinion, it is desirable for prices of individual services to be based on EN costs in order to recover common costs as well as pure TSLRIC.

18. EN costs measure the cost of producing all units of the relevant service. When EN costs are divided by the number of units of service produced, the resulting value measures the cost per unit, averaged over the entire increment of the service[5].

19. Much of the access provider’s network consists of capital investment in network elements, whose costs must be recovered over the lifetimes of those assets. Because demand for services is often growing and technology is changing, the efficient recovery of such costs requires analysis of dynamic conditions over many years.

20. In my opinion, prices for UT Services that are based on EN costs are consistent with the Australian legislative criteria for determining access prices. Such EN cost-based prices ensure recovery of the efficiently-incurred costs of providing the services, promote the legitimate business interests of the access provider and the

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(B) Oftel, in setting charges for call termination and for general network baskets, “decided to use an equal proportionate mark-up” to recover the common costs between conveyance and access. See Oftel, “Network Charges from 1997,” July 1997, ¶ 3.18 (“Oftel Network Charges”).

(C) In the ACCC’s terminology, “TSLRIC also includes common costs that are causally related to the access service” and the ACCC found that, “where appropriate, TSLRIC can include a portion of common costs.” See Access Pricing Principles, pp. 22, 32. More recently, the ACCC has used the term “**TSLRIC+**” to refer to TSLRIC plus a portion of common costs. ACCC, “Local Carriage Service Pricing Principles and Indicative Prices - Final Report,” 5 April 2002.

(D) **“**TSLRIC, in relation to a telecommunications service, (a) means the forward-looking costs over the long run of the total quantity of the facilities and functions that are directly attributable to, or reasonably identifiable as incremental to, the service, taking into account the service provider's provision of other telecommunications services; and (b) includes a reasonable allocation of forward-looking common costs”. New Zealand Telecommunications Act 2001, 20 December 2001, Designated services and specified services, Schedule 1.

[5] “The forward-looking economic cost per unit of [a network] element equals the forward-looking economic cost of the element … divided by a reasonable projection of the sum of the total number of units of the element that the [access provider] is likely to provide to requesting telecommunications carriers and the total number of units of the element that the [access provider] is likely to use in offering its own services, during a reasonable measuring period.” FCC Local Competition Order, Appendix B – Final Rules, Section 51.511 (a).

long-term interests of end-users of services, and encourage economically efficient use of, and investment in, the infrastructure that supplies those services.

3.2 TSLRIC principles

21. The TSLRIC concept has been widely used by telecommunications regulators in other countries to set the price of services such as the UT Services"[6]. The guiding principles that have evolved from this practical experience in the US, the UK and Europe are directly and appropriately applicable to measuring the EN costs of the UT Services. Like the ACCC, the regulators in those countries are responding to similar legislative imperatives, including promoting competition in the market for the relevant services, encouraging economically efficient production and investment, and promoting the long-term interests of end-users.

4 EFFICIENT NETWORK COSTS IN PRACTICE

22. Implementation of the theoretical costing and pricing principles discussed in the previous chapter raises difficult practical issues that must be confronted when calculating the EN costs of telecommunications services.

4.1 Practical models are based on costing network elements

23. Analysing costs in terms of services is extremely complicated and thus impractical[7]. However, the calculations required by economic theory can be very substantially simplified in practice by representing each telecommunications

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[6] (A) US: "[P]rices for interconnection and unbundled elements … should be set at forward-looking long-run economic cost. In practice, this will mean that prices are based on the TSLRIC of the network element, which we will call Total Element Long Run Incremental Cost (TELRIC), and will include a reasonable allocation of forward-looking joint and common costs." FCC Local Competition Order,¶ 672.

(B) Europe: "[The Independent Regulators Group] endorses the view of the European Commission that the FL[forward-looking]-LRIC approach to cost allocation is the one that will lead to results that best reflect interconnection tariffs that would occur in a competitive environment;" "Principles of implementation and best practice, regarding FL-LRIC cost modelling" as decided by the Independent Regulators Group, 24 November 2000. Henceforth, IRG Principles of Implementation.

(C) UK: "[T]he cost methodology used should be long run incremental cost **(LRIC)**, as that most closely reflects the way in which charges would be set in a competitive market." Oftel's submission to the Monopolies and Mergers Commission inquiry into the prices of calls to mobile phones, May 1998, ¶ 1.12. Henceforth, Oftel's Submission.

(D) NZ: "Final pricing principle: Either-- (a) TSLRIC; or (b) … (i) a pure bill and keep method; or (ii) a pure bill and keep method applied to two-way traffic in balance (or to a specified margin of out-of-balance traffic) and TSLRIC applied to out-of-balance traffic (or traffic beyond a specified out-of-balance margin)", Telecommunications Act 2001, 20 December 2001, Designated services and specified services, Schedule 1.

[7] See Annexure D.

service as the product of the intermediate services of particular network elements or components – local loop, local switch, interexchange transport, and so on. The individual network elements are then combined in a model to produce the costs of final telecommunications services demanded.

24. In the US the FCC found that:

> "*separate telecommunications services are typically provided over shared network facilities, the costs of which may be joint or common with respect to some services ... The network elements ... largely correspond to distinct network facilities*"[8].

25. Confronted with the substantial practical difficulties of EN cost analysis at the level of the final telecommunications service, the FCC established guidelines for modelling EN costs of telecommunications services at the network level. It termed the analogous incremental cost Total Element Long-Run Incremental Cost **("TELRIC")** and determined that:

> "*the amount of joint and common costs that must be allocated among separate offerings is likely to be much smaller using a TELRIC methodology rather than a TSLRIC approach that measures the costs of conventional services. Because it is difficult for regulators to determine an economically-optimal allocation of any such joint and common costs, we believe that pricing elements, defined as facilities with associated features and functions, is more reliable from the standpoint of economic efficiency than pricing services that use shared network facilities*"[9].

26. At the network element level, the usage of a single network element by different PSTN Services is essentially homogeneous. For example, a minute of traffic processed at a given switch at its peak period imposes the same capacity and

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[8] FCC, "In the Matter of Implementation of the Local Competition Provisions in the Telecommunications Act of 1996", CC Docket No. 96-98, First Report and Order, Released: August 8, 1996, ¶678. Henceforth, FCC Local Competition Order.

[9] Ibid.

operating cost requirements whether the traffic is due to STD, IDD, or PSTN OTA. Consequently, the peak-period minutes of the different PSTN Services can be summed to obtain the aggregate demand for an element. The incremental cost of an additional unit of peak-period traffic supplied by that element is then the same for each of those services.

27. I discuss the requirements for designing a forward-looking network elements model of EN costs in light of best international practice further in chapter 7. In chapter 8 I then examine Telstra's PIE II model in light of these requirements.

4.2 Services are well-defined by their uses of the network elements

28. In a TELRIC model, *routing factors* measure the uses of a network element per unit of service. Different services make somewhat different uses of the network elements and these differences are represented by different routing factor values. Differences in the UT Services supplied to an access seeker and similar services that are self-supplied by the access provider are well defined by differences in their routing factors[10].

29. If the access provider's final services (local calls, STD calls, etc.) make use of the same network elements as the UT Services, but with somewhat different values of routing factors, the cost of that self-supply differs from the cost of the UT Services.

4.3 Common costs in a network-elements model

30. In a TELRIC model all of the costs of a network element are included in the costs calculated by the model. The TELRIC of the element is the total cost of the element. The per-unit TELRIC of an element is obtained by dividing the total cost of the element by total units of use of the element (e.g., number of minutes for switching or transport). The effect of this calculation is that the fixed costs of

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[10] For example, in the PIE II model, a typical metropolitan minute of voice local calls uses 2 minutes of remote access unit ("**RAU**") capacity (one RAU is required at each end of the call), about 1.9 minutes of local area switching ("**LAS**"), and about 0.3 minutes of transit switching ("**TNS**"). In contrast, a typical metropolitan PSTN originating or terminating access interconnect call uses 1 minute of RAU, 1 minute of LAS, and 0.5 minutes of TNS.

the element and any cost reductions due to economies of scale are allocated to individual services in proportion to their use of the element[11].

31. Any common costs in a TELRIC model, such as corporate overhead expenses and indirect costs, are costs that are common to more than one type of network element. The common costs are generally allocated to the network elements in proportion to each element's asset value. The resulting per-unit cost is a TSLRIC-based value for the network element that includes the TELRIC of that element plus a mark-up for that network element's common costs that is proportionate to the use of the element.

32. The analysis of costs in terms of network elements, rather than services, substantially reduces the magnitude of the problem of measuring and allocating common costs[12]. As the FCC observed:

> "*Because the unbundled network elements correspond, to a great extent, to discrete network facilities, and have different operating characteristics, we expect that common costs should be smaller than the common costs associated with the long-run incremental cost of a service. We expect that many facility costs that may be common with respect to the individual services provided by the facilities can be directly attributed to the facilities when offered as unbundled network elements. ... A properly conducted TELRIC methodology will attribute costs to specific elements to the greatest possible extent, which will reduce the common costs. Nevertheless, there will remain*

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[11] For example, in the PIE II model the estimate of the costs of the CAN are determined by the total number of basic access SIOs and all other copper-based access services including leased lines, data access services, and ISDN lines. The CAN costs are then divided by the total number of copper lines used by those services to obtain a per-unit TELRIC of the access network element, so that the direct costs of the access network are effectively distributed in a proportionate fashion to PSTN SIOs, and all other users of the copper access network.

[12] I am informed by Telstra that in the PIE II model approximately 9.2% of the total costs of the PSTN are indirect costs, which are allocated to network elements in proportion to the direct investment in those elements. I understand that calculations made by Telstra using the PIE II model indicate that when an approximation of TSLRIC is calculated for each of the major PSTN Services at a network services level, rather than at the network elements level, more than 90% of the total costs of the PSTN Services are common costs. Consequently, the prices that result from a TSLRIC model based on network services, rather than a TELRIC model based on network elements, would be extremely sensitive to how common costs were allocated to the individual services. This would open up a huge scope for error – nearly the entire price of each service would depend on the allocation rule used for common costs.

> *some common costs that must be allocated among network elements and interconnection services*"[13].

5 THE SCOPE OF THE MODELLED NETWORK

5.1 Included services

33. To calculate the EN cost of supplying the UT Services, one must first determine:

- which services and what quantities of those services should be included in the increment whose cost is to be calculated, and
- which other (baseline) services should be assumed to be produced in the absence of those services.

34. In establishing guidelines for TELRIC models, regulators in most countries have specified the set of baseline services and the increments whose costs are to be measured by those models[14]. Typically, the services included in a cost model of access services (such as the UT services) are the basic PSTN Services offered to residential and business customers and the UT Services supplied to access seekers. The entire quantity of these services is included in the increment[15].

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[13] FCC Local Competition Order, ¶695.

[14] (A) FCC: "The cost study or model must estimate the cost of providing service for all businesses and households within a geographic region. This includes the provision of multi-line business services, special access, private lines, and multiple residential lines." FCC's Universal Service Order, ¶ 250.

(B) Oftel: "The network assumed for the purpose of developing the incremental cost methodology is a stand-alone network of inland Public Switched Telephone Network (PSTN) services and inland private circuits." Oftel's Bottom-Up Model, p. 1.

(C) WIK for the RegTP: "We must also remember that network elements can be used by circuit-switched services, packet-switched services and fixed connections/leased lines alike." WIK Core Network Model, p. 4.

[15](A) "For our specific purposes it follows that traffic demand as a whole, including all the calls fully remaining in the interconnection service provider's network, is relevant as well as (additional) demand for interconnection services." WIK Core Network Model, p. 4.

(B) "The term 'total service,' in the context of TSLRIC, indicates that the relevant increment is the entire quantity of the service that a firm produces, rather than just a marginal increment over and above a given level of production." FCC Local Competition Order, ¶ 677.

(C) "In the methodology to calculate incremental costs, the increment in question is the whole of the output of a service … The long run incremental cost of conveyance is the cost that would be saved in the long run if *no* traffic were provided over the network, but access were to continue to be provided**."** (emphasis added) Bottom-Up Model, p. 2.

35. It would be incorrect to calculate an incremental cost for less than the total increment of service or to exclude fixed costs of providing the service. Such a calculation would measure only the *additional* costs of providing some additional units of a PSTN service and would carry a very substantial risk of understating the efficient cost of that service. For example, the incremental cost of providing an increment consisting of just the originating minutes of traffic delivered to an access seeker would measure only the additional costs of expanding and operating additional capacity needed to augment an existing network of access lines, local switches and interexchange transport facilities. That calculation would exclude the fixed costs of the customer access network, local switches, and transport equipment that are incurred to provide the PSTN service supplied by the access provider to its end-user customers. A price obtained from such a calculation would fail to recover some costs essential to producing the service. Competition in the supply of other services that share in the common costs would limit the access provider's ability to recover those common costs from other services. This would be inconsistent with the legislative principle that any prices that are set should account for the legitimate business interests of the access provider, and the access provider's investment in facilities used to supply the service. A price that failed to provide for recovery of some common costs would also disadvantage the access provider relative to competitors and thus not be competitively neutral and would not promote competition in the market for declared services.

36. Regulators have also indicated that, for the purpose of calculating costs of PSTN OTA-like services, such as LCS and ULLS, the baseline is one in which there is no production of any service. With a zero baseline, the calculated TELRIC is equivalent to the *stand-alone cost* of the services included in the increment – that is, the cost of producing those services on their own with no others[16].

