Final Report for the Australian Competition and Consumer Commission

Review of specific issues in Telstra's PIE II model
PUBLIC VERSION

24 May 2006

Our ref: 255-193

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Contents

0 Executive summary

In the context of the current regulatory proceedings surrounding Telstra’s latest ULLS undertakings, the Australian Competition and Consumer Commission (ACCC) has commissioned Analysys Consulting to undertake a review of certain key aspects of the model underlying Telstra’s proposed charges (the PIE II model). The PIE II model is an engineering economic model, and has been developed by Telstra over several years since 2000. It is a complex and data-intensive model which is designed to emulate the construction and costing of an efficient PSTN network serving Telstra’s user base.

In this report, we provide an independent assessment of the issues of interest to the ACCC and outline a number of other points that the ACCC may wish to investigate further. We have also attempted to quantify the materiality of the issues outlined here. In carrying out our investigations, we have reviewed the source code of the PIE II model, and changed some of the input parameters, as far as allowed by the interface.

Due to the time required to run the model, no detailed sensitivity analysis has been undertaken. When our concerns relate to algorithmic choices, the impact assessment has been carried out outside the model, in accordance with the copyright of the model.

The ACCC version contains reference to confidential information. In this public version, this has been replaced with the following symbol <✂>.

0.1 Design of the access network

The first set of issues raised by the ACCC relate to the network design algorithm used in the PIE II model.

The access network design algorithms may not result in an efficient design

The ACCC is concerned that the PIE II model may be overestimating the length of trenches and cable in the access network, due to the use of an uncorrected rectilinear distance and the use of minimum spanning tree optimisation. The way in which the model designs distribution areas (DAs), without using clustering algorithms, has already been outlined in previous reports but has not been corrected.

A correction factor should be applied to the distance metric used in the model

A rectilinear (or 'Manhattan') calculation quantifies distances based on a square grid layout. Although this is typically reasonably accurate in urban areas, it is likely to distort real-life distances substantially in more rural areas, where the road layout is not grid-like. It is difficult to be certain by how much, but it may be of the order of 2%.

We agree that minimising trenching distance rather than total customer access network (CAN) cost is wrong. However in practice we do not see this as introducing material errors.

Minimum spanning trees could be further optimised by the use of Steiner nodes

The PIE II model does not consider the possibility of using Steiner trees despite previous suggestions, in particular by NERA. Readily available algorithms exist to modify MST into Steiner minimum trees.

The use of minimum spanning tree rather than a minimum Steiner tree will lead to a further inflation of the total cost by up to a maximum of 10%.

Using clustering algorithms would improve the robustness of the DA design

The absence of a clustering algorithm leads to a greater probability that trench and cable distances will be overestimated in relatively low density areas, where population centres are inherently more clustered than in urban areas. In a geographically averaged price for the unconditional local loop service (ULLS), this could have a disproportionate impact on the estimated cost of the service for those seeking access in urban areas, where the bulk of the ULLS demand currently arises.

Although it is difficult to ascertain the impact of not using clustering algorithms to define the boundaries of distribution areas, we note that their implementation should not require significant re-engineering of the model. Such algorithms have been used in other jurisdictions, and are readily available.

The benefit of trench sharing and trenches in new estates is underestimated by the model

The model attempts to capture two separate effects that reduce the cost of construction of the access network:

- An efficient entrant is able to use trenches and ducts to bury access network cables as well as inter-exchange network (IEN) cables. This results in a cost saving for both the access and the IEN.

- Developers typically allow telecoms operators to use open trenches in new estates at no cost. This allows customers in new estates to be connected at a substantial discount.

The availability of free trenches in new estates provides an opportunity for a new entrant planning its network deployment over a greater number of years than is currently acknowledged in the PIE II model. Real-life constraints, such as the shortage of skilled labour, would justify a network deployment spread across several years.

The degree of trench sharing between the IEN and the CAN that is assumed in the model is set to reflect Telstra’s actual deployment, which is the product of a very long history. A new entrant would optimise the sharing of trenches and ducts between the IEN and the CAN further than is currently modelled, particularly within more urban areas.

An increase in sharing could have an impact of up to a few percent on the cost of the access network. This could be further affected by the choice of method to allocate the cost of the shared trenches and ducts in different proportions to the IEN and the CAN, rather than the current equal distribution.

The calculation of costs in rural ESAs presents a number of problems

In the PIE II model, rural exchange service areas (ESAs) are connected to the PSTN network using a variety of technologies: satellite, radio, small capacity distributed systems. The choice of technology follows a set of rules that does not seem to reflect Telstra's actual practice, or indeed a least-cost design.

Moreover, recent technological developments, in particular with regard to new radio system such as WiMAX, raise the question of whether the technologies captured by the model indeed constitute relevant modern equivalent assets.

Given the weight of the cost of ULLS in Band 4 ESAs in the geographically averaged price, this is a material consideration and should be taken into account by Telstra.

0.2 Forward-looking costing issues

Other issues of specific concern to the ACCC relate to the way the model calculates, allocates and forecasts costs.

The model risks systematically overestimates operation and maintenance costs for long-lived assets

O&M in the PIE II model are calculated as a proportion of the capital cost of assets. This constitutes a practical solution to a shortage of detailed, bottom-up data. However, wherever possible, Telstra could be expected to attempt a more in-depth analysis of the O&M factors generated.

Long-lived assets are treated in a purely top-down fashion: the actual O&M expense incurred by Telstra (which includes O&M for both aerial and buried cable) is apportioned to the capital cost produced by the model. However, the model assumes that all cable is buried, which is cheaper to maintain than aerial cables: the risk is that this higher O&M expense is allocated to buried cables as a results of the allocation method chosen.

This presents a risk of overestimation that could be as much as 10%. Telstra should provide more information on these assets so as to correct any potential error in estimating O&M.

Provisioning for fault and future demand is reasonable, although the modularity of equipment could be improved

Provisioning for future and heterogeneous demand is standard practice. Strictly speaking an economic form of depreciation (rather than the current annuity calculation) would result in depreciation charges that recognise the varying demand profile for the assets, and recover costs accordingly. However, this effect may be quite small in the access network.

Some of the modularity of equipment assumed in the model appears unnecessarily overstated, and may result in higher charges than necessary. If the model were to assume lower capacity cables, for instance, it would be possible to quantify this effect.

The projection of costs for financial years 05/06, 06/07 and 07/08 uses unclear price trends

Telstra has designed a roll-over methodology to project the costs of the PSTN services in future years, covering the period of the Undertakings. We are concerned that the roll-over of O&M costs is directly linked to the evolution of capital costs, which is simplistic and does not recognise the separate evolution of operation and maintenance costs. This could be remedied by setting specific O&M price trends for different asset classes.

Moreover, two different sets of price trends have been presented by Telstra in the model and in the documentation of the Undertakings. It is unclear which of these has been used to support the Undertakings.

1 General review of the PIE II model and identification of potential issues

1.1 The PIE II model

The PIE II model is an engineering economic model, developed by Telstra since 2000 to support its wholesale PSTN service Undertakings. It uses Microsoft Access for data storage and manipulation. Microsoft Visual Basic is used for coding the algorithms that compute the network required to support a given demand scenario, in a bottom-up fashion, and generate total element and service incremental costs (TELRIC/TSLRIC) for the PSTN.