37. In addition to the PSTN Services, some regulators have required that certain non-PSTN Services be included in the service increment whose cost is calculated in a

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[16] Bottom-Up Model, p. 1.

TELRIC model. The principal such services are *leased lines* and *Integrated Services Digital Network* **("ISDN")**[17].

38. These non-PSTN Services are supplied using the network elements that are shared with PSTN Services. Including leased lines and some data services in the TSLRIC increment causes the total number of lines and aggregate volume of traffic to be increased. Because some of those components benefit from economies of scale, the enlarged definition of included services results in a lower per-unit cost for the PSTN Services, when TELRIC is measured from a zero baseline.

39. In my view, services included in the increment should include the total volume of services that are close substitutes in demand or services that use the same network elements and thus have a similar cost structure.

40. In this context, for the reasons set out in Annexure E:

    (a) in terms of traffic, the increment should include all of the PSTN, UT and ISDN services and also traffic from other services that use the PSTN; and

    (b) in terms of access services the increment should include all services, which use copper-based lines.

    I am informed by Telstra that the PIE II model includes all such traffic and services.

41. When the increment of services included in a TELRIC model encompasses a broad set of services (in the PIE II model, all PSTN, ISDN and UT services plus

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[17] In the US, the services to be costed are specified by the FCC's guidelines as the total volume of all narrowband (voice and low-speed data) switched and leased line services, beginning at (and including) the network interface device at the end-user customer's premises and going to the point of interconnection with another service provider. Leased lines are included in the customer access and interexchange networks, while transport for mobile and broadband services is excluded.

In the UK, Oftel's bottom-up model of the local network is a "a stand-alone network of inland Public Switched Telephone Network (PSTN) services and inland private circuits. The network ... excludes international services and advanced services such as Integrated Services Digital Network (ISDN) and Virtual Private Networks".

In Germany, where the ISDN is used for a substantial proportion of the switched voice services, the WIK model for RegTP includes PSTN, ISDN, and leased lines.

all copper-based access services) the cost analysis will capture substantially all of the relevant shared costs. A zero baseline can then be used without excluding from the cost analysis any services and costs that would have a substantial effect on the EN costs estimates for the individual services included in the increment. The TELRIC approach to estimating EN costs for a service includes in the definition of the increment those services that share the use of a network element, and provides the economic foundation for the use of a zero baseline.

42. In my opinion, the inclusion of the services set out in paragraph 40 above in the increment is consistent with the legislative objective of promoting competition in the market for the listed services by ensuring that the prices for the UT Services used by the access seeker are based on the same costs as are allocated to PSTN Services.

5.2 Cost of a specific service

43. The fact that a TELRIC model estimates total stand-alone costs of all the services in the increment does *not* mean that the per-unit cost of the UT Services – or any specific service – is calculated by dividing the stand-alone cost by the total volume of services to obtain an average per-unit cost.

44. In the PIE II model, costs are calculated separately for each network element. To calculate the cost of a *specific* service included in the model, the model first determines the amount of each network element that is needed for that service. “Routing factors” measure the proportion of each network element required per unit of service.

45. The per-unit costs of the specific service are obtained by applying that service’s routing factors to the unitised cost of each of the network elements and summing those calculated values over all elements used. In general, each specific service will have a *different* calculated per-unit cost because it uses the network elements in different proportions. A TELRIC model properly distinguishes differences in the incremental costs of different services and suppliers according to their relative uses of network elements.

5.3 Forecasts

46. A TELRIC model constructs an hypothetical network to serve the forecast traffic and the forecast number of customers included in the increment for the model planning period. When the model is used to estimate costs for a future date, the number and location of customers are forecast based on recent counts of customers and the traffic volumes are forecast from measurements of recent traffic.

47. The PIE II model uses forecast values of customers and traffic. In my opinion, it is consistent with the forward-looking principles of TSLRIC analysis to use the most current forecast value available prior to the period for which the EN costs calculations are to be made.

5.4 Customer locations

48. The degree of geographic detail incorporated into TELRIC models varies in international practice. The FCC's hybrid cost model uses geographically-coded customer-specific location data in each individual exchange area. That model has developed optimisation algorithms to minimise the overall costs of the distribution network by first grouping customers into trial "clusters" and calculating for that grouping the total costs of cable, conduit and trenching, and remote terminals. The grouping and calculation of costs is then revised and iterated until further iterations do not result in a lower total cost for the distribution network in that local exchange area.

49. The PIE II model also uses geographically-coded customer-specific location data and optimises the layout of the distribution network by first disaggregating each exchange service area into a number of distribution areas. In most distribution areas, cable routes are constructed to end-user subscriber addresses from distribution pillars, and main cable routes linking those distribution areas are determined using a minimum distance algorithm. Very low-density distribution areas are served directly by main cable.

50. In my opinion, the PIE II model's use of location data for individual end users should provide reasonable estimates of efficient CAN and conveyance costs by

accounting for differences in capacity requirements in different exchange service areas.

6 PROVISIONING OF THE PSTN

51. Network provisioning raises several related issues – the values of key provisioning parameters required to achieve efficient levels of investment and operating expenses, the efficient investment in spare capacity, and the recovery of the cost of that investment in the prices of the PSTN and UT Services. I review each of these matters in this chapter and discuss the particular provisioning factors used in the PIE II model in section 8.5.

6.1 Provisioning to meet current demand

52. Efficient provisioning to meet current demand requires, at a minimum, sufficient capacity to serve all current SIOs and traffic generated by the modelled services. In addition, to serve that fixed number of SIOs, additional capacity is needed to repair faults and to provide services to subscribers who change locations.

53. In order to be able to repair faults all telecommunications operators construct their networks with spare cables and electronic components. For components, such as cables, that incur high fixed costs of installation it is efficient to provision sufficient spare capacity to make physical replacement unlikely.

54. The mobility of the subscriber population requires the access provider to maintain spare capacity in the distribution network in order to accommodate movement of customers – the disconnections and reconnections of the SIOs. By this means, the access provider can reduce the time required to connect a service and thus to satisfy its Customer Service Guarantee, and also to reduce ongoing operational expenses.

6.2 Efficient investment in spare capacity

55. Investment in spare capacity to serve a larger future demand is efficient when there are:

- economies of scale from indivisible assets; or

- when the costs of activities that create more capacity at a later time exceed the financing cost of investing in the spare capacity in advance of its use.

56. The provisioning practices of telecommunications operators include investment in spare capacity when growth in demand is anticipated, and all of the TELRIC models with which I am familiar provide for spare capacity to efficiently accommodate growth.

57. When demand is growing, if no provision is made for spare capacity the access provider will incur higher operating costs in endeavouring to meet its service quality standards. Over the lifetime of the network assets these costs, and the costs of incremental additions to capacity, which are not included in the PIE II model, would exceed the additional costs of efficiently incurred spare capacity.

6.3 Recovery of provisioning costs

58. When it is efficient to invest in some capacity in advance of its use, it is necessary to recover the cost of that investment in the prices charged in one or more periods. If the access provider is denied the ability to recover costs of efficient spare capacity, it will not undertake the pre-provisioning investment, and higher total costs will be incurred as the network is expanded incrementally each time there is an increase in demand. In my opinion, the recovery of efficiently incurred costs of spare capacity in both current-period and future-period prices is appropriate.

59. The ACCC, in its final decision on Telstra's first PSTN undertaking for 1997/98, adopted parameters for CAN provisioning (NERA option 2) that did not provide for the recovery of spare capacity costs[18]. Further, in its final decision on Telstra's first PSTN undertaking, the ACCC reported PSTN rates for 1998/99 on the basis of the same methodology as for 1997/98 and hence included the same parameters for CAN provisioning. However, this position fails to provide an alternate means to recover efficient investment in spare capacity and is inconsistent with section 152CR(1) of the Trade Practices Act, which requires that the legitimate

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[18] **(a)** ACCC, “Assessment of Telstra's Undertaking for Domestic PSTN Originating and Terminating Access,” Final Decision, June 1999, p. 67. **(b)** NERA's "option 2" parameters provided for 1.33 copper pairs per SIO in the distribution network and 1.25 per SIO in the feeder network. NERA, “Estimating the Long Run Incremental Cost of PSTN Access, Final Report for ACCC”, 1999, p. 41 (“NERA Report”).

commercial interests of the access provider and its investment in facilities used to supply access services be recognized.

60. This position also stands in contrast to international practice. Elsewhere, TELRIC models make explicit provision for spare capacity to serve growing demand and in other jurisdictions regulators have consistently recognized the appropriateness of recovering some of the costs of spare capacity in the current period. In my opinion, the PIE II model appropriately follows this position and provides for recovery of some of the costs of spare capacity in the current period.

61. In principle, there is a choice of *when* to recover efficiently incurred spare capacity costs. Costs of spare capacity needed for future use can be recovered in current period charges, as has been calculated in the PIE II model. Alternatively, one could take a *backward-looking* approach to pricing. In that case, current-period access prices would need to include payments for spare capacity that had been incurred in the past[19]. I have analysed the likely effect of the latter approach in Annexure F. That analysis suggests that backward-looking pricing would likely result in *higher* charges in the current period than would forward-looking pricing principles.

62. To satisfy the legislative criterion of recognizing the legitimate business interests of the access provider, and the provider's investment in facilities used to supply the UT Services, prices based on EN costs should provide a competitive rate of return on the invested capital and recovery of efficient levels of investment and expenses. It is efficient to have spare capacity in a TELRIC model, i.e., capacity that exceeds the level that would be efficient if costs are minimized with no provision for growth and thus no consideration to achieving economies of scale beyond the pricing period. Telstra's PIE II model, like the US TELRIC models, appropriately includes the costs of spare capacity in its calculation of forward-looking prices.

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[19] This argument is recognized by NERA. NERA Final Report, p. 12.

7 ESTIMATING THE COSTS OF SUPPLYING THE UT SERVICES USING A COST MODEL

63. This chapter describes the principles applicable to constructing a bottom-up engineering cost model to estimate the efficient costs of supplying the UT Services.

64. Any model of an actual network must necessarily simplify the myriad details of building and operating a network. A TELRIC model can, however, represent in summary form the effects of a more detailed optimisation of the components of an actual network's design. EN costs estimated using TELRIC models represent current best international practice in assessing the costs of supplying the UT Services. The sensitivity of final cost estimates to the assumptions required for a bottom-up model can be assessed by calculating results under a range of alternative conditions that represent the uncertainty or imprecision of important parameters.

7.1 TELRIC models in regulatory proceedings

65. TELRIC models are ordinarily models in which a hypothetical network is designed to serve current and projected demand, based on (a) best-practice technology, and **(b)** efficient operation.

66. In such models, the entire PSTN is designed afresh. As a result, equipment costs and operating procedures are unconstrained by past choices and past technologies. The network design should be informed by industry experience and incorporate the most cost-efficient technologies and procedures currently available and in use.

67. In Australia, Telstra has constructed a TELRIC model of its PSTN, the PIE II model. Bottom-up models have also been constructed in other major jurisdictions[20].

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[20] The principal TELRIC models of the local telephone network include:

(1) In the US, the Benchmark Cost Proxy Model ("BCPM") (see BellSouth, INDETEC International, Sprint and US WEST, "Benchmark Cost Proxy Model Release 3.1, Model Methodology," April 30, 1998 Edition. The Hatfield Model ("HM") (see HAI Consulting, "HAI Model, Release 5.0a – Model Description," February 16, 1998, p. 56. and the FCC's Hybrid Cost Proxy Model (HCPM), also termed the Synthesis Model (which incorporates some features of the HAI Model version 5.0a and the Benchmark Cost Proxy Model version 3

68. In all cases, the TELRIC cost models adopted by regulators are used to estimate the EN costs of relevant services using forward-looking principles. All of these models use broadly the same methodological approach – estimating the bottom-up, forward-looking cost of building a local telephone network employing currently efficient technologies and constructing that network using the existing locations of local switches to serve current exchange areas. Each of the models includes three fundamental structural elements: (1) a customer access or "local loop" network, (2) digital switching and signalling, and (3) digital transport connecting the switches to each other and to other operators.

7.2 Requirements for TELRIC models

69. In my opinion, the international experience accumulated in the development of TELRIC models should be used in the construction and assessment of a TELRIC model for the pricing of the UT Services in Australia. There is broad agreement in international practice on the major requirements for a TELRIC model, and in my opinion these requirements have been incorporated in the PIE II model.

70. In my view, a TELRIC model should include (a) efficient production of services, (b) best-in-use technology, and (c) a forward-looking perspective. I review these criteria below.

7.2.1 Efficient production of services

71. Efficient production of services requires that the modelled network be designed to serve the forecast number and distribution of customers and their traffic, meet the established quality of service standards, and satisfy other regulatory requirements.

(BCPM)). (See FCC, "In the Matter of Federal-State Joint Board on Universal Service," CC Docket No. 96-45, Fifth Report and Order, Released: October 28, 1998, ¶ 4. Henceforth, Fifth Order).

(2) In the UK, Oftel's Bottom-Up Network Model.

(3) In Germany, bottom-up models of both local access and core (long-distance) networks constructed by the Scientific Institute for Communications Services (WIK) for the German regulator RegTP (see WIK: "Analytical Cost Model Local Loop, Consultative Document 2.0," 8 November 2000 (henceforth, WIK Local Loop Model) and "Analytical Cost Model – National Core Network, Consultative Document 2.0, Prepared by WIK for the RegTP," 30 June 2000 (henceforth, WIK Core Network Model).

(4) In Europe, the European Commission commissioned development of a flexible bottom-up model that can be used by member states of the European Union (see Europe Economics, "Study On The Preparation Of An Adaptable Bottom-Up Costing Model For Interconnection And Access Pricing In European Union Countries: A Final Report for Information Society Directorate-General of the European Commission," April 2000. Henceforth, Europe Economics Report.)

The model should dimension components of the network to exploit economies of scale and deploy the most cost-efficient technologies that are currently in use by access providers.

7.2.2 Best-in-use technology

72. The technology of telecommunications has evolved almost continuously since Alexander Graham Bell's invention of the telephone in 1876. Telephone networks have been constructed and expanded to take advantage of technological advances. At any given time, however, an actual network will likely include a mix of equipment from current and earlier generations of technology[21]. For example, network operators continued to use analogue electronic switches for a decade or more while installing digital switches.

73. TSLRIC principles require that costs be calculated for an hypothetical network that is newly constructed and makes use of current-generation technology. The *best-in-use* standard has generally been held to require using technology and equipment that is actually deployed in operating networks and has been proven feasible and cost-effective[22]. Therefore technologies that are not yet in commercial use in an access provider's network would not qualify for inclusion in a TELRIC model.

74. Most TELRIC models have not, as yet, explicitly incorporated a range of alternative technologies. In evaluating bottom-up cost models presented for its consideration, the FCC focused on the conditions under which fibre-optic cable in the customer access network is "more efficient" than copper cable. However, while recognizing the potential to use wireless technology in the customer access network in sparsely populated serving areas, the FCC has not required cost models

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[21] "[A] mixture of switching technologies will usually exist at any point in time. Eventually, old technologies are entirely replaced by newer systems." R. F. Rey, ed., *Engineering and Operations in the Bell System,* Second Ed., 1983, AT&T Bell Laboratories, Murray Hill, NJ, p. 735. Henceforth, Engineering and Operations in the Bell System.

[22] The FCC requires that the "technology assumed in the cost study or model must be the least-cost, most-efficient, and reasonable technology for providing the supported services *that is currently being deployed*" FCC's Universal Service Order, ¶250 (emphasis added), and be "*based on the most efficient technology deployed in the* [access provider's] *current wire centre locations*" FCC's Local Competition Order, ¶ 685. Similarly, Oftel requires that assets in a TSLRIC bottom-up model be valued in terms of "*the latest available and proven technology ... the asset which a new entrant might be expected to employ*". The Bottom-Up Model, p. 1. The ACCC emphasizes that in TSLRIC methodology, best-in-use technology must be "*compatible with existing network design*" Access Pricing Principles, p. 23.

to incorporate wireless technology, and a best-in-use wireless technology has not yet been defined. In reviewing submissions in the Universal Service proceeding, the FCC states: "*No party has yet come forward with an algorithm or sufficient data to incorporate wireless technology into the model*"[23]. The HM5.0a and BCPM models include only a maximum value on the per-line investment cost to represent the cost effects of alternative potential wireless access, while the HCPM envisions a future modelling upgrade that would estimate wireless technology costs. The NERA model commissioned by the ACCC makes a "*somewhat arbitrary assumption*" that radio access for a single category consisting of rural and remote rural customers is a simple multiple of the investment cost per rural customer[24].

75. The PIE II model has advanced the modelling of best-in-use technology by expressly incorporating radio technology and comparing the costs of access alternatives for remote areas. In each rural ESA, the model selects between the least-cost cable-based and radio-based access technologies. In this respect, the PIE II model provides for a more efficient network than has been modelled elsewhere.

7.2.3 Forward-looking perspective

76. A TELRIC model is forward-looking in that it should:

(a) assume that all inputs are variable and are purchased at current or future market prices;

(b) calculate the annualised capital costs of network investments using a cost of capital that reflects expected future returns in competitive markets and a depreciation allowance that takes into account the economic lifetimes of each class of assets;

(c) base expenses for maintaining and operating the network on current and future prices for materials;

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[23] Letter from David L. Sieradzki, Western Wireless, to Magalie Roman Salas, FCC, dated July 15, 1998. FCC's Fifth Order, footnote 27.

[24] NERA Final Report, p. 19.

(d) take into account expected changes in asset prices due to technological advances, projected future prices of labour and materials, and growth in demand for services over the investment planning period.

77. Current and future regulatory and environmental constraints should be incorporated into a forward-looking perspective. In the case of Australia, I have been advised by Telstra that local government practice is such that permission to construct the PSTN above ground is likely to be refused. In most areas the cables in a freshly constructed network are likely to be placed under ground[25]. This is the assumption used in the PIE II model.

78. The extent to which future developments are explicitly incorporated into TELRIC models varies in international practice. The PIE II model projects future prices for major classes of assets and labour and incorporates these trends into the calculation of asset depreciation and annual capital costs. The UK model and the ACCC's model follow the same practice. The US models, however, do not project future prices and implicitly assume that current prices will apply in future years.

7.3 Scorched-node design

79. TELRIC models are sometimes called *engineering-economic* cost models to emphasize a distinctive characteristic – that costs are developed out of a simplified engineering representation of an actual network's components and operation.

80. In determining EN costs, regulatory bodies have considered two alternative baseline scenarios: a "scorched node" design and a "scorched earth" design. For a *scorched node* approach, it is assumed that the modelled network is constructed using the existing locations of the incumbent's nodes. For a *scorched earth* approach, the network design would determine both the number and the locations of all nodes as part of minimizing overall costs. To date, the scorched node assumption has been used in almost every TELRIC model because of its

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[25] "It is the ACCC's view that, on a forward looking basis, it is unlikely that there will be much aerial cabling." NERA Final Report, p. 49.

substantially greater simplicity, and the recognition that, for historical reasons, a scorched earth design is not feasible for incumbents[26].

81. A scorched-earth TELRIC model of a national network would require that the model evaluate at least a substantial number of possible alternative locations for each network switch and simultaneously evaluate alternative switch sizes, technology, functionality and traffic routing. Each alternative location and switch type would potentially incur a different cost. Transport facilities connecting each alternative location would require evaluating distances, feasible routing, and construction conditions. Each potential location would need to be tested for feasibility to ensure that switching equipment could be economically housed and installed. Some locations would effectively be ruled out by existing buildings or structures, while others could be very costly. Determination of the least-cost design from all combinations of these alternatives would require the use of advanced network-optimisation algorithms. The data requirements for such a model far exceed the scale of any TELRIC model constructed to date.

82. Constraining the cost models to locate switches at predetermined locations in the current network (ie, the existing building locations) very substantially simplifies the analysis and calculations that would otherwise be required to design an optimal network on a "greenfield". As noted above, in a scorched-earth model network designers would have the choice of both the number and the locations of the switches. In principle, these decisions could take into account the tradeoffs between the costs of switches, the costs of land and buildings at potential locations, and the costs of transport and the land on which it is located. However, at the current state of modelling technology this effort would introduce much greater uncertainty into the final cost estimates and require much greater time and effort than a scorched-node approach. It is likely, for example, that in some instances a calculated alternative location that reduces transport distances would

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[26] "Also because of reasons of feasibility, IRG considers it appropriate and reasonable to adhere to a bounded rationality approach, and thus to take the existing network topology as the starting point for the cost allocation process. Such a scorched node approach would imply that the technology at and in between existing switching nodes is optimised to meet the demands of a forward-looking efficient operator." IRG Principles of Implementation, p. 3.

be simply infeasible or only available at a higher cost for land and building than the costs currently incurred at the existing node[27].

83. In the jurisdictions I have examined, a scorched node baseline is used to fix the locations of nodes when calculating EN costs[28, 29]. In some instances, a cost model provides some flexibility for the choice of equipment installed in the nodes. Thus, modern remote switches might replace existing small host switches in some nodes if that replacement results in lower costs[30].

84. In a scorched node design, the network is assumed to have the same degree of hierarchy as the incumbent's deployed network. For example, in the US, the forward-looking network consists of two levels of switching: local switches and

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[27] The choice of a scorched node approach and the decision to use the number of levels of switching currently deployed in the incumbent's network are exceptions to the principle that the most efficient, lowest cost design be used to calculate costs. However, strict cost-minimisation with respect to these two aspects of network design has not been seen as practical. In addition, wishing to encourage facilities-based entry into the supply of local services and network elements, regulators have left open the possibility that entrants, free to select node locations, could achieve lower costs. The FCC found that, while a scorched-node model would not necessarily achieve the theoretical minimum cost of a scorched-earth network, a benchmark of "forward-looking cost and existing network design most closely represents the incremental costs that incumbents actually expect to incur in making network elements available to new entrants" and that "this approach encourages facilities-based competition to the extent that new entrants, by designing more efficient network configurations, are able to provide the service at a lower cost than the [access provider]". See FCC's Local Competition Order, ¶ 685

[28] (A) In the US: "A model, however, must include the [access provider's] wire centers as the center of the loop network and the outside plant should terminate at [access providers'] current wire centers." FCC Universal Service Order, ¶ 250.

(B) In Germany: "MDF locations will follow those of the existing network architecture, as the possibility of restructuring access networks, in particular, is limited, even in the long term." WIK Core Network Model, p. 5.

(C) In the EU: The recommended cost methodology "… models the incumbent's current switching centres ("scorched node approach"), as well as providing an alternative option that can perform a preliminary optimisation ("modified scorched node approach"). The modified scorched option offers a high level approach, using either benchmarks or a node database." Europe Economics Report, p. 6.

(D) In the UK: "In the network model, it has been assumed that the number and location of nodes in [the access provider's] network are taken as given (the 'scorched node' assumption)." The Bottom-Up Model, p. 4.

[29] One TSLRIC model (LECOM) was developed to incorporate scorched-earth assumptions as part of an ongoing project described in Gabel, D. and D.M. Kennet, 1991, *Estimating the Cost Structure of the Local Telephone Exchange Network*, National Regulatory Research Institute, Report 91-16, Colombus, Ohio. A more recent description is in *Cost Proxy Models and Telecommunications Policy: A New Empirical Approach to Regulation*, by F. Gasmi, D.M. Kennet, J.J. Laffont and W.W. Sharkey. MIT Press, 2002. However, although proposed in some state regulatory proceedings, LECOM apparently has not been used to optimise local switching locations and switching and transport investment.

[30] (A) In the US: "If the user selects the explicit host, remote, standalone option, the user must specify for each wire center whether the housed switches are hosts or remotes …" Hatfield Model, p. 56.

(B) In the UK: "A point of presence is required at each of the nodes, though not necessarily the same type of switch as [the access provider] currently deploys …" The Bottom-Up Model, p. 4.

tandem switches[31]. In the UK model, all interconnected calls from an access seeker's network are routed through a local switch. In addition, some interconnected calls will be routed through a tandem switch, and some will be routed through two tandem switches. For this reason, the UK cost model adopts a three-level switching hierarchy corresponding to local switching, single transit and double transit interconnection services[32].

85. In Australia, I am informed that interconnection of an access seeker to Telstra's network is usually at a point of interconnection associated with a local access switch, with additional points of interconnection at some transit switches. This routing of interconnected traffic is reflected in the PIE II model in the dimensioning of the interexchange network.

86. In a scorched-node TELRIC model, the efficient amount of investment is calculated anew, using efficient, best-in-use technology. Only the *locations* of the nodal investments are determined by the existing network.

87. I have been advised by Telstra that in recent years Telstra has redesigned its network, reducing and rationalizing the total number of switches from some 5,000 switches previously used, to a network consisting of just 133 local area switch sites which are connected to remotely-located multiplexing or switching stages plus 24 transit switches. This rationalization of the network is consistent with the recommendation of the Independent Regulators Group "to modify the scorched node approach … taking the existing topology as starting point, followed by an elimination of inefficiencies (e.g. this may involve attempting to simplify the switching hierarchy)".[33] As a consequence, the locations of nodes in the PIE II model quite likely represents a more efficient design than is achieved in scorched-

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[31] In the US, remote switches are considered a part of the local-switch switching level, not a third level of switching. Tandem switches are the highest level in the hierarchy and are fully meshed: "At the highest level in the ring network, the HM must provide a path for tandem to tandem traffic for tandems that are located in the same [local access area]. This is accomplished through the use of inter-ring-system connectors." Hatfield Model, p. 61.

[32] The Bottom-Up Model, Table 3.1. Similarly, the approach recommended to the European Union member states requires that a forward-looking cost model be capable of calculating the costs of local level interconnection, single transit interconnection and double transit interconnection. However, there is a recognition in Europe that this framework may not be suitable for countries with three or four levels of (analog) switches in their networks, even though current best practice with digital switching may require a flatter hierarchy. Europe Economics Report, p. 12.

[33] IRG Principles of Implementation, p. 3.

node TELRIC models of other networks that have retained switch locations that were designed for earlier technologies.

88. However, the PIE II model goes beyond a strict implementation of the scorched-node assumption in several respects because it (a) optimises the choice of equipment located in remote access sites that are connected to a local area switch, (b) determines the locations of those remote sites, and (c) optimises the number of local area switches required at each site. The PIE II model thus achieves a more cost-efficient design than would be obtained from a strict scorched-node model, which would require that each LAS and remote switching unit in the current Telstra network be retained in its current location.