We understand that the ACCC has until now refused to accept PIE II as a basis for Telstra's Undertakings, for a variety of reasons set out in the ACCC Final Decision, dated December 2005.[1] In the context of this ongoing dispute, the ACCC has commissioned Analysys to provide expert opinion about some aspects of the PIE II model.

This draft report addresses these issues, detailed in Section 1.2, below, and points the ACCC towards a number of other issues we identified during our review of the model in Section 4.

1.2 Issues raised by the ACCC

The ACCC has raised a number of issues with the PIE II model, relating to the assumptions and algorithms used in the model. We have organised these issues around two main axes, detailed in Sections 2 and 3 of this report.

The first set of issues relate to the bottom-up way the PIE II model designs the access network. The methodology used, as well as the assumptions made in the model, are a source of concern for the ACCC. We have examined the following aspects of the network design:

- definition of distance and the optimisation of trench length
- design of the distribution areas, not making use of clustering algorithms

1 ACCC, *Assessment of Telstra's ULLS and LSS monthly charge undertakings, Final Decision*, 2005

- extent of trench sharing and free access to trenches in new estates
- network deployment and associated costs in remote areas of Australia.

The second set of issues relates to the costing side of the model, and in particular, the choices made to calculate forward-looking costs. Bearing in mind that these must be reflective of the TE/TSLRIC methodology, we have examined in detail:

- calculation of operation and maintenance costs
- provisioning for faults and future demand and the recovery of associated costs
- the way the model has been used to roll forward network costs in order to determine efficient charges for future years.

1.3 Methodology and approach

For each aspect of the model that we have considered, we first describe the way in which the PIE II model functions, then discuss a range of potential problems. We have then indicated possible solutions to these issues that use or do not use the PIE II model.

We have attempted, as much as possible, to produce a high-level quantification of the impact of the problems identified. In a number of cases, this had to be done outside the model, for two main reasons:

- The Confidentiality Undertaking to which we are bound for this project does not allow us to make changes to the model itself.

- The length of time required to run any module in the model and the inter-dependence of modules make it extremely difficult to produce meaningful sensitivities in a relatively short period of time.

As a result, whenever possible, we have developed some simple models to assess the materiality of these issues.

2 Design of the access network

The PIE II model is an economic-engineering model that aims at building an efficient PSTN network in a bottom-up fashion, using Telstra's exchange service areas (ESA) topology as a starting point. The costs relating to this hypothetical efficient network are considered in a forward-looking perspective.

The topology of Telstra's access network has two levels: <✂> ESA, sub-divided into a larger number of distribution areas (DA), which contain a pillar (for urban areas) or one cable tree (for non-urban areas).

ESAs are administrative areas that historically correspond to "an area that can be served efficiently using an electro-mechanical (Strowger) exchange"[2]. They are still used for defining call charging areas. ESAs are split into 11 categories, which are mapped onto 4 zones in the model, as shown in Exhibit 1. Each category is also assigned an urban or non-urban flag.

ESA Category	*Modelled zone*	*Urban flag*
CBC	Metro	Y
CBD	CBD	Y
MET	Metro	Y
MNU	Rural	N
PVA	Prov	N
PVB	Prov	N
PVC	Prov	N
RCO	Metro	N
RCC	Metro	N
REM	Rural	N
RUR	Rural	N

Exhibit 1: *Simplification of ESAs categories in the model [Source: PIE II model]*

ESAs are then further classified into bands, which are used to geographically de-average the price of ULLS but are not strictly defined by Telstra. Only <✂> ESAs are classified in bands, so the total number of services in operation (SIO) that are in bands is <✂>, compared to <✂> SIOs in total. The two categorisations of ESAs are broadly consistent:

2 See NERA, *Comments on PSTN conveyance costs in PIE II*, March 2004

- all CBD ESAs are in Band 1
- Bands 2 and 3 are a mixture of metro and provincial ESAs
- most rural ESAs are in Band 4.

This results in similar repartitions of SIOs between bands and zones, as shown in Exhibit 2.

Band	*ESAs*	*SIOs*
Band 1	<✂>	<✂>
Band 2	<✂>	<✂>
Band 3	<✂>	<✂>
Band 4	<✂>	<✂>

Zone	*ESAs*	*SIOs*
CBD	<✂>	<✂>
Metro	<✂>	<✂>
Prov.	<✂>	<✂>
Rural	<✂>	<✂>

Exhibit 2: *Distribution of ESAs and SIOs between bands and zones [Source: PIE II model, Analysys]*

DAs are further classified into three different types of areas: dense urban, urban and rural, depending on the number of SIOs in the DA, and the density of SIOs per address. In each DA, the network design follows a different set of rules. Each DA is connected to the remote access unit (RAU or CMUX[3]) that is nearest its centre.

3 Customer multiplexing equipment, which are the modern incarnation of RAUs in Telstra's network

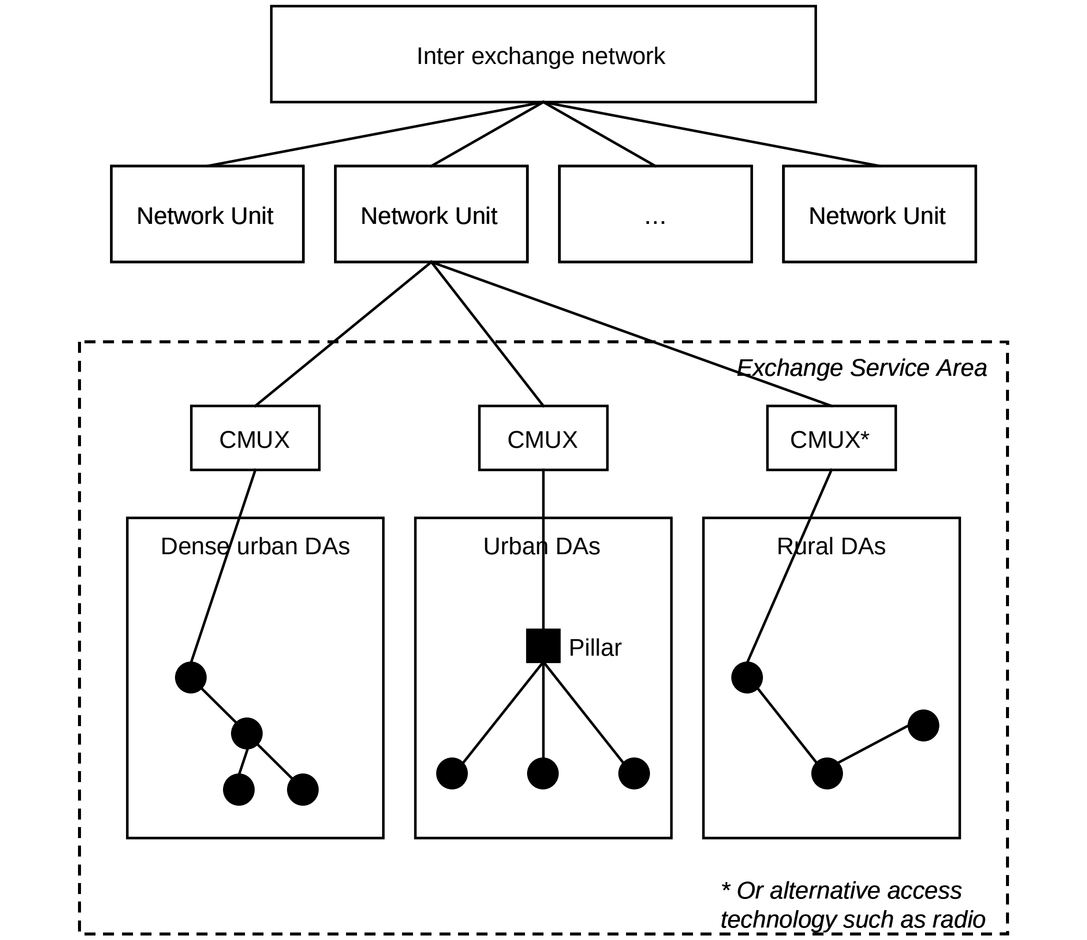

Exhibit 3: *Access network topology as represented in the PIE II model [Source: Analysys, based on Telstra's documentation]*