8 THE PIE II MODEL SATISFIES THE REQUIREMENTS FOR TELRIC MODELS

8.1 Overall methodology

89. Telstra's PIE II model is based on best-practice network design to supply the UT Services for the years 2002/03, 2003/04 and 2004/05. Extensive details of the PIE II model are contained in Annexure A to Telstra's Submission in relation to the Methodology used for Deriving Prices Proposed in its Undertakings dated 9 January 2003.

90. The bottom-up PIE II model is constructed from the basic network components and processes that are required to provide the PSTN Services. It also provides cost estimates of some components required to supply leased line service and ISDN calls. Annexure B contains a glossary of network terms and acronyms and Annexure C provides a schematic overview of the major components of the network.

91. As compared with Telstra's earlier network design, the overall design of the PIE II model network is based on fibre-optic cables to connect LAS and transit network switches in the interexchange network and also to link the remote access units to the LAS. The final several hundred meters' access to individual end users (except those located in high-density buildings) is over copper cable. The extensive use of

fibre-optic cables allows placement of remote terminals close to end users and thus limits the length of copper cables deployed.

92. The use of fibre-optic cable, combined with CMUXs, is consistent with the network design practices of the local networks of major carriers in other advanced economies and incorporated in TELRIC models elsewhere[34].

93. The PIE II model calculates the major capital components required for the network from forward-looking network design principles. Annual capital costs are calculated from assumed asset-specific service lives and depreciation curves and the PSTN operator's cost of capital and company tax rates. To estimate operating and maintenance costs of shorter-lived components the PIE II model uses the ratios of latest-year actual costs of operating and maintaining the current components of Telstra's PSTN to the asset values of those components. It then applies those ratios to the investment for the model network components. For cabling and trenches, the model uses ratios based on actual operating and maintenance costs as fractions of model-estimated investments, as the historical costs of fully depreciated cables and trenches are not retained in Telstra's accounting system. Costs of overhead activities are also estimated from actually incurred costs and allocated to network components.

8.2 Network planning

94. TELRIC models have not attempted to model the activities associated with the tasks needed to plan (i.e., "engineer") and install the individual network components. Instead, the models have generally applied an "uplift" factor to the investment cost of each component (e.g., investment per meter of cable) to account for the average cost of these tasks.

95. In a scorched-node TSLRIC network, the costs of planning and designing a new network using the existing nodal locations is an essential expenditure. Rather than

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[34] For example, in the FCC's cost model end users are connected by copper cable to remote terminals that are fed by copper or fibre-optic cable from a local area switch. The interexchange portion of the FCC's model incorporates the HM5.0a model's interexchange network, which is engineered in a number of interlinked high-bandwidth fibre-optic rings. Hatfield Model, pp. 58-62. Similarly, the WIK model uses a mixed copper/fibre technology for the customer access network and high bandwidth fibre rings to link switches in the interexchange network. WIK Core Network Model, pp. 19-40.

estimate the planning costs of a complete design of the entire network, the PIE II model includesthe current expenditure on network planning as an annual cost factor. Because current planning activities are limited to network expansion, this provides a conservative calculation of network planning costs.

96. As noted in paragraph 88 above, the PIE model assumes that this network design optimises the mixture of remote access units and switches.

8.3 Subscriber locations

97. Both the PIE II model and the US TELRIC models dimension the customer access networks by using data for each local service area to estimate the actual number of end users in that area. The PIE II model uses existing address information to define where service locations would be placed if the network were built anew. The address information includes locations where there is currently a service in operation, where there has previously been a service, or where in the near future a new service may be located.

98. The PIE II model and the US models use somewhat similar procedures to arrive at the costs of end-user access lines. To determine end-user distances from an exchange, the US models contain highly detailed algorithms for geographically grouping individual end users into clusters within individual service areas or grids and calculating distribution cable, main (or feeder) cable, and digital loop carrier (or remote multiplexer) requirements to serve those locations. In the PIE II model, each exchange serving area **("ESA")** is partitioned into a number of distribution areas. The locations of individual end users are connected to pillars, and minimum-distance algorithms are used to connect those locations so as to minimize the total length of main cabling. In estimating cable costs, the US models calculate main (feeder) and distribution cable lengths by using graduated sizes of cable; for main cable, the PIE II model also employs graduated sizes of cable in an ESA, and for distribution cable the PIE II model uses 100 pair and 50 pair non-tapered cable.

8.4 Routing factors

99. Both the PIE II model and the US models calculate the total costs of each of the major individual network elements (e.g., local loop, remote multiplexers and remote switches, local switch, interexchange transport). Each total cost is unitised by the total usage of that network element, e.g., total minutes of traffic or number of lines. The models then obtain the average cost per minute of PSTN OTA or LCS traffic by multiplying each element cost by a *routing factor* – the proportion of a minute of PSTN OTA and LCS traffic that on average requires that element – to obtain the average cost per minute of PSTN OTA and LCS traffic. In the case of costs that are sensitive to call attempts, the total call attempt costs are divided by the total number of call attempts processed by that element. The average cost per call attempt for a given type of traffic is then obtained by multiplying each element's per call attempt cost by the corresponding routing factor. In the case of ULLS, the total costs of the CAN are divided by the total number of copper access lines.

8.5 Dimensioning the major network elements

8.5.1 Distribution cable

100. The PIE II model dimensions the distribution and main (feeder) cables, the number of cables hauled through ducts, and the pillars in the customer access network based on the total number of living units and business units as well as the number of copper-based access services.

101. Each ESA is partitioned into several distribution areas **("DA"s)**. In the urban areas of the network, a DA is sized (based on the density of living units) so that it can be served by 100-pair distribution cables connected to a pillar located near the centre of the DA.

102. Distribution cable is not used in high-density urban areas where the average number of SIOs at a single address is at least "c-i-c"; these locations are instead served directly by main cable. In non-urban areas in which cable runs do not exceed "c-i-c" km, pillars and distribution cable are not used; instead, living units are connected by main cable directly to remote access units.

103. The PIE II model's provisioning calculations, which distinguish serving areas by the density of living units, follow the provisioning rules used by Telstra's network designers as at 30 June 2002. In the US TELRIC models, differences in subscriber density are taken into account by assuming that the utilisation of distribution and main cables increases with the density of end users in a serving area[35].

104. By calculating the distribution cable required in each ESA using the current design principles for the consumer access network the PIE II model obtains an estimate of the efficient costs of this network component.

8.5.2 CMUX

105. In provisioning its remote access units the PIE II model has adopted CMUX technology as being the most appropriate best-in-use technology for the network. RAUs can be provisioned either within Telstra buildings or as street furniture. The RAUs are dimensioned on the basis of the number of services required within each individual exchange service area. In the densest areas of the network, a Network Unit CMUX is provided within the exchange building, and in outlying areas the ESAs are served by remote CMUXs.

8.5.3 Main cable

106. For provisioning of main (feeder) cable, the PIE II and US cost models use the same general methodology, calculating costs based on the sizes of standard cables available for installation, and the number of SIOs in the serving area.

107. The PIE II model provides sufficient cable to service the number of SIOs in the serving area, starting from 100-pair cables for rural customers up to 4,200 pair cables in high-density areas. The provisioning rules are not based on the number of pairs per SIO, but reference the number of SIOs connect to each pillar.

108. Each Distribution Area (DA) is provisioned as follows:

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[35] HCPM: hcpm_inputs_June2001.xls - FILLFACT!

- If there are too few SIOs to warrant the placement of a pillar, all SIOs within the DA are connected to the RAU using 100-pair cable.

- Otherwise, the amount of cable, the cable lengths and the trench lengths of the reference DA are adjusted to account for the number of SIOs and the area covered by the DA.

109. By calculating the main cable required for each serving area using the current design principles for the Customer Access Network the PIE II model obtains an estimate of the efficient costs of this network component.

8.5.4 Pillars

110. PIE II dimensions the pillars that support cross-connection of main (feeder) and distribution cables in the CAN based on the number of distribution cable pairs and the number of main cable pairs terminated at the pillar. As with cable dimensioning, this calculation includes a provision for spare capacity.

111. I am advised by Telstra that a pillar consists of nine 100-line modules and that one module is held in reserve, in the event that a fault develops in one of the others. Each of the remaining modules is allocated to either the main cables or the distribution cables. Up to five modules are used to terminate distribution cables, and the remaining three to terminate main cables. The maximum number of SIOs that can be supported by one pillar is determined by the 500-line capacity of the distribution-cable-side modules, the 300-line capacity of the feeder-cable-side modules and the number of living units served within the distribution area. The PIE II model calculates the size of a distribution area so that, given the actual number of living units and services, they can be served from a single pillar located within the distribution area.

8.5.5 Access switches

112. A local switch has a limited capacity to terminate lines that can be connected to it and to process their traffic. It is standard engineering practice to dimension switches to handle the total number of subscriber lines plus an utilisation allowance for administrative lines, moves and changes, faults, and anticipated

growth[36]. The PIE II model dimensions the distribution-cable-side elements of local switches that connect to subscriber lines based on the number of SIOs connected to them, and dimensions the processing capacity of the switches using the peak-period volume of traffic those SIOs are projected to carry.

113. TELRIC models use rules of thumb to dimension the capacity of remote terminals and switches based on the number of lines connected to them. For comparison, the HM5.0a dimensions remote terminals assuming a utilization rate of 90% of terminated lines[37]. For local switches HM5.0a assumes that a maximum of 80% of the switch's rated line capacity can be used[38]. Beginning from this capacity assumption, the FCC's hybrid cost model then dimensions the available switch at a 94% utilization rate[39].

114. Switching capacity that is sensitive to the volume of peak-period traffic is dimensioned to provide spare capacity to account for changes in traffic patterns and growth. For comparison, the HM 5.0a model calculates that an additional local switch must be added when 90% of the switch's designed capacity, measured in busy hour call attempts, is reached[40].

115. The PIE II model dimensions access switches, transit network switches, and signal transfer points based on traffic projections at each switch. Traffic forecasts are developed from separate routing factors in each state for each category of service and switch.

116. As noted earlier (paragraph ¶87) the PIE II model is based on a modified-scorched node network that reduces the number of switch sites previously used in the Telstra network. Following international practice, switching capacity is dimensioned based on traffic forecasts and utilisation margins to accommodate faults, subscriber mobility, and growth.

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[36] Engineering and Operations in the Bell System, pp. 588-589.

[37] HAI Inputs, p. 64.

[38] HAI Inputs, p. 74.

[39] FCC's Tenth Order, ¶ 332.

[40] HAI Inputs, p.75.

8.5.6 Transport

117. TELRIC models of local telephone networks assume that the best-in-use technology for transporting traffic and network control information between network nodes is based on high-bandwidth fibre-optic cables using synchronized transport protocols[41]. The primary transport path is supplied by a ring architecture, which establishes two paths between nodes connected to the ring and thus provides an essential element of redundancy in the event of a cable fault. Traffic enters and leaves the fibre-optic ring at several locations around the ring through add/drop multiplexers **("ADMs")**.

118. I am advised by Telstra that the PIE II model designs network transport using best-in-use technology consisting of SDH (synchronous digital hierarchy) fibre-optic rings, ADMs and point-to-point fibre-optic links that connect remote access units to the rings. In non-metropolitan ESAs the lengths of the transport links are calculated using a minimum spanning tree algorithm. All of the transport network components that are dimensioned within the model are dimensioned to serve the peak period traffic projected for each link or segment. Rings are provisioned up to "c-i-c" of their circuit capacity.

119. The PIE II model's transport design is broadly comparable to the transport design included in the HM5.0a model and incorporated into the FCC's cost model. Those US models design an interexchange network consisting of two classes of high-bandwidth fibre-optic rings, one class that connects remote switches to local switches, and a second class for interconnecting local area switches and transit switches. Transport distances are optimised by selecting the least-cost of several alternative placements of switches on possible rings[42].

8.5.7 Trenches

120. Trenches for the cables of the access provider's network are resources that are potentially sharable with other service providers. In a scorched-node approach,

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[41] "The model assumes that wire centers are interconnected with one another using optical fiber networks known as Synchronous Optical Network **(SONET)** rings." FCC's Tenth Order, ¶ 15.

[42] Hatfield Model, pp 58-62.

the access provider can, in theory, either construct new trenches or, if the required capacity is available, lease the capacity from another supplier.

121. I am advised by Telstra that Telstra's opportunities to lease ducts and tunnels in trenches from other suppliers is limited largely to a small number of selected CBD areas in which power companies have spare ducts available. I have been further instructed that sharing of ducts with gas and water utilities is not a generally accepted practice in Australia. Ducts are generally not available for lease from other telecommunications carriers; rather, other carriers often lease space in Telstra's trenches. Although sharing of aboveground utility poles is a theoretical possibility in some areas, I understand that council approval is rarely granted. It is therefore my understanding that the opportunities for Telstra to lease trench capacity from other suppliers are *de minimus*.

122. The PIE II model assumes that the main cables in the CAN and the IEN are placed underground, running in ducts in the CBD areas, and either in ducts or ploughed directly into the ground in the metropolitan, provincial areas, and rural areas. In the model, the costs of trenching to install ducts and ploughing to bury cable account are some "c-i-c" of the total network investment.

123. According to Telstra, a large proportion of its cables are laid in trenches that run parallel to existing roads. The costs of trenching depend principally on the length of trench, the type of road, and local construction conditions.

124. Two or more cables that follow the same route for a portion of their length may be able to share a common trench, reducing the total cost of trenching required in the network. For example, in some locations the copper main cable in a section of the CAN and the optical fibre cable in the IEN connecting a RAU to the LAS can be run in separate ducts within the same trench along one side of a road.

125. The opportunities for CAN and IEN cables to share trenches will vary greatly. The PIE II model assumes that throughout the CAN, nearly all ("c-i-c") of the total length of the trenches housing main cables can be shared with another cable, provided that main cable lengths are at least 1,000 metres. Trench sharing is thus determined separately in each ESA.

126. Telstra has compared the total trench length calculated by the PIE II model with a calculation based on the length of roads in Australia[43]. As at 30 June 2002 that analysis:

(a) estimated a minimum length of ducted trenches of "c-i-c"km

(b) estimated a minimum length of total trenches of "c-i-c"km.

The PIE model estimates that as at 30 June 2003 ducted trenches are "c-i-c"km and total trenches are "c-i-c"km.

127. In my opinion, the reasonably close correspondence between the PIE II model's estimate of total trench lengths and the separate calculation based on road lengths enables one to place confidence in the reasonableness of the PIE II model's estimates of total trenching costs.

128. When telephone service is extended to previously unserved areas, additional trenching is required beyond that needed for the initial number and location of services. I understand that it is the practice of estate developers to provide access to trenches in their developments at no cost to Telstra, and that in each year estate developments represent approximately 1% of all PSTN access services. On the assumption that new trenches will not be a cost to Telstra, in my opinion it is appropriate for the PIE II model to not include trenching costs for new estates but to include the costs of additional cable to provide service in those areas.

129. The trench lengths calculated in the PIE II model do not take into account increased distances and costs due to terrain. In this regard the costs calculated in the PIE II model are conservative estimates in some geographic areas. In contrast, the HCPM model adjusts feeder cable distances by factors, which depend on the maximum and minimum slope within a cluster. That model also allows the user to specify a road factor, which converts model distance computations to an empirical estimate of road distance.

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[43] Telstra's Submission dated 9th Jan 2003 - ANNEXURE G -TRENCH LENGTHS.

8.5.8 Price trends of assets

130. The future prices of assets enter the calculation of annual capital costs in the PIE II model by determining the tilt factor used in the tilted annuity formula for annualising capital costs. As inputs, the PIE II model includes projected price trends of each major category of asset and labour expense used in the network, starting from actual prices paid by Telstra in 2001/2002. Those prices are projected using indices reported by the Australian Bureau of Statistics **(ABS)**, or, for assets with substantial electronics content, using an information technology index from the US Bureau of Labour Statistics. Price trends for switching are projected from the decline in purchase prices paid by Telstra to a major vendor between 1999 and 2000.

131. In my opinion, it is appropriate to include price projections for the relevant years in modelling EN costs. Economic depreciation of investment in new network assets is directly affected by changes in the prices of new assets over time, and taking price changes into account improves the reliability of estimates of the annual capital costs. Oftel's TELRIC model provided explicitly for assumed annual changes in the prices of switches, optical fibre, and transmission electronics, and for increases in future operating costs for each major category of asset[44]. By comparison, the US cost models use only a less advanced, entirely static methodology of capital costs with asset prices that are unchanged over their economic lifetime.

8.5.9 Operating and maintenance expenses and common support expenses

132. TELRIC models have, to date, not attempted to model the activities and supporting assets used to supply operating and maintenance **("O&M")** services to the network[45]. Instead, the models have turned to historical accounts of actual

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[44] Bottom-Up Model, Annex D, March 1997.

[45] (A) Oftel: "[O]ne approach would be to model the impact of all of the key drivers that affect the level of operating costs in the network. This was considered by the Working Group to be an unduly large and complex modelling task." Bottom-Up Model, p. 32.

(B) WIK: "[T]he complex work processes … make it hard to identify the cost drivers [of asset-related operating costs], and the company-specific nature of the processes" WIK Local Loop Model, Section 4.2.

expenses and sought to adjust expense amounts to more nearly reflect a forward-looking view of expenses[46].

133. Telstra has calculated ratios of current O&M costs to asset values for shorter-lived network assets by detailed examination of its regulatory accounts for both expenses and assets. I am informed by Telstra that the O&M ratios used in the PIE II model have been based largely on the O&M expenses incurred for current-generation assets. For example, Telstra has disaggregated expenses associated with an individual asset category so that expense ratios for maintenance of fibre optic systems are limited to SDH equipment, and excludes the earlier-generation PDH equipment. This qualified use of historical accounts captures the maintenance expense experience for the most recently installed assets and avoids the use of costs associated with earlier technologies. It is thus the most nearly forward-looking calculation that can be extracted from accounting models of operating experience. In the PIE II model these expense ratios are then applied to calculated investment to estimate current expenses.

134. For long-lived cabling and trench assets, which have been substantially depreciated in the regulatory accounts, Telstra has calculated the ratio of current operating costs to the new asset costs estimated by the PIE II model. This procedure avoids the overstatement of O&M costs that would result from using ratios based on regulatory asset values for long-lived, substantially depreciated assets.

135. In the US, TSLRIC models have relied on historically incurred expenses reported in regulatory accounts to develop expense factors that are then applied to investment or to the number of end-user lines. For expenses associated with plant-specific operations and common support services, the early version of US cost models used the ratio of historical expenses to book asset values to generate expense factors[47]. Because the recorded expenses and asset values included costs

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(C) FCC: The FCC did not "develop [general support facilities] investments on some other basis, such as an activity based approach, rather than as a ratio of investment. .... Such an approach also would require changes to the model platform." FCC's Tenth Order, ¶ 415, footnote 1308.

[46] "[W]e use … factors that express the operating costs for various asset categories as a percentage of the investment sum." WIK Local Loop Model, Section 4.2.

[47] Hatfield Model pp. 67-68.

for both current-generation and older equipment, these ratios were considered unreliable. Subsequently, the FCC obtained current-cost values of plant-specific assets from five major local carriers and calculated average expense factors based on current asset values in order to derive expense-to-investment ratios[48].

136. As shown in Annexure G, the historical O&M expense-to-asset ratios of the largest access providers in five US states vary considerably. For example, the factor for buildings varies from 6.95% to 11.59%. In its investigation of input values for its TELRIC model, the FCC established a factor of 9.06% for buildings, based on nationwide historical cost data. In comparison, the PIE II model uses an O&M expense factor of "c-i-c" for the consolidated land and buildings account.

137. International comparisons of expense factors across access providers are problematic because operators use different accounting practices to classify expense activities. Telstra's expense factors are not easily compared to factors used in overseas models. For example, I am advised by Telstra that the expenses recorded in the standard regulatory accounts for the SDH Transmission (SD) asset category include both "SDH equipment" and "PDH equipment" as well as "echo cancellers" and "common synchronisation network". In the US accounts, the most closely corresponding asset category is Circuit Equipment (USOA 2232). However, that category includes not only SDH and PDH equipment, but also copper-based transmission equipment. In the case of switching equipment, Telstra has advised me that its accounts distinguish between local and remote access switches, transit switches, and signalling switching equipment, whereas the US accounts have a single category for digital electronic switching.

138. The PIE II model's O&M expense factors for main cable, distribution cable, and optical fibre are a composite of Telstra's expenses for maintaining aerial, buried, and underground cable in its current network. However, aerial cable is not used in the forward-looking network in the PIE II model, and in overseas TELRIC models aerial cable is assumed to be generally more costly to maintain than cable that is buried or in underground conduit. Consequently, a composite O&M factor will somewhat overstate the cost of maintaining an entirely underground cable

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[48] FCC's Tenth Order, ¶ 347.

network. Nevertheless, because aerial cable is, I understand, only about “c-i-c” of total cable in Telstra’s network, this factor, in my opinion, can cause at most only a small bias in the overall O&M expense estimate.

139. Bearing in mind the irreducible differences in expense categories produced by different accounting practices in Australia and the US, the data in Annexure G suggest that the PIE II model’s expense factors are broadly consistent with TELRIC models in the US. In my opinion, the PIE II model’s expense factors are appropriate for calculating the efficient costs of the UT Services.

8.5.10 Indirect capital cost methodology

140. For indirect capital costs, the PIE II model estimates the investment in supporting assets, including non-network land and buildings, office furniture and equipment, light and power, etc. on the basis of asset values recorded in its regulatory accounts. These indirect assets are expressed as a percentage of four categories of directly employed assets recorded in the accounts for access, IEN, switching, and network support[49]. These percentages are then multiplied by the levels of direct investment calculated by the model and the amount of the resulting indirect investment is expressed as an annual cost.

141. The PIE II model’s approach is consistent with the method used by the HM5.0a model, which calculates a single ratio of investments for general support equipment (furniture, office equipment, general purpose computers, buildings, motor vehicles, garage work equipment, and other work equipment) to total investment obtained from US local access providers’ historical accounts[50]. Similarly, with respect to indirect capital costs the national core network model constructed for the German regulator notes that “*It is not possible to model the investments directly by using the cost drivers considered because of their common*

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[49] Telstra’s Methodology Submission.

[50] Hatfield Model, p. 70.

cost characteristics"[51] and therefore marks up the investment in each network element by a common percentage to reflect indirect capital investment.

142. The FCC's cost model relies on historical accounts to estimate general support facilities investment (including buildings, motor vehicles, and general purpose computers) in each access provider's statewide service area. This investment is then adjusted by a nationwide allocation factor derived from a statistical analysis of the proportion of common support expenses and plant-specific operations expenses attributable to local service[52].

143. In my opinion, the PIE II model's methodology for estimating indirect capital costs is appropriate and consistent with international practice.

8.5.11 Indirect O&M costs

144. The PIE II model estimates the costs of indirect operations and maintenance expenses – for finance, employee relations, and corporate centre activities – by applying an indirect cost factor to the direct O&M costs in each asset category. The indirect O&M cost factors are derived from regulatory accounts.

145. For common support services expenses (such as corporate operations, customer service, and other non-plant specific expenses) the FCC calculated expenses on a per-line basis in order to statistically adjust historical data from all non-rural carriers to remove expenses attributable to special access lines and long-distance services. The estimated expenses are then expressed as an expense-per-subscriber-line factor in the HCPM model.

146. The PIE II model generally follows international practice in estimating indirect O&M costs by deriving cost factors from expense ratios calculated from actual expenses recorded regulatory accounts.

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[51] WIK, "An Analytical Cost Model for the National Core Network," Consultative Document Prepared by WIK for the Regulatory Authority for Telecommunications and Posts; Project Team: Dr Frank Schmidt, Florentín González López; Contributors: Prof Klaus Hackbarth, Antonio Cuadra; 14 April 1999; page 50.

[52] FCC's Tenth Order, ¶ 418.

9 CONCLUSION

147. The PIE II model is based on Telstra's best-practice network technology. It is forward-looking, incorporating subscriber and traffic forecasts for the years 2002/03 – 2004/05. Provisioning of each network element is based on efficient engineering principles that take into account subscriber and traffic density. Asset prices and operating, maintenance, and indirect expenses are estimated based on recent experience with current-technology equipment.

148. In my opinion, Telstra's cost-estimating methodology and the PIE II model appropriately incorporate the principles for TELRIC modelling that have been developed and applied in international practice.

ANNEXURE A: QUALIFICATIONS

1. I am a vice president of Charles River Associates Incorporated, an economics, finance and business-consulting firm with offices in Boston, Massachusetts and eleven other cities. I am the director of the Palo Alto office, which is located at 285 Hamilton Avenue, Palo Alto, California.

2. I received a Bachelor of Arts with a major in economics from Stanford University in 1962 and a Ph.D. in economics from the Massachusetts Institute of Technology in 1970.

3. I was an assistant professor in the Department of Economics at Stanford University from 1966 to 1971, and I have subsequently taught economics courses at Stanford as an acting associate professor and at the University of California at Los Angeles as a lecturer in economics.

4. In 1971 and 1972, I was an economics policy fellow at the Brookings Institution and the Department of Health, Education and Welfare. From 1972 to 1994, I was a senior economist at the RAND Corporation in Santa Monica, CA.

5. I am a member of the American Economics Association and the International Telecommunications Society.

6. My fields of specialisation within economics are industrial organisation, regulation, and microeconomics. I have co-authored five books, most recently *Telecommunications Competition: The Last Ten Miles* (1997) and *Telecommunications Pricing: Theory and Practice* (1991). I have published a large number of articles on telecommunications topics in professional journals and monographs. Those research papers include descriptions of cost models which I constructed or critiqued of local telephone service; network interconnection and pricing; demand for telephone services; universal service; number portability; internet peering policies; cable television regulation; and allocation of spectrum resources.

7. Under a research grant from the Public Utilities Commission and the two major local telephone service providers in California, in 1988-1989 I constructed the first published model of long-run incremental costs of local telephone service. In 2000-2001 I advised SprintPCS on the development of its model of the costs of call

termination service in a mobile telephone network. Between 1997 and 2001, I advised Telstra on aspects of the development of its cost model of the Public Switched Telephone Network ("PSTN") and of the domestic PSTN originating and terminating access services ("the PSTN OTA").