The ACCC has concerns relating to the way the model constructs an efficient (least-cost) network following the principles set out above. Some of these concerns have already been examined in detail by NERA for Optus, in a submission to the ACCC in July 2003.[4] We have further reviewed the following aspects of the network design model:

- the estimation of distances in the model and the optimisation of costs only in relation to trenches costs, neglecting copper costs
- the design of distribution areas and the possible use of clustering algorithms

4 NERA, *Assessment of the PIE II model*, July 2003

- the extent of trench sharing, in particular with regard to new estates
- the calculation of costs in rural ESAs, using multiple technological solutions.

2.1 Estimation of distances and optimisation of links costs

Description of the issue

A large proportion (<✂>[5]) of the total network investment costs is made up of trenches and ducts that are used by the access network cables, and sometimes shared with the inter-exchange transmission links.

It is therefore crucial for an efficient network design to optimise these building costs. These costs are driven by the amount of civil works required, directly linked to the total distance covered by trenches and ducts, and the length of the copper and optical cables laid out inside them (though in the case of architectures using pillars or where the cables are "tapered" (i.e. have decreasing numbers of pairs along the length), the cabling cost may not be purely proportional to the length of cable).

Where customer access is done through copper pairs, it is necessary to deploy an end-to-end copper pair between the customer premises and the customer multiplexing equipment (CMUX).

How the PIE II model estimates distances and minimises trench costs

The PIE II model estimates distances using the rectilinear distance metric between two points, rather than a straight line. This is, as has been argued by Bridger Mitchell, a common simplifying assumption. As shown in Exhibit 4, the rectilinear distance is always

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5 Bridger Mitchell, *Appropriateness of Telstra's 2005 cost modelling methodology*, 2005, p41 (139)

greater than the Cartesian distance. The orientation used in the model refers to the standard planar coordinates used in Australia, oriented north-south and east-west.[6]

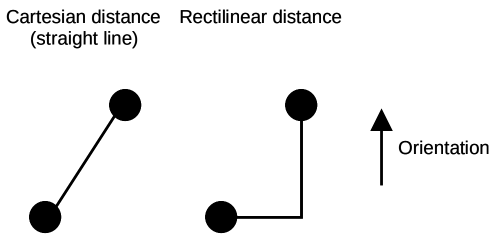

Exhibit 4:
Cartesian vs. rectilinear distance
[Source: Analysys]

The PIE II model only optimises the costs of links in the customer access network (CAN) with respect to trench length. (i.e. the cost of the cabling is neglected for the purposes of finding the minimum cost solution).[7]

The total trench distance in a given DA is calculated using a minimum spanning tree between the addresses contained in the DA.

Accordingly there are three issues of interest:

- use of a rectilinear or 'Manhattan' metric
- use of minimum spanning tree
- minimising trench lengths as a proxy for minimising the total link cost.

Discussion

Manhattan metric

It is possible to test whether the metric used is a realistic one by the use of real addresses served and real network layout constraints (or road layout data, which is a realistic alternative as many telecoms networks follow roads). The paper of Love et al.[8] has studied

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6 The rectilinear distance function is define in the CAN Library model of CAN_AF.mdb as Rectilinear_Dist((X1,Y1),(X2,Y2)) = |X1-X2| + |Y1-Y2| where Xn and Yn are the planar coordinates of a given point.

7 Bridger Mitchell, *op. cit*., 2005, p41 (139) and (140)

8 Love, Morris, and Wesolovsky in "Facilities location models and Methods", Ed Saul J Goss, North Holland

a number of the possible generalised distance metrics, including Manhattan and Euclidean, in the form:

$$l_p(q,r) = \left[|q_1 - r_1|^p + |q_2 - r_2|^p \right]^{\frac{1}{p}}, \text{ p>=1}$$

Here p=1 is the Manhattan, or rectilinear, metric and p=2 is the Euclidean.

This paper concluded that "it is inappropriate to simply assume a convenient value for p in a location study". This suggests that asserting a Manhattan metric is unwise. Further, this study suggests that a scaling factor k also be applied.

$$kl_p(q,r) = k\left[|q_1 - r_1|^p + |q_2 - r_2|^p \right]^{\frac{1}{p}}$$

Experimental data has found a variety of best fit points for p (leading to the conclusion above regarding not making a simple assumption regarding p).

As pointed out in Bridger Mitchell's report,[9] no correction factor has been applied to the distance metric used in the PIE II model.

Accordingly, the method would be materially improved if it was based on values of p and k, justified by means of a statistical sample of real distances between Australian addresses (ideally, representing CAN segments).

We note that whilst it is easy to see how urban centres might have road networks that lead to a lower value of p (more 'Manhattan' than 'Euclidean') due to street grids, in rural areas it may be significantly different. Accordingly, the values of k and p used might need to be varied by the ESA type.

It is not straightforward to estimate the materiality of this effect, but we may use Table 10.2 of the Love paper as a starting point. In this paper, the unrotated Manhattan metric requires a k value ranging from 0.94 to 1.05 with an average of 0.977; there is therefore a

9 Ibid, pp 43-44

real risk of overstating the trench length by a factor of around 2% (though depending on the real geography of Australia and the sample of points, we note that this may be greater or indeed, smaller). We note that alternative metrics gave a significantly better fit to the measured data in that study, implying the possibility of some greater savings. It is impossible to be categorical without analysis of the real data, but additional changes of order 5% of duct or trench length might be possible (for the avoidance of doubt, including the possibility of both increases or decreases).

Use of minimum spanning tree

A minimum spanning tree is a computationally cheap way of evaluating a reasonable network linking a set of points. It does not allow new nodes to be added to the network; it is simply the shortest connected series of straight lines visiting all of the nodes (and no other nodes).

As NERA has noted in their paper, it does not, however, lead to the shortest network, which is a so-called ‘Steiner tree’ in which intermediate points can be created.

The minimum Steiner tree is known to be up to a maximum of 13.4% shorter than the minimum spanning tree; in practice it is often within a few percent. Nevertheless, it is always greater than (or in the very unlikely limit equal to) the length of the minimum Steiner tree, so this error is always in Telstra’s favour. NERA’s report argues for a possible <✂> overstatement, which is certainly possible.

Accordingly, if trenching and cable costs represent approximately <✂> of the total cost calculated by PIE 2, then using a minimum Steiner tree could be expected to reduce the total annualised cost of ULL by up to an additional 10% (and possibly rather less).

Our proposed changes to the estimated length of trenching are compatible with Telstra’s comparison of its estimated trench length, with road network statistics for Australia as reported in Telstra’s Submission dated 9 Jan 2003 – ANNEXURE J, because that comparison is by nature approximate.

Optimising trench costs rather than total CAN costs

Telstra has chosen to optimise exclusively trench distances, on the basis that the cost of copper is so much lower than the cost of trenching that the optimal solution would nearly always be identical with the two methods. This assumption seems reasonable, given the relative costs of trenching and ducting and the costs of the copper cable itself.

The optimisation of trench costs by considering two separate cost variables (trenching and copper) is algorithmically feasible, as indicated by NERA (2003). NERA’s suggested changes, although theoretically correct, are unlikely to materially impact the resulting cost.

Conclusion

We would prefer a distance metric to be used whose properties have been investigated in an Australian context. A correction factor applied to the Manhattan metric would be a possible solution; a non-integer value of p is also a possibility. The lack of correction factor risks overestimating the costs of the CAN; it is difficult to be certain by how much, but it may be of the order of 2%.

We agree that minimising trenching distance rather than total CAN cost is wrong in theory, but we do not see it as introducing material errors in practice.

The use of minimum spanning tree rather than a minimum Steiner tree will also overestimate the total cost by up to a few % (with a maximum of 10%).

2.2 Design of distribution areas and clustering algorithms

Description of the issue

The access network represents the majority of the costs allocated to the ULLS service. The way it is designed in the modelled efficient network is therefore critical to the resulting cost for unbundled copper loops. This section examines the principles employed in designing distribution areas and the optimisation principles implemented to make this design efficient.

How the PIE II model builds the access network

The topology of the efficient network computed by the PIE II model is shown in Exhibit 4 above. The model takes existing exchange service areas, or ESAs, as a starting point to the calculation. Optimisation of the access network is only carried out in the distribution area layer.

ESAs are split into DAs. Geographically, DAs are grid rectangles with a comprised size between $0.625km^2$ and $20.25km^2$. DAs can be dense urban, urban or rural. Rural DAs can be linked to a CMUX by a main cable or by alternative access technology such as radio links. In urban DAs, the SIOs are connected to a pillar located near the centre of the DA, which acts as a first level concentrator before the CMUX.

Two main issues have already been raised with the way DAs are calculated, in particular in (NERA, 2003):

- DAs constitute a paving of Australia that does not consider *a priori* the distribution of addresses in Australia. As a result, the boundaries between two given DA can split a relatively dense area into two. This creates two DAs with artificially low densities, which do not correspond to a reasonable network deployment (Exhibit 5, Figure 1).

- The model does not make use of clustering algorithms. As a result, pillars and main cable points of connection may be unnecessarily far from the majority of SIOs, creating important inefficiencies in trenching and cabling (Exhibit 5, Figure 2).

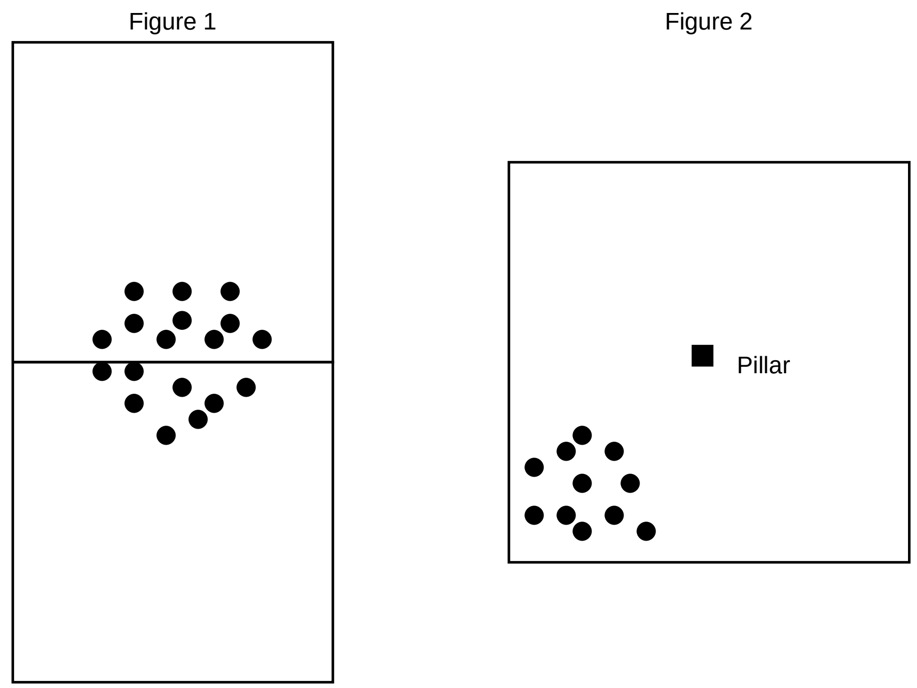

Exhibit 5: *Issues with DA definition identified by NERA [Source: NERA, 2003]*

Although the principles governing the deployment of remote access units (RAUs) are not explicit in the documentation to which we have access, examining the model code[10] indicates that the location of RAUs is calculated based on the definition of DAs. Section A.2 contains a textual transcription of this algorithm.

In essence, a RAU is deployed in a DA with a high number of SIOs. The capacity of the RAU is then filled by connecting neighbouring DAs. This procedure is repeated until all DAs are connected to a RAU.

Network units (NU), on the other hand, are located at specific sites, according to a scorched node approach. DAs that are within a certain distance of the NU are connected directly to the NU without the need for a RAU.

10 in CAN_AF.mdb, query *ProvisionRAUs()*, function *ProvisionAUs()*

Discussion

Telstra has not yet addressed the points brought forward by NERA, according to the model documentation available and our preliminary investigation of the code used to build up distribution areas in the PIE II model. These are good points and can materially impact the length of trenches and cables produced by the model.

The mixture of different network deployment algorithms used in dense urban, urban, and rural DAs, the variable size of DAs, and the interaction with 'typical' housing clusters in different geographies of Australia makes it particularly hard to estimate the quantitative impact of the placement of the boundaries between DAs. Nevertheless, this approach can certainly lead to low estimates of the density of SIOs compared to a more optimised network design.

SIO density governs the choice of technology in a given DA, and is a significant driver of network costs. It would be odd to use a radio technology simply because a SIO was 100m from its nearest neighbour, but over the boundary into an otherwise unoccupied DA).

It is extremely difficult to estimate the possible size of this effect, due to the lack of statistical information on whether there are in fact significant 'clustering' effects, and the subtle way in which these will affect the technology deployment.

While a small, systematic error in the overall estimate of density may not have a massive effect on the network costs, the DA placement also affects the amount of infrastructure deployed, because it sets the location of certain pieces of infrastructure (RAU sites, pillars), as discussed below. Accordingly, there may be too much duct and cable deployed when the pillar or RAU is placed in an inefficient location. We note that some of the network design algorithms use an 'average address', calculated as the centre of gravity of the SIOs in a DA. This appears to be restricted to the location of network units in ESAs where there is no 'support site' documented – i.e. an exception rather than a general rule. Generalising the use of centres of gravity rather than grid centres would alleviate some of the problems identified in Exhibit 5.

The deployment of RAUs detailed in Annex A, is not documented in any of the papers to which we have had access. This deployment, however, is a significant driver of the cost of the CAN. The algorithm employed by the model deploys RAUs in distribution areas that have a large number of SIOs, then connects neighbouring DAs in order to fill in the spare capacity on the RAU.