8. I have provided expert consultation and testimony in telecommunications litigation, as listed in my curriculum vitae. The matters that concern cost modeling include the following:

- In 1994 in the UK, I provided written evidence on behalf of Mercury Communications concerning the costs of interconnection.
- In 1998 in Pennsylvania, I provided written evidence on behalf of Vanguard Cellular concerning the costs of call termination on wireline networks.
- In 2000-2001, on behalf of SprintPCS, I provided a report to the Federal Communications Commission (FCC) and provided written evidence in regulatory state proceedings in Florida and New York concerning the application of total service long run incremental cost ("TSLRIC") methodology to the construction of a cost model of mobile telephone networks.
- In 2001 in Australia, I provided written evidence on behalf of Telstra in the Federal Court of Australia, evaluating the claim of Optus Networks that Telstra earned monopoly profits from local telephony services.
- In 2002 in Australia, I provided written evidence on behalf of Telstra in the Australian Competition Tribunal concerning the application of TSLRIC methodology to Telstra's PIE model.

9. I have written the following books:

(a) *Telecommunications Competition: The Last Ten Miles*. With I. Vogelsang. Cambridge, MA: MIT Press and AEI Press, 1997. (Also published in Korean, Korean Information Society Development Institute, 1998.)

(b) *Universal Access to E-Mail: Feasibility and Societal Implications*. With R. H. Anderson, T. K. Bikson and S. A. Law. Santa Monica, CA: RAND, 1995.

(c) *Telecommunications Pricing: Theory and Practice*. With I. Vogelsang. Cambridge: Cambridge University Press, 1991. (Also published in Japanese, Tuttle-Mori Agency, Inc., Tokyo, 1995.)

(d) *Regulated Industries and Public Enterprise: European and United States Perspectives*. Editor. With P. R. Kleindorfer. Lexington, MA: Lexington Books, 1980.

(e) *Peak-Load Pricing: European Lessons for US Energy Policy*. With J. P. Acton and W. G. Manning, Jr. Cambridge, MA: Ballinger Publishing Company, 1978.

10. I have written the following articles and refereed chapters in books:

(a) "Advances in Routing Technologies and Internet Peering Agreements," With Stanley Besen, Paul Milgrom, and Padmanabhan Srinagesh, *American Economic Review*, May 2001.

(b) "Competitive Effects of Internet Peering Policies." With P. Milgrom and P. Srinagesh. *Proceedings of the 27th Telecommunications Policy Research Conference*, B. Compaine and I. Vogelsang, eds., MIT Press, forthcoming 2000.

(c) "An Economic Analysis of Telephone Number Portability." With P. Srinagesh. *Competition, Regulation, and Convergence*, S. E. Gillett and I. Vogelsang, eds., Lawrence Erlbaum, 1999.

(d) "Markup Pricing for Interconnection: A Conceptual Framework." With I. Vogelsang. *Opening Networks to Competition: The Regulation and Pricing of Access*, D. Gabel and D. Weiman, eds., Kluwer Academic Publishers. Boston, 1998.

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(k) “Network Interconnection in the Domain of ONP: Country Studies.” With J. Arnbak, G. N’Guyen, B. Ickenroth, W. Neu, K-H Neumann, and I. Vogelsang. *European Commission DG XIII*, Brussels, November 1994.

(l) “Efficient Pricing of Telecommunications Services and the Ways to Get There.” In S. Globerman, W. T. Stanbury, and T. A. Wilson (eds.), *The Future of Telecommunications Policy in Canada*. Toronto, 1994.

(m) “Het toewijzen van spectrum voor cellulaire telefonie: Evaringen in de VS.” *Mediaform* 4, No. 7–8 (1992): 82–84.

(n) “Allocating Spectrum for Cellular Telephones: US Experience and Issues.” In Franca Klaver and Paul Slaa (eds.), *Telecommunications: New Signposts to Old Roads*. Proceedings, IOS Press, Amsterdam, 1992.

(o) "Telephone Penetration." In B. Cole (ed.), *After the Breakup: Assessing the New Post-AT&T Divestiture Era*. Columbia University Press, 1991, pp. 370–376.

(p) "Incremental Capital Costs of Telephone Access and Local Use." In *Telecommunications Costing in a Dynamic Environment*. Hull, Quebec: Bell Canada, 1989.

(q) "Measuring Technological Change of Heterogeneous Products." With A. J. Alexander. *Technological Forecasting and Social Change* 27 (1985): 161–195.

(r) "Pricing Subscriber Access to the Telephone Network." In A. Baughcum and G. R. Faulhaber (eds.), *Telecommunications Access and Public Policy*. Norwood, NJ: Ablex, 1984.

(s) "Response to Residential Time-of-Use Electricity Rates: How Transferable Are the Findings?" With D. F. Kohler. *Journal of Econometrics* 26 (1984): 141–177.

(t) "Local Telephone Costs and Design of Rate Structures." In L. Courville, A. de Fontenay, and A. R. Dobell (eds.), *Economic Analysis of Telecommunications: Theory and Applications*. North-Holland Publishing Company, 1983.

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(zz) "National Health Insurance: Some Costs and Effects of Mandated Employee Coverage." With C. E. Phelps. *Journal of Political Economy* 84, No. 3 (June 1976): 553–571.

(A) "The Financing of National Health Insurance." With W. B. Schwartz. *Science* 192 (May 14, 1976): 621–636.

(B) "Impact of Competition on an Independent Telephone Company." With W. S. Baer. *Public Utilities Fortnightly* (October 23, 1975).

(C) "Health and Taxes: An Assessment of the Medical Deduction." With R. J. Vogel. *Southern Economic Journal* 41, No. 4 (April 1975): 660–672.

(D) "Cable, Cities, and Copyrights." With W. S. Comanor. *Bell Journal of Economics and Management Science* 5, No. 1 (Spring 1974): 235–263.

(E) "Fixed Point Estimation of Econometric Models." *Australian Economic Papers* (December 1974): 250-266.

(F) "Short-Run Prediction and Long-Run Simulation of the Wharton Model: Discussion." In B. G. Hickman (ed.), *Econometric Models of Cyclical Behavior*. National Bureau of Economic Research, 1972.

(G) "The Cost of Planning: The FCC and Cable Television." With W. S. Comanor. *Journal of Law and Economics* 15, No. 1 (April 1972): 177–206.

(H) "Cable Television and the Impact of Regulation." With W. S. Comanor. *Bell Journal of Economics and Management Science* 2, No. 1 (Spring 1971): 154–212.

(I) "Estimation of Large Econometric Models by Principal Component and Instrumental Variable Methods." *Review of Economics and Statistics* (May 1971).

(J) "A Linear Logarithmic Expenditure System: An Application to US Data." With L. J. Lau. Presented at the Second World Congress, Econometric Society, September 1970. *Econometrica* 39, No. 4 (1971): 87–88.

(K) "The Choice of Instrumental Variables in the Estimation of Economy-Wide Econometric Models: Some Further Thoughts." With F. M. Fisher. *International Economic Review* 11, No. 2 (June 1970): 226–234.

(L) "Estimating Joint Production Functions by Canonical Correlation Analysis." With P. J. Dhrymes. *Econometrica* 37, No. 4 (October 1969).

(M) "Community Antenna Television Systems and Local Television Station Audience." With F. M. Fisher, V. E. Ferrall, Jr., and D. Belsley. *Quarterly Journal of Economics* 80 (May 1966): 227–251.

11. I have written the following review article:

(a) *Economic Aspects of Television Regulation*., by G. Noll, M. J. Peck, and J. J. McGowan,. Written with S. M. Besen in *Bell Journal of Economics and Management Science* 5, No. 1 (Spring 1974): 301–319.

12. I have reviewed the following books:

(a) *Economic Innovations in Public Utility Regulation*, edited by M. A. Crew. *Journal of Economics/Zeitschrift für Nationalökonomie* 59, No. 3 (July 1994).

(b) *Economic Analysis of Product Innovation: The Case of CT Scanners* by M. Trajtenberg. *Journal of Economic Literature* 30, No. 2 (June 1992): 935–936.

(c) *Econometric Studies of US Energy Policy*, edited by D. W. Jorgenson. *Journal of Econometrics* 6 (1977).

(d) *Structure and Performance of the US Communications Industry* by Kurt Borchardt. *Annals of the American Academy of Political and Social Science* (March 1972).

(e) *Principles of Econometrics* by K. Chu. *American Economic Review* 58, No. 5 (December 1968).

13. I have also published the following:

(a) "Information, Telecommunications, and Markets," 19th Pacific Telecommunications Conference, Honolulu, Jan. 22, 1997.

(b) “Utilization of the US Telephone Network.” Discussion Paper No. 126, Wissenschaftliches Institut für Kommunikationsdienste, March 1994.

(c) “Incremental Costs of Telephone Access and Local Use.” R-3909-ICTF, Rand, July 1990. Also published in W. Pollard (ed.), *Marginal Cost Techniques for Telephone Services: Symposium Proceedings*. National Regulatory Research Institute, NRRI 96–1, January 1991.

(d) “Theory of Telecommunications Pricing.” With I. Vogelsang. Wissenschaftliches Institut für Kommunikationsdienste, May 1991.

(e) “US Practice of Telecommunications Pricing.” With I. Vogelsang. Wissenschaftliches Institut für Kommunikationsdienste, May 1991.

(f) “Pricing Local Exchange Services: A Futuristic View.” In J. H. Alleman (ed.) and R. D. Emmerson (eds.), *Perspectives on the Telephone Industry: The Challenge for the Future*. Ballinger, 1989.

(g) “Optimal Peak Load Pricing for Local Telephone Calls,” With R. E. Park. The Rand Corporation, R-3404-1-RC, 1987.

(h) “A Framework for Considering Local Measured Service.” In Richard J. Schultz and Peter Barnes (eds.), *Local Telephone Pricing: Is There A Better Way?* Center for the Study of Regulated Industries, Montreal 1984.

(i) “Demographic Effects of Local Calling Under Measured vs. Flat Service: Analysis of Data from the GTE Illinois Experiment.” With R. E. Park. In *Pacific Telecommunications Conference Proceedings*. Pacific Telecommunications Conference ’80, Honolulu, 1980.

(j) “Economic Aspects of Measured-Service Telephone Pricing.” In *Ratemaking Problems of Regulated Industries*. Proceedings of the Symposium on Problems for Regulated Industries, University of Missouri, 1980.

(k) “The Effect of Time-of-Day Rates in the Los Angeles Electricity Rate Study.” With J. P. Acton. In *Electric Rate Demonstration Conference: Papers and Proceedings*. Denver, Colorado, April 1980.

(l) “Economic Issues in Local Measured Service.” In J. A. Baude (ed.), *Perspectives on Local Measured Service*. Telecommunications Industry Workshop, Organizing Committee, Kansas City, 1979.

(m) “Foreign Experience with Peak-Load Pricing of Electricity.” In *Impact of the National Energy Act on Utilities and Industries Due to the Conversion of Coal*. Information Transfer, Silver Springs, Maryland, 1979.

(n) “The Costs of Constructing and Operating a CATV System.” In *CATV Today: A Discussion of Current Issues*. Georgetown University, School for Summer and Continuing Education, February 1975.

ANNEXURE B: GLOSSARY OF TERMS

Australian Telephone Terms			Approximately Comparable US Telephone Terms		
Acronym	**Term**	**Meaning**	**Acronym**	**Term**	**Meaning**
	access line	continuous circuit from end-user to LAS		local loop	from end-user to end-office switch
ACCC	Australian Competition and Consumer Commission		DOJ	Department of Justice	Enforces antitrust law
			FCC	Federal Communications Commission	Regulates telecommunications industry; addresses antitrust issues
ADM	Add/Drop Multiplexer	extracts/inserts traffic from RAU or LAS into SDH transmission ring	ADM		
	distribution cable	connects end-user to pillar		distribution cable	
CAN	Customer Access Network	network from end-user to RAU		Local Loop Network	network from end-user to wire center
CPE	Customer Premises Equipment	end-user's telephone equipment	CPE		
CMUX	Customer Multiplexer	Modern type of RAU replacing IRIM, RSS and RSU types of RAU.			
DIE	Directly Incurred Expenses	Expenses incurred by an organisational unit, excluding intrafirm transfers			
ESA	Exchange Service Area	area serviced by a RAU		wire center service area	Area served by a wire center
				serving area	area served by a serving area interface
	fibre ring	ring connecting several ADMs, to deliver SDH network traffic	fibre ring		
ETC	Exchange Termination Circuit	Component LAS/TNS			
IEN	Interexchange Network	cables and equipment used to interconnect LASs		Interoffice Network	cables and equipment used to interconnect end offices
IRIM	Integrated Remote Integrated Module	multiplexes traffic from several SIOs onto a smaller number of high-	DLC	Digital Loop Carrier	