In some situations, however, this method may create inefficiencies. For instance, in the case shown in Exhibit 6, RAU1 gets deployed in the area with the most SIOs. The nearest DA contains too many SIOs to be connected to RAU1, but DA3, DA4 and DA5 could be connected. As a result, RAU2 is deployed in DA2, and linked to DA6. This is not guaranteed to optimise network deployment. For instance, the average utilisation of RAUs in more dense areas may be quite low, with a large number of units deployed, as shown in DA1 and DA2 in Exhibit 6.

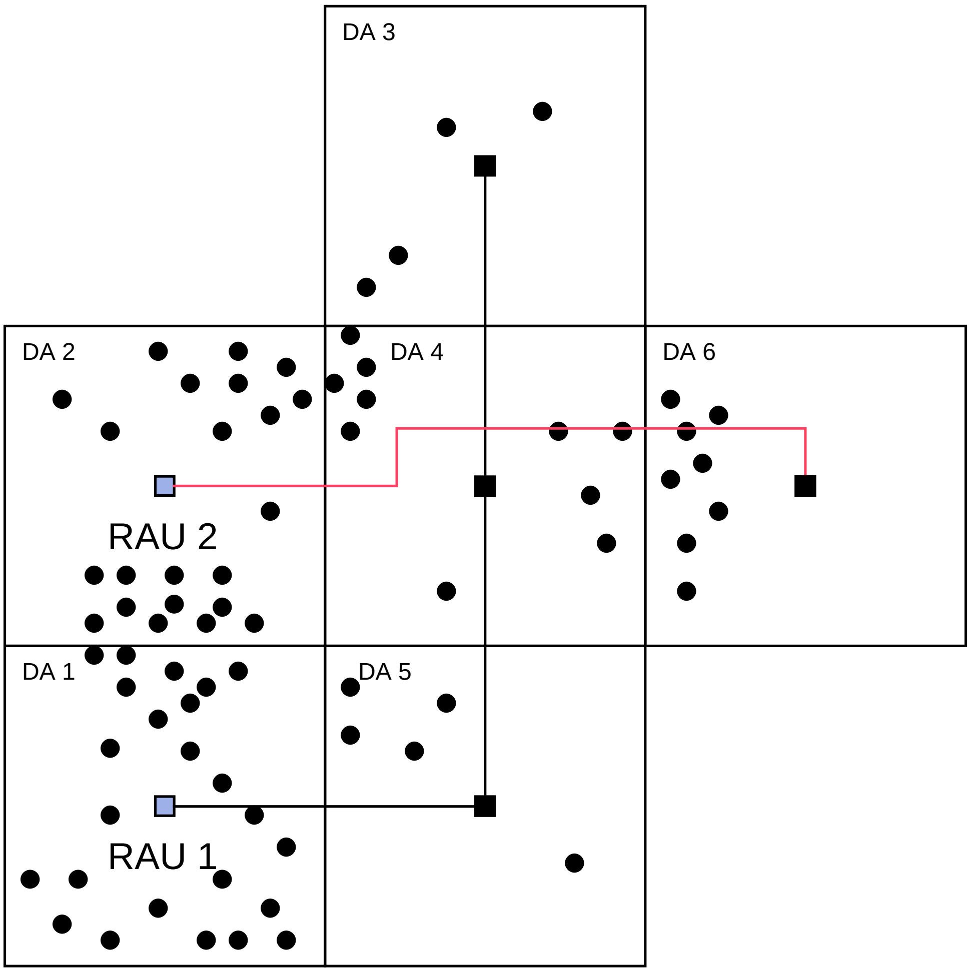

Exhibit 6: *Example RAU deployment creating longer than required cabling [Source: Analysys, based on PIE II algorithms]*

In this example, it would be more efficient to allow DAs 3 and 4 to connect to RAU2. Further examination of the materiality of this specific issue could be investigated further in a subsequent phase of this project.

Conclusion

The likelihood of overestimation of trench and cable distances due to the absence of clustering algorithm is higher in relatively low density areas, where population centres are inherently more clustered than in urban areas. In a geographically averaged price for ULLS, this could have a disproportionate impact on the cost of the service for those seeking access in urban areas, where the bulk of the ULLS demand currently arises.

Although it is difficult to ascertain the impact of not using clustering algorithms to define the boundaries of distribution areas, we note that their implementing should not require a significant re-engineering of the model. Such algorithms have been used in other jurisdictions, and are readily available.[11]

2.3 Trench sharing and trenches in new estates

Description of the issue

We understand that Telstra shares some of its trenches and ducts with other telecoms providers. Trench sharing also occurs between the CAN and the IEN. In newly built estates, we understand that developers allow Telstra to deploy infrastructure in open trenches effectively for free. About <✂> of lines in each year are in newly constructed estates.

A new entrant deploying a greenfield network in Australia could realise some cost savings when deploying lines in new estates, and from sharing its trenches and ducts with existing providers.

11 See for example, *FCC Public Notice*, 7 August 1998, available at http://www.fcc.gov/Bureaus/Common_Carrier/Public_Notices/1998/da981587.pdf

How the PIE II model accounts for trench sharing and trenches in new estates

The PIE II model recognises the existence of trench sharing and reduced costs in new estates. However, the model does not capture the benefit derived from new estate construction over time, and only considers the cost savings to relate to about <✂> of SIOs deployed. Bridger Mitchell (2005) argues in favour of Telstra's approach when he states that the relevant forward looking cost in each year is the cost of a wholly new entrant, and therefore that the benefit of new estate construction cannot be accrued over several years.

In contrast, we note that in its 2003 Undertakings, Telstra[12] explicitly accounts for trenches in new estates when calculating estimates of trenches and ducts based on road length. In Annexure J, page 5, Telstra "assumes that there was a <✂> per annum growth in trenching in new urban and major rural areas" between 1996 and 2002.

Trench sharing with third parties in the CAN is about <✂> of the trench length. <✂> of the CAN length is also shared with the IEN.

Discussion

According to Bridger Mitchell (2005), a strictly forward-looking approach to costing the ULLS service would imply that a wholly new entrant be modelled, serving the whole of Australia from Day 1. This is indeed consistent with a pure interpretation of TSLRIC principles simulating a fully competitive, fully contestable market.

However, in practice, the length of time required to build out the network, and in particular, all the civil works required to build trenches and lay cables, would take several years, during which the new entrant could progressively make use of open trenches in new estates at no cost.

12 Telstra's detailed submission in support of its detailed undertakings dated 9 January 2003, Annexure J: Trench Lengths

In addition, Telstra states in two instances[13] that the growth in the number of households in Australia is around <✂> per annum, and that the recent decline in the demand for lines is not representative of the medium term outlook. However, Telstra also estimates the proportion of lines that are in new estates to be <✂> in each year.

A new entrant would also attempt to maximise sharing between its IENand its customer access network. The current level of sharing in Telstra's network, only <✂> of the total IEN length, is the product of the development of the network over a very long period of time. The model outputs (for 2002/03) show substantial differences between the different geotypes, as shown in Exhibit 7. A new entrant would probably be able to optimise its routes better at least in CBD and Metro; rural networks cannot be shared in locations in between centres of habitation where there are no customers.