Australian Telephone Terms			Approximately Comparable US Telephone Terms		
Acronym	**Term**	**Meaning**	**Acronym**	**Term**	**Meaning**
		speed cables			
GSS	Group Switching Stage	Component of LAS	LCU	Line Connection Unit	
LAS	Local Area Switch	switch	EO	end-office switch	
	lead-in	cable connecting NBP to distribution cable	drop		
	line card	the component of a local switch on which an access line terminates	line card		
LTH	Local Transmission Hub	cross-connect device sited at the LAS	MDF	Main Distributing Frame	Terminates feeder facilities in a wire center
MDF	Main Distribution Frame	terminates main cables at RAU			
	main cable	connects pillar to RAU		Feeder cable	
MTH	Main Transmission Hub	Major cross connect point for transmission network			
MUX	Multiplexer	Device that combines several calls onto a single cable	MUX	Multiplexer	
NBP	Network Boundary Point	Connects CPE to network at end-user's premises	NID	Network Interface Device	
OFDF	Optical Fibre Distributing Frame	Termination point for optical fibre	OFDF		
	pillar	first distribution point; cross-connects distribution cable to main cable	SAI	serving area interface	Cross-connects distribution cable to copper or optical feeder cable
POI	Point of Interconnect	where traffic is exchanged between two networks	POI	Point of Interconnection	
PSTN	Public Switched Telephone Network	Network designed to route and transport traditional voice calls placed by subscribers	PSTN		
RAU	Remote Access Unit	An IRIM or RSS			
	Regenerator	Device that receives an incoming digital signal and		Regenerator	

Australian Telephone Terms			Approximately Comparable US Telephone Terms		
Acronym	**Term**	**Meaning**	**Acronym**	**Term**	**Meaning**
		generates a new signal for transmission; replaces amplifier			
RIM	Remote Integrated Multiplexer	Includes IRIM and non-IRIM	RT	Remote Terminal	
RSS or RSU	Remote Switching Stage	Local switch component, often located remotely		Remote Switch	
	Scorched earth	Network design can select number and locations of nodes		Scorched Earth	
	Scorched Node	Network design takes as given the number and locations of incumbent's nodes		Scorched Node	
SDH	Synchronous Digital Hierarchy	Transmission protocol used on optical transmission network	SONET		
SIO	Service in Operation	a PSTN service		subscriber line	
STP	Signal Transfer Points	Packet switches used to set up and close down	STP		
TAP	Transmission Access Point	Lowest point in network where aggregation to 2 Mbps may be required	Remote Terminal, Digital Loop Carrier	Aggregation to 1.5 Mbps, US equivalent of 2 Mbps	
TNS	Transit (Trunk) Network Switch	subtends several LASs; part of interLAS transport network	TS	tandem switch	subtends several end office switches; part of interoffice transport
	transport network	Connections from RAU to LAS and LAS to TNS		interoffice transport	

ANNEXURE C: COMPONENTS OF THE NETWORK

1. To aid the discussion of key assumptions used in the PIE II model, and how those terms compare with those used in other TELRIC models, it is necessary to refer to a number of the basic elements that make up a local telephone network as modelled by various TELRIC bottom-up models. Some of the more frequently-referenced terms used in the PIE II model are gathered together in the Glossary in Annexure B, along with approximately comparable terms used in the US.

2. The relationship of network elements described in this annexure and illustrated in the accompanying diagrams is the one most frequently used in the PIE II model. The glossary and summary description below are based on information provided by Telstra and on documentation for several other TELRIC models.

3. Diagram 1 shows an overview of the PSTN. The end-user's customer premises equipment (**"CPE"**) includes his or her telephone instruments, answering and fax machines, and computer modems. For business customers, multi-line telephone instruments and private branch exchanges (**"PBXs"**) are also considered CPE.

4. A *line* is a continuous communications path from an end user's premises to a local access switch (**"LAS"**) and the PSTN. When a line is activated it is termed a Service in Operation ("**SIO**").

5. For the purpose of building the network, end-users are grouped into a number of Exchange Service Areas ("**ESAs**").

6. As shown in Diagram 2, the Customer Access Network ("**CAN**") in each ESA comprises the network equipment connecting end-users to remote access units. This is also referred to as the *local loop* network. Although the layout of network components varies according to local conditions, the following describes a typical configuration.

7. The CAN begins at a Network Boundary Point ("**NBP**") where the CPE is connected to a *lead-in cable* that then connects to a *distribution cable* that serves a number of adjacent end-users. As shown in the second cable path of the diagram, the distribution cables from a number of neighbourhoods or other small areas may

converge at a *pillar*, where they are cross-connected to a larger *main cable* with a capacity to serve several hundred end-users.

8. The main cable terminates on a Main Distribution Frame ("**MDF**") at the site of a Remote Access Unit ("**RAU**"). This is the boundary between the CAN and the Interexchange Network ("**IEN**").

9. At the RAU, the analogue PSTN signals originating at the end-user's CPE are converted to digital format. The RAU is a Customer Multiplexer, situated at either an existing network equipment building or as street furniture.

10. The digital signals are then typically combined in a multiplexer ("**MUX**") [and, as shown in Diagram 3, transported over a fibre-optic cable to an Add/Drop Multiplexer ("**ADM**") The ADM combines circuits from a number of RAUs and injects them into a fibre-optic ring for transport to a LAS. The LAS includes one or more Group Switching Stage ("**GSS**") modules. Local calls to other end-users served by this LAS are switched and sent on to the end-users. The remaining calls are injected by the ADM and transported further into the network to a Transit Network Switch("**TNS**"), where they are routed to another LAS, an international gateway switch, or a point of interconnection ("**POI**") with an access seeker.

Diagram 1: The PSTN

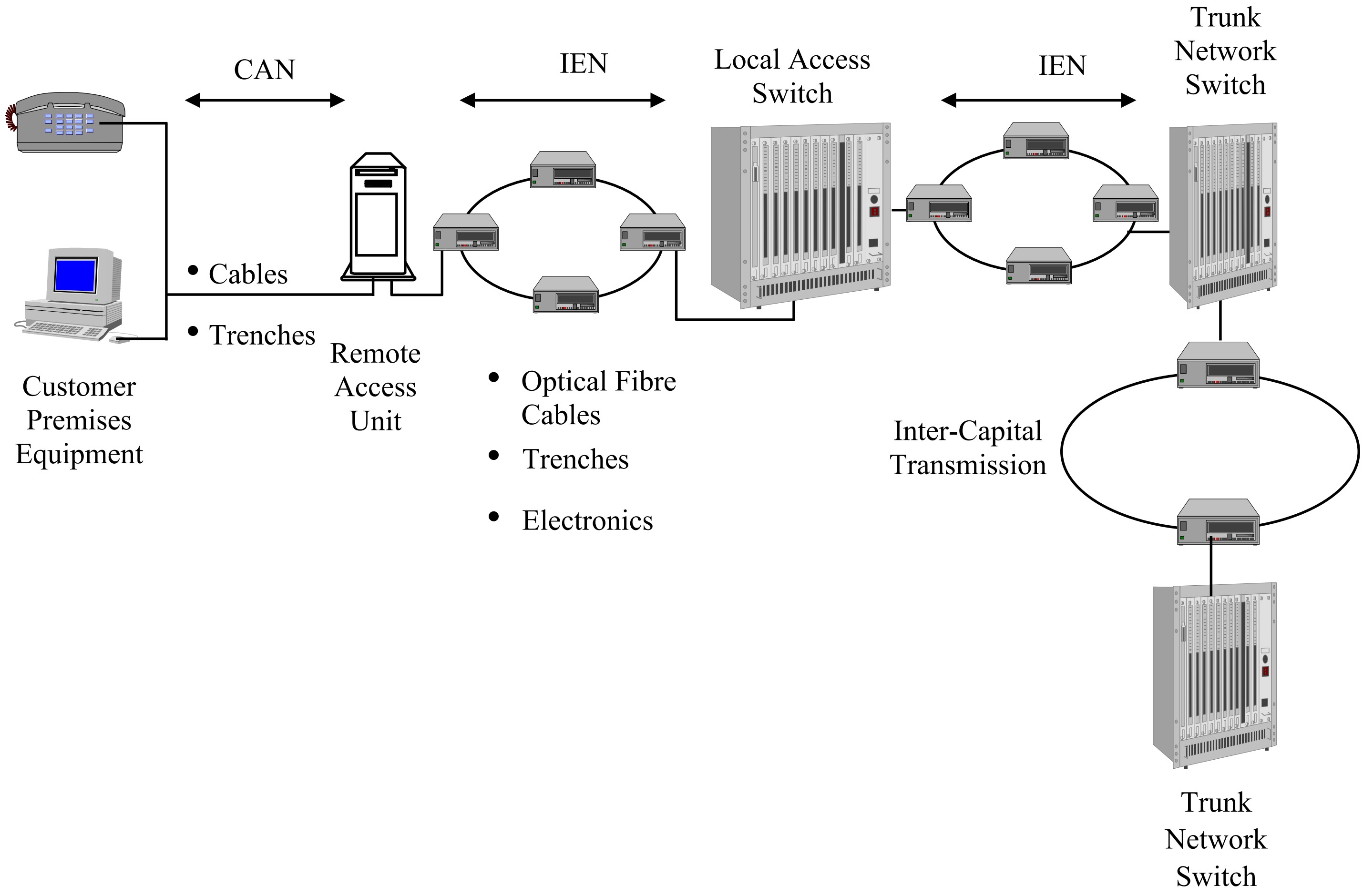


Diagram 2: The PSTN Cable Configurations

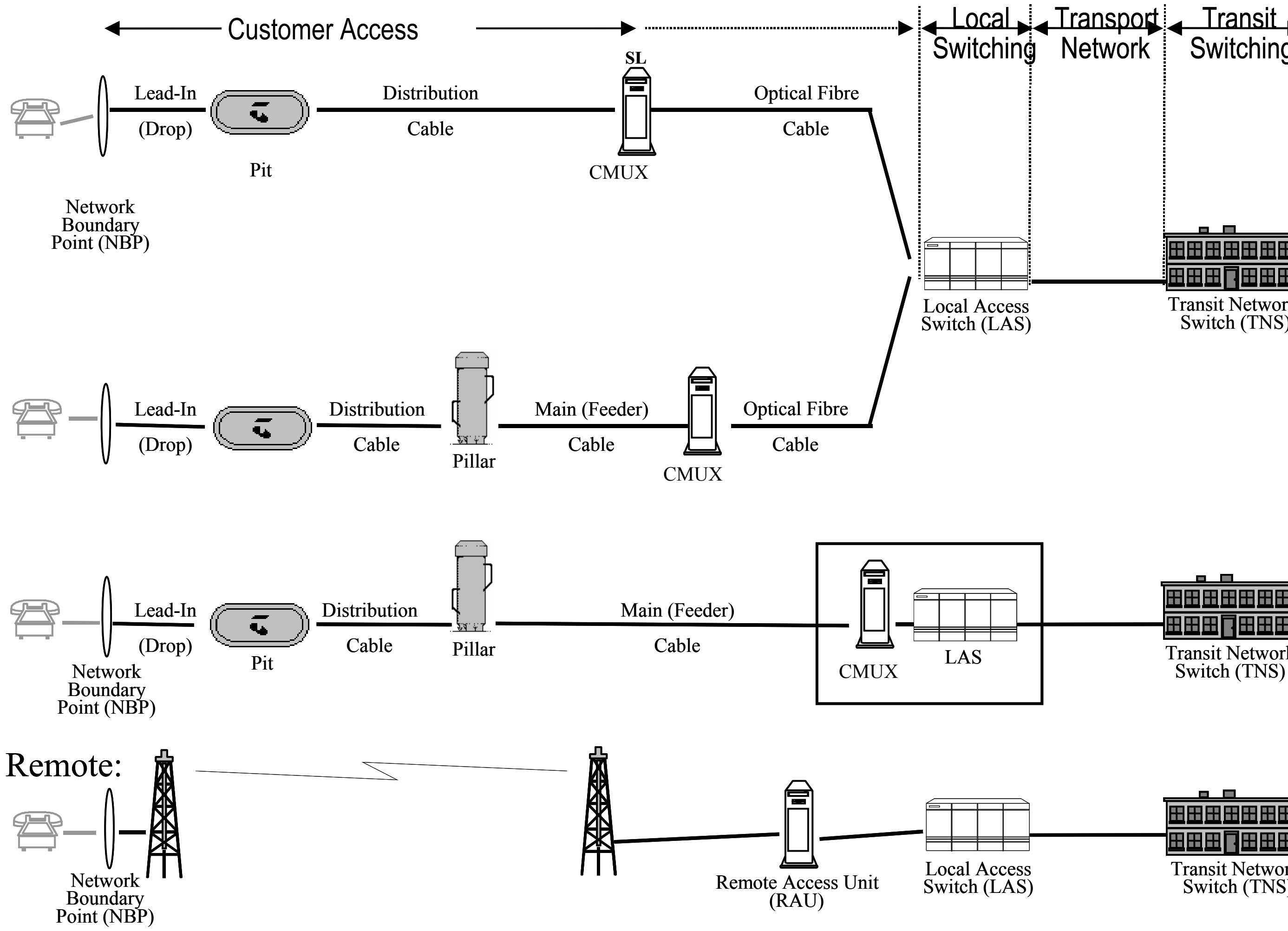
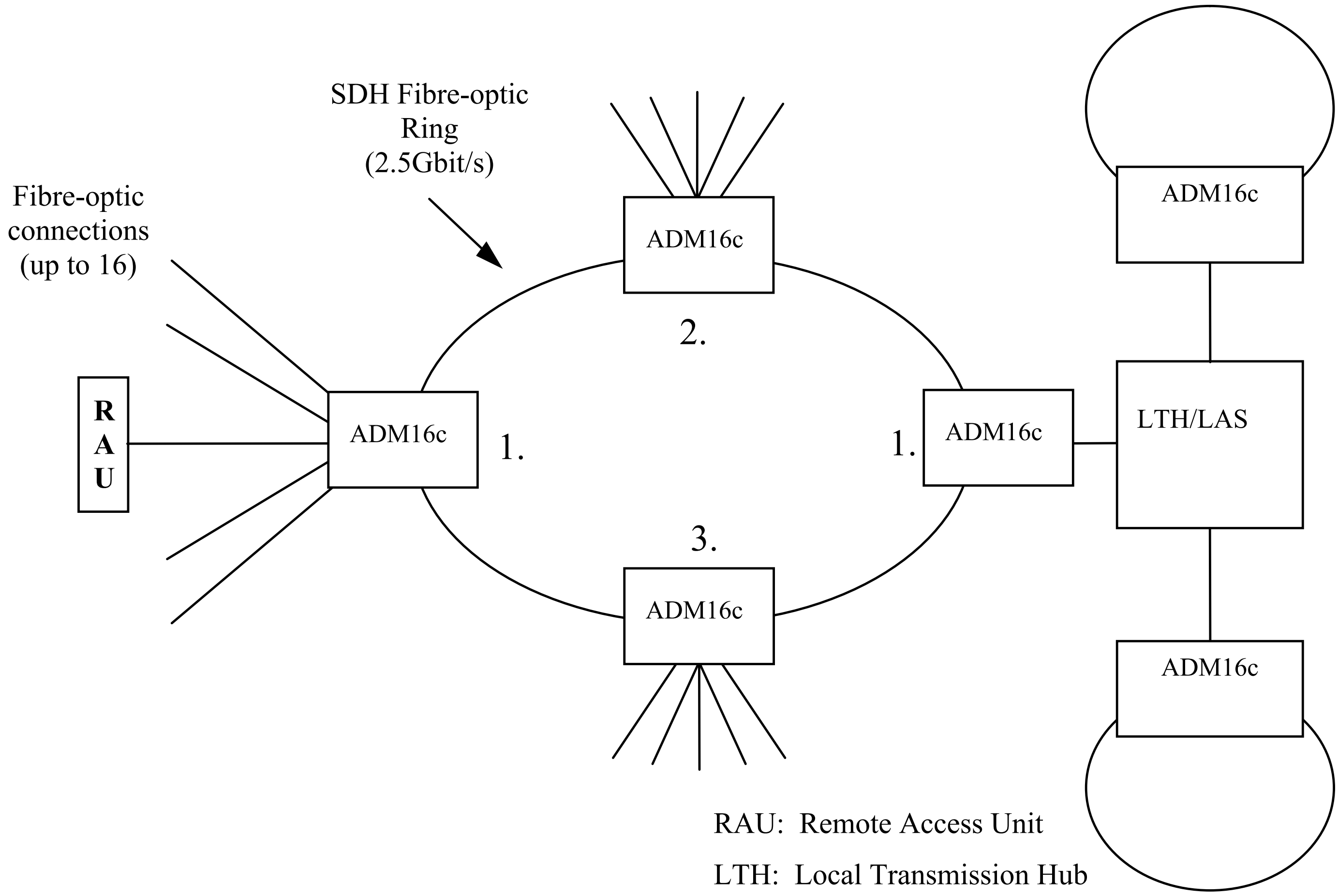