Metres of cabling	*CBD*	*Metro*	*Provincial*	*Rural*
Distribution	<✂>	<✂>	<✂>	<✂>
Main	<✂>	<✂>	<✂>	<✂>
IEN	<✂>	<✂>	<✂>	<✂>
% of IEN shared with main or distribution	<✂>	<✂>	<✂>	<✂>
% of IEN length in geotype	<✂>	<✂>	<✂>	<✂>

Exhibit 7: *Trench length and sharing in different types of ESA [Source: PIE II model]*

We have attempted to quantify the effect of increase sharing between the IEN and the CAN, based on high-level estimates of cost of trenches in both networks. Exhibit 8, below, shows the CAN and IEN investment in conduit and trenches under different sharing scenarios. The impact is likely to be quite limited, as the proportion of IEN shared is somewhat constrained by the fact that the majority of the IEN is in rural ESAs.

13 *TELSTRA'S SUBMISSION IN SUPPORT OF THE ULLS MONTHLY CHARGES UNDERTAKINGS DATED DECEMBER 2005 ANNEXURE E NETWORK COSTS* and *ANNEXURE J TO TELSTRA'S DETAILED SUBMISSION IN SUPPORT OF ITS UNDERTAKINGS DATED 9 JANUARY 2003*

% of IEN shared with CAN	*CAN trench costs (AUD million)*	*IEN trench costs (AUD million)*	*Total trench costs (AUD million)*	*Overall saving due to sharing*	*Saving on access only*
0%	<✂>	<✂>	<✂>	<✂>	<✂>
<✂>	<✂>	<✂>	<✂>	<✂>	<✂>
10%	<✂>	<✂>	<✂>	<✂>	<✂>
25%	<✂>	<✂>	<✂>	<✂>	<✂>
50%	<✂>	<✂>	<✂>	<✂>	<✂>
75%	<✂>	<✂>	<✂>	<✂>	<✂>
98%	<✂>	<✂>	<✂>	<✂>	<✂>

Exhibit 8: *Potential cost saving with different amounts of sharing between the IEN and CAN [Source: Analysys estimates based on PIE II model]*

The scenarios shown above consider that the cost of a shared trench is shared equally between the CAN and the IEN. As the IEN trench length only represents a fraction of the CAN trench length, the impact on access is therefore limited. Under different cost allocation rules, where, for instance, all the cost saving is allocated to the access, the impact on ULLS cost would be higher.

Determining the appropriate allocation of the cost saving due to trench sharing could be done in a more accurate manner, based, for instance, on bandwidth or duct tubes occupied, or indeed Ramsey pricing applied to access vs. conveyance services.

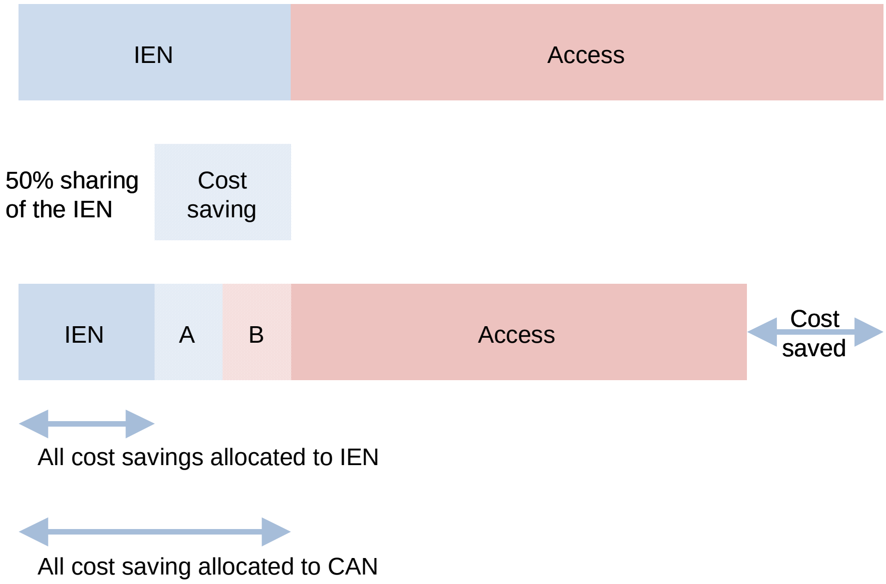

Exhibit 9: *Allocation of cost saving due to trench sharing [Source: Analysys]*

Conclusion

The availability of free trenches in new estates provides an opportunity for a new entrant planning its network deployment over a number of years that is higher than currently acknowledged in the PIE II model. Real-life constraints, such as the shortage of skilled labour, would justify a network deployment spread across several years.

Trench sharing between the IEN and the CAN in the model is set to reflect Telstra's actual deployment, which is the product of a very long history. A new entrant would optimise the sharing of trenches and ducts between the IEN and the CAN further than is currently modelled, particularly within more urban areas.

An increase in sharing could have an impact of up to a few percent on the cost of the access network. This could be further impacted by the choice of a method that would allocate the cost of the shared trenches and ducts in different proportions to the IEN and the CAN, rather than the current equal distribution.

2.4 Calculation of costs in rural ESA

Description of the issue

The PIE II model results show a very large cost imbalance between the different types of ESA, with the cost of ULLS in remote areas (Band 4) being significantly more expensive than the cost in other areas.

As described above, non-urban DAs are subject to a specific set of network dimensioning rules. In particular, in non-urban Das, which are more than 6km away from the nearest CMUX, the use of technologies alternative to copper is investigated.

How the PIE II model calculates the cost of serving rural ESAs

ESAs which have less than 15 SIOs are served by satellite.

Non-urban DAs which have between 0 and 10 SIOs can be served either by SCAR/DCAR (radio systems) or SCADS (small capacity distributed systems, fibre-based).

Non-urban DAs that have more than 10 SIOs can be served either by high-capacity radio concentrators (HCRC) or fibre-based SCADS (small capacity distributed systems). If a DA is served by HCRC, all DAs in the same ESA are automatically served by HCRC.

Discussion

Judging from the documentation to which we have access, Telstra has so far failed to demonstrate the appropriateness of the rules applied in the PIE II model for remote areas. In particular:

- the maximum copper distance from a RAU to a non-urban DA is 6km
- satellite is not considered for isolated SIOs in DAs that are served by copper
- where HCRC is used, it is deployed in all the DAs served by radio in a given ESA, even though they may be at opposite ends of the ESA.

The model does not appear to compute the cost of serving these remote DAs with copper: there is an implicit assumption that copper would be more expensive than alternative technologies more than a certain distance from the exchange.

We think that it would be reasonable for the ACCC to question whether the above rules that Telstra uses result in efficient deployment for a number of realistic configurations of distribution areas. This may, for instance, be based on an analysis of the clustering of SIOs in remote DAs.

<✂> Emerging radio technologies such as WiMax, (which may become the modern equivalent asset in the coming years), are more economic to deploy than cable-based systems. Specifically for the ULLS service, the estimated cost of providing the service through WiMAX rather than copper is significantly lower than outputs of the PIE II model, as shown in Exhibit 10.

<✂>

Exhibit 10: *Band 4 cost estimates using WiMAX vs. PIE II model output [Source: Analysys estimates]*

Note 1: <✂>

Note 2: <✂>

The PIE II model was established based on the technological solutions available in 2000 and does not incorporate recent evolutions. Given the impact of the cost of ULLS in rural areas on the geographically averaged cost, the efficient forward-looking solution should attempt to capture the most modern equivalent asset to provide access in these areas.

Conclusion

In order to demonstrate to the ACCC that the engineering rules employed in the PIE II are indeed suited to network deployment conditions in Australia, Telstra could compare its own, real-life deployment rules and the resulting network architecture.

Given the time elapsed since the development of the PIE II model, the modern equivalent asset for providing PSTN services to rural Australia has evolved, and is not captured by the current version of the model. <✂>. Given the weight of the cost of ULLS in Band 4 ESAs in the geographically average price, this consideration is very material and should be taken into account by Telstra.

3 Forward-looking costing issues

3.1 Operation and maintenance costs calculation

Description of the issue

The total cost base used to determine the network cost of ULLS is composed of the annualised capital cost of the assets deployed in the efficient network and an operation and maintenance cost, which refers to the network and to overheads of the business that support the network operation (e.g. the central corporate functions).

How the PIE II model estimates network O&M costs

Operation and maintenance costs are derived from Telstra's actual cost base. For each class of asset, the most recent asset has been extracted from Telstra's accounts. The ratio of operating costs over capital costs for this asset is then applied to all assets in this category.

For long-lived assets, however, the current opex has been apportioned to the asset cost estimated by the PIE II model.

Indirect expenses, such as general overheads, are allocated in function of direct O&M costs. No additional detail is provided on this.

Discussion

The PIE II model does not calculate O&M expenses in a bottom-up fashion, for any categories of expenses. With regard to overheads or indirect costs, a top-down approach, based on actual accounting expenses may be justified. For network assets, however, Telstra could be expected to have more granular bottom-up data, such as that used in internal engineering business case evaluation.

For long-lived assets such as trenches and cables, Telstra seems to have apportioned the whole of its actual O&M expenses allocated to these assets to the cost produced by the model. This has two main shortcomings:

- If the network produced by the model is somehow more compact, or has less network elements, than Telstra's actual network, then a portion of the O&M costs would certainly not be incurred by an efficient entrant.
- The use of O&M for a mixture of technologies is inconsistent with the objective to produce a forward-looking, MEA-adjusted cost. For instance, some of Telstra's expenses linked to the distribution network may include the maintenance for overhead distribution cables, which the PIE II model does not deploy, and are typically higher than for buried cable.

Quantifying the first effect is very difficult in the absence of detailed data on Telstra's actual network deployment. The second effect, however, can be estimated at a high level. Exhibit 11 shows a number of realistic assumptions about the relative costs of building and maintaining buried and aerial cable. Buried cables are a mixture of trenched, ducted and ploughed cables. The method employed by Telstra to calculate O&M for long-lived assets consequently overestimates the O&M required for overhead cable in Telstra's network, but modelled in PIE II as buried.

<✂>

Exhibit 11: *Example of double counting in the way O&M mark-ups are applied for long-lived assets [Source: Analysys estimates]*

In his 2005 report, Bridger Mitchell acknowledges this issue[14] and estimates that about <✂> of Telstra's current cable deployment is still overhead. Considering this proportion in relation to the high-level calculation set out in Exhibit 11 above, the total overstatement of O&M can be estimated. This depends on the assumptions used, but a reasonable estimate could be around 15%.

<✂>

Exhibit 12: *Estimation of the possible overstatement of O&M due to differences between Telstra's actual asset base and the modelled asset base [Source: Analysys estimates]*

Telstra's accounts may contain enough information on O&M to estimate this effect and correct for it accordingly (this should be attempted).

Conclusion

We acknowledge that the treatment of O&M in the PIE II model constitutes a practical solution to a shortage of granular, bottom-up data. However, whenever this is possible, Telstra could be expected to attempt a more in-depth analysis of the O&M factors generated.

14 See B. Mitchell, 2005, p56 (192)

In particular, there is a significant risk of over-estimation of O&M, which could be over 10%, for long-lived assets that are treated in a purely top-down fashion. This is significant for access services such as ULLS, which mostly make use of this type of assets (such as trenches/ducts and cables). Telstra should provide more information on these assets so as to correct any potential error in estimating O&M.

3.2 Provisioning for fault and future demand

Description of the issue

An efficient cost model must include provisions for a number of variables. Bridger Mitchell's 2005 report describes six reasons justifying the provisions made by Telstra in the PIE II model.

- maintenance and repair
- modularity of components
- economies of scale
- growing demand
- uncertain demand
- heterogeneous demand.

How the PIE II model determines the amount of provision for fault and future demand

The PIE II model contains a 'current' and 'target' value for SIOs in each ESA. This is used to dimension the network, taking into account future demand. There is no indication as to the period over which these forecasts are made. The average SIO growth is <✂>, mainly in CBD areas (<✂>).

The recovery of the costs incurred to efficiently provision capacity for future demand is recovered over the lifetime of the asset, according to Bridger Mitchell's report. However, the method of depreciation used in the model does not link cost recovery to future demand.

Discussion

We note that growing, uncertain and heterogeneous demand are all related to the same risk, which is the uncertainty of demand forecasts. However, whilst there are uncertainties at the national level (how many customers will Telstra have in ten years' time?) they are greater at the local level (how many loops do I need in this street given future housing developments, growth in businesses, re-zoning, etc.). Accordingly, it is common for telcos to overprovision in those parts of the network that are more susceptible to larger statistical demand fluctuations (i.e. the distribution cables, rather than main cables).

Analysys recently completed work for the UK regulator, Ofcom, that contained a public report that includes estimates of the effect on the annualised cost of copper loops of the amount of spares provisioned. Even highly significant changes in the number of spares (a move from approximately 1 spare pair per installed pair in the D side to 0 spares) only reduces the cost by some 3.2%. Accordingly, even substantial changes in spares provisioning policy will not have a material effect on the ULL costs.

Having said this, we are not convinced that the PIE 2 model is using the best cable dimensions in its rural cabling (100 pairs as a minimum). While cable is, in general, a small fraction of the annualised cost compared to the cost of trenching or ploughing the cable, many rural DAs will have significantly fewer than 100 SIOs and 100-pair cable may be unnecessarily expensive; even the urban DA policy uses a small amount of tapering of the cable (using smaller cables to connect the 'last SAM').

The depreciation method used in the PIE II model is not linked to the demand supported by the network assets. The depreciation charge that will be recovered in each year is therefore constant (assuming constant asset prices). The capacity provisioned for future demand is effectively recovered across current demand.

If demand is forecast to grow and the network is dimensioned to support this growth, this may result in unsustainably high unit costs in the first few years. An economic type of depreciation avoids this problem by linking cost recovery to the demand the investment is made to serve, whilst still recovering the whole cost of the asset in present value.

This impacts assets that do not scale directly with demand (i.e. which have a relatively large capacity). As they get more and more ‘filled’ with demand, the annuity charge per unit decreases, whereas the economic depreciation charge stays stable, This is shown for a simplistic example in Exhibit 13, for a single asset, deployed in Year 1 with a capacity sufficient to accommodate all the future demand in its lifetime.