Diagram 3: Fibre-optic Local Transmission Ring



RAU: Remote Access Unit

LTH: Local Transmission Hub

LAS: Local Area Switch

ADM: (Add-Drop Multiplexers)

1. is the minimal configuration
2. is added to fill the capacity load
3. is added after 2. if necessary

ANNEXURE D: MODELING SERVICES RATHER THAN NETWORK ELEMENTS

1. A full implementation of the theory of TSLRIC pricing of telecommunications services requires a number of distinct steps to model the incremental and common costs incurred in producing different combinations of services. They are summarized below.

2. *First*, in order to determine the total magnitude of common costs, one must determine efficient production configurations for N+1 separate groupings of services – one for all N services, and then one for each configuration that excludes one of the N services. If different technologies are efficient for producing different sets of services the resulting cost calculations will require several different cost models and data.

3. The total cost of each such configuration must be calculated as a preliminary step to obtaining the TSLRIC of each of the N services. Total common costs are then obtained as the difference between total costs of all N services and the sum of the TSLRIC of each of the N services.

4. *Second,* in order to assess a potentially larger scope of services, provisional calculations must be expanded to include additional, possibly "extraneous" services in order to determine that those additional services can, in fact, be excluded from the final cost model without biasing the TSLRIC calculations. To assess additional services one must determine the technology that is efficient for producing the larger set of services and the technologies that are efficient for producing each subset that includes all but one of the services. In each case one must then calculate the forward-looking cost of that subset using the corresponding technology.

5. The cost calculations for an additional service must encompass all elements of the end-to-end service in order to calculate TSLRIC and common costs. For example, consideration of the inclusion of high-speed data services would require that the TSLRIC of these services be calculated and that all costs common to the production of these services are identified, in order to calculate the allocation of common costs. Even costs not common to the production of the relevant services being assessed would need to be considered to determine the total level of common costs that should be allocated to the high-speed data services.

6. *Third,* it is necessary to determine what common costs are shared by subsets of services, but not by all of the services. Common costs for all possible subsets of the N services must be examined. This requires far more than the N+1 separate production configurations. An efficient production configuration must also be determined for *every subset* of two or more of the N services.

7. For each of the service combinations just described, the network configuration that is efficient for producing a particular set of services must be determined. This would require considering alternate possible combinations of best-in-use technologies and constructing a bottom-up cost model of the selected design. As one example, when high-speed data services are included with PSTN Services in the mix of services, the efficient network design may require a fundamentally different type of switch or network architecture. Accurate cost modelling for such different technologies would likely require separate computer cost modules, if not fully separate models, for each technological variant. To my knowledge, no model that incorporates such optimised alternatives has been put forward in any regulatory proceeding.

8. *Fourth,* in order to carry out efficient allocations of common costs determined in the preceding steps, demand calculations must account for substitution and complementarity among services as each of the different combinations is modelled. For example, if one combination includes ISDN voice calls it will be necessary to recalculate the volume of local and long-distance PSTN voice-call services to account for shifts in traffic between PSTN and ISDN services. Then, as common costs are allocated to those services, the adjustments in demand due to marked-up prices to provide contributions to common costs will also need to be modelled. The required demand information includes both own and cross-price elasticities for all of the services.

9. In summary, it is impractical to carry out the complete calculation of TSLRIC required by economic theory because of the complexity of modelling required, the substantially increased costs of such modelling, the imprecision of the results, and the lack of necessary data. To date, no cost model for access services has been constructed to satisfy the demanding requirements summarised above.

ANNEXURE E: SERVICES INCLUDED IN THE INCREMENT

1. In my view, services included in the increment should include the total volume of services which are close substitutes in demand or services that use the same network elements and thus have a similar cost structure**.**

Substitutes in demand

2. The PSTN OTA service is used by an access seeker to supply local calls, STD, IDD and fixed-to-mobile calls. For end users these calls are close substitutes for the local calls, STD, IDD and fixed-to-mobile calls sold by the access provider. Similarly, LCS is used by access seekers to provide local calls. These LCS calls and the local calls provided by the access provider are close substitutes for end users. ISDN service provides switched voice calls that are close substitutes for PSTN switched voice calls.

3. Similarly, ULLS provided to access seekers and the basic access services supplied by the access provider are close substitutes for end users and will impose similar costs on the access provider.

Sharing of network elements

4. In my opinion, for purposes of calculating the TELRIC of supplying the UT Services it is appropriate to include in the increment both the UT Services provided to the access seekers and the PSTN Services provided by the access provider to end user customers. The network elements used by both types of services are essentially identical, even though I am advised that the configuration of network elements used by the UT Services is different to that used by PSTN Services.

5. Similarly, in a given ESA a PSTN SIO and another copper-based access service require approximately the same CAN elements. An increase in the number of PSTN SIOs or the number of other copper-based access service would impose approximately the same additional costs on those network elements.

ANNEXURE F: RECOVERY OF THE COST OF SPARE CAPACITY

1. TELRIC models have generally assumed that the costs of spare capacity, when provisioned efficiently, would be recovered in both the current price per unit of service and in future prices. Current consumers, then, would pay the costs of some capacity that remains unutilised until a later date. An alternative means of recovering this investment cost is to include in the price of service to current customers a charge for investment in spare capacity incurred in the past.

2. To assess this alternative, one must ask the questions, What are the costs today of spare capacity efficiently incurred in the past? and, How do they compare to a regime in which current users pay for future costs? In order to calculate past costs incurred for current users, TELRIC has to be adapted by assuming that those past costs represent past best-practice technology.

3. Let us assume that the optimal amount of such spare capacities is unaffected by who pays for those investments (something that is strictly true only if both methods result in the same telecommunications service prices). Assume also that the rate of price change for capital goods is independent of the rate of physical depreciation. We call ΔK^t the proportionate value of extra capacity held in period t for future use. The annual cost of this capacity depends on three parameters – r, the applicable interest rate; δ, the rate of physical depreciation of capital; and i, the rate of price change for the relevant capital goods. The annual cost is then $c\Delta K^t = (r + \delta + i)\Delta K^t$ and with q_t units of output, the current unit cost of current spare capacity is $\Delta p^t = c\Delta K^t/q_t$.

4. In the previous period, $t-1$, the annual cost of past spare capacity was $c\Delta K^{t-1}$. In the current period, this cost is $c\Delta K^{t-1}(1+r)$, and per unit of current output is $\Delta p^{t-1} = c\Delta K^{t-1}(1 + r)/q^t$.

5. The value of spare capacity changes from one year to the next – it is increased by the growth rate g of demand but reduced by the decline in capital goods prices i, so that $\Delta K^t = \Delta K^{t-1}(1 + g)(1 + i)$. I can then make the comparison between the two regimes[53].

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[53] There is also a question of depreciation. However, if the interest rate, price change of the capital good and the physical depreciation are constant percentages of the capital good value then depreciation cancels out.

Representing the method of recovering past spare capacity costs from current users by Δp^{t-1}, the ratio of current cost to past cost per unit of current demand is

$$\Delta p^{t}/\Delta p^{t-1} = \Delta K^{t}/[\Delta K^{t-1}(1 + r)] = (1 + i)(1 + g)/(1 + r).$$

6. For example, if capital goods prices are declining at 5% per year, demand is growing at 5% per year, and the interest rate is 15% per year, the value of the ratio is 0.87. This means that, when current users are charged for some future spare capacity, they pay just 87% of the charge they would instead have to pay to recover the costs of spare capacity incurred in the past.

7. Charging current users for the costs of past spare capacity can therefore only lead to lower current prices if i and g are sufficiently large. Reasonable ranges are $0 \geq i \geq -5\%$, $10\% \geq g \geq 3\%$, $15\% \geq r \geq 11\%$. These numbers imply $0.85 \leq \Delta p^{t}/\Delta p^{t-1} \leq 0.99$. Thus, it is very unlikely that current users would face lower prices under the backward-looking method than under current capacity cost pricing.

ANNEXURE G: OPERATIONS AND MAINTENANCE EXPENSES

Telstra Accounts	PIE II Model Factors	USOA Accounts	HM5.0a Factors, Five States		HCPM/FCC Factors
			Min	Max	
Land & Buildings (Properties)	“c-i-c”	Buildings (2121)	6.95%	11.59%	9.06%
SDH Transmission (SD)	“c-i-c”	Circuit Equipment (2232)	1.53%	1.53%	2.00%
Main cable (XU)	“c-i-c”	Aerial Cable (2421) Copper	7.25%	23.84%	6.69%
		Underground Cable (2422) Copper	1.68%	2.43%	2.10%
		Buried Cable (2423) Copper	2.79%	7.88%	4.46%
Distribution Cable (SC)	“c-i-c”	Aerial Cable (2421) Copper	7.25%	23.84%	6.69%
		Underground cable (2422) Copper	1.68%	2.43%	2.10%
		Buried Cable (2423) Copper	2.79%	7.88%	4.46%
Optical Fibre (BO)	“c-i-c”	Aerial Cable (2421) Copper	7.25%	23.84%	0.73%
		Underground cable (2422) Copper	1.68%	2.43%	0.84%
		Buried Cable (2423) Copper	2.79%	7.88%	0.61%
Main Conduit (XC)	“c-i-c”				
Distribution Conduit (XN)		Conduit Systems (2441)	0.08%	0.96%	0.58%
Switching (SL)	“c-i-c”				5.58%
Transit Switching (ST)		Digital Electronic Switching (2212)	2.69%	2.69%	
Signalling Transfer Point (SP)					
Misc Transmission (ZT)	“c-i-c”				
DC Power (DP)		No directly comparable data			
Network Management (NM)		No directly comparabel data			
Customer Radio (XR)	“c-i-c”	Not applicable			
Radio transmission (BD)		Not applicable			

SOURCES

HM 5.0a: Output by wire center for Florida, Georgia, Maryland, Missouri & Montana, Worksheet “96 Actuals”. Maximum and minimum calculated after negative ratios were removed.

HCPM: Output by wire center for Contel, Alabama, worksheet “96 Actuals”.

FCC: CC Docket 96-45, Tenth Report and Order, Appendix A.

NOTES:

HM 5.0a does not distinguish between copper and fibre cable. In the table, the model’s values for aerial, buried and underground cable are shown for both copper and optical fiber cables.

The US circuit equipment account includes copper-based transmission equipment.