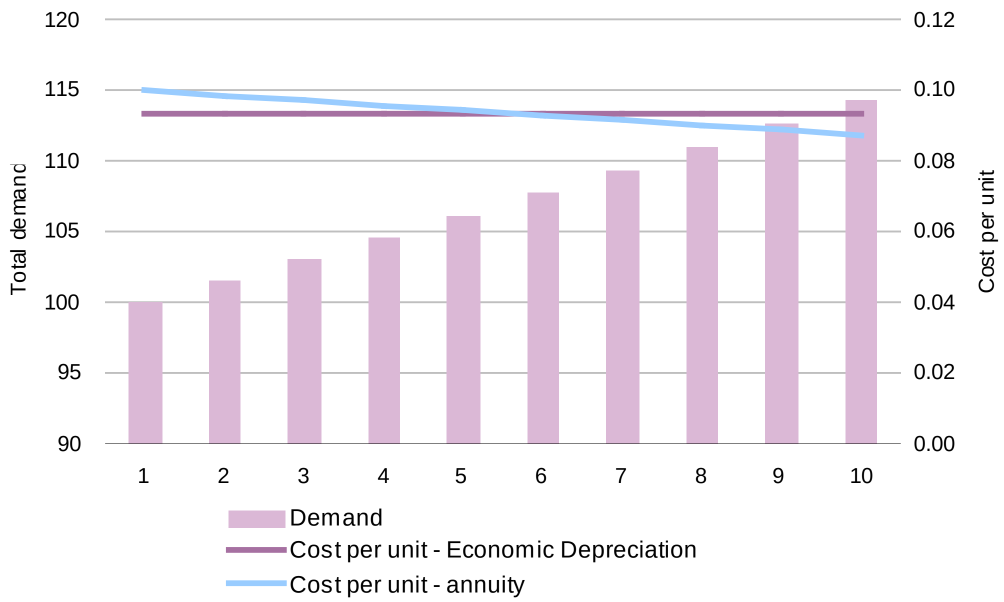

Exhibit 13: *Example comparison between annuity based charges and economic depreciation charges [Source: Analysys, for illustration purposes] Note: this assumes a 0% cost of capital but can be adapted to include an appropriate WACC*

This effect is nevertheless quite small when demand grows by only a small amount, and does not affect more modular assets as much. The annuity charge is therefore a reasonable proxy for economic depreciation.

Conclusion

Provisioning for future and heterogeneous demand is standard practice. Although strictly speaking an economic form of depreciation would result in depreciation charges that recognise the varying demand profile for the assets, and recover costs accordingly, this effect may be quite small in the access network.

Some of the modularity of equipment assumed in the model appears unnecessarily large, and may result in higher than required charges. Including lower capacity cables, for instance, would allow the quantification of such an effect.

3.3 Projection of costs for financial years 05/06, 06/07 and 07/08

Description of the issue

Regulatory certainty is valuable to regulated entities and their shareholders, as well as users of regulated services. One aspect of such certainty relates to the prices applied to declared services such as ULLS. In particular, access seekers will value information and certainty on the evolution of prices for ULLS over the next few years when making investment decisions.

In order to provide some level of certainty on price levels for regulated services, it is necessary to project both the demand and the costs that will arise in future years. A bottom-up model provides the ideal framework to project costs in function of a given demand forecast.

How the PIE II model projects the cost of ULLS over future years

The PIE II model produces network costs up to 2007/08. The total number of lines is assumed to be constant over the period, so the forecast is limited to the number of lines unbundled, as far as ULLS is concerned. Specific trends are assumed for the capital cost of each class of assets. The price trends used in the PIE II model are reproduced in Exhibit 14 below.

Asset category	*Price trend*
Copper cable	<✂>
Trenches and ducts	<✂>
Optical fibre	<✂>
Switching	<✂>
IT	<✂>
Other	<✂>

Exhibit 14: *Price trends in the PIE II model [Source: PIE II model]*

As the assets to be operated in future years are the same as the ones operated in the first year of the model, and given the way operation and maintenance costs are calculated, operating costs per asset will represent a constant proportion of capital costs. Therefore, if the capital costs required to deploy the network go up over time, then the operating costs will also be modelled to go up in the same proportion.

The projection of costs in the future also relies on the depreciation method, using an annuity calculation, with a tilt reflecting the expected annual change in the building cost of assets. The formula used in the PIE II model also incorporates in the annual capital charge a remuneration of the capital tied in the asset, using a given cost of capital. We note that the ACCC has expressed concerns about the level of WACC used by Telstra, although this is outside the scope of this report.

Discussion

A bottom-up model is very well suited to the projection of costs, given a forecast demand profile and an indication of the evolution of the price of the factors of production. The PIE II model is able, given a forecast number of SIOs in operation, to generate the amount of network assets that are required to serve this demand.

The annuity calculation used to compute the annualised capital charge in each year will provide a consistent cost-recovery path, equal in present value to the build cost of an asset over the lifetime of this asset.

A decreasing price trend coupled with the annuity calculation results in a downward tilt in the cost recovery (or depreciation) profile: early years recover more costs than later years.

Conversely, an upward trend allows the cost recovery to be delayed, resulting in an upward trend in the depreciation profile, as shown in Exhibit 15.

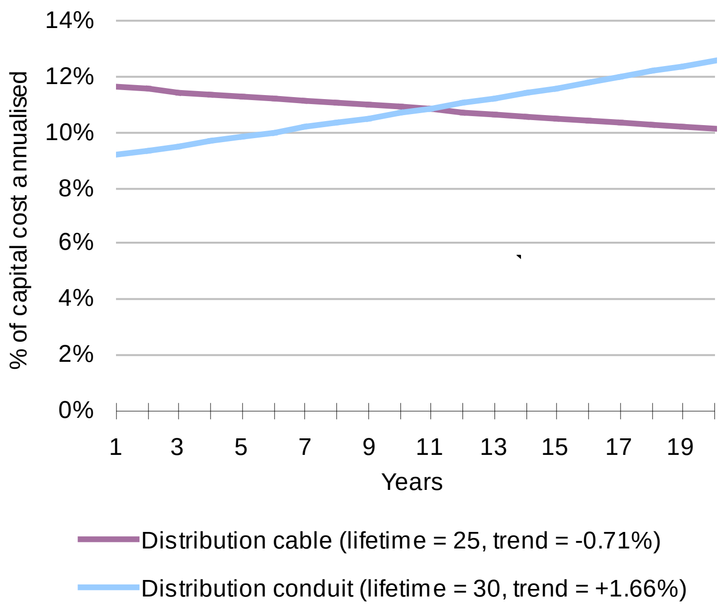

Exhibit 15:
Example of front loading and back-loading of depreciation [Source: PIE II model price trends assumptions, WACC = 10%]

When using the PIE II model to compute costs over a number of years, the capital cost modelled for each asset must be consistent with the price trend implemented. For instance, if an asset has a purchase value in 2001/02 of AUD1000, and a price trend of –10% per annum, the cost calculation for 2002/03 must take into account a new purchase value of AUD900. Telstra’s December 2005 submission indicates that the same price trends have been used to update the capital cost of assets for the roll-forward calculation.

However, the submission also presents a different set of price trends from the one that is visible in the model, for a range of assets. These differences are shown in Exhibit 16.

	Model v4.4.2	Undertakings
Main cable	<✂>	<✂>
Main conduit	<✂>	<✂>
Distribution cable	<✂>	<✂>
Distribution conduit	<✂>	<✂>
Land and buildings	<✂>	<✂>
Indirects (fleet, IT etc.)	<✂>	<✂>

Exhibit 16: *Comparison between the PIE II model inputs and the December 2005 Undertakings [Source: PIE II model, Telstra]*

These differences have not been explained by Telstra in any of the documentation that we have seen. From looking at the model, it is unclear where the trends documented in the Undertakings are applied, if at all.

The projection of O&M costs follows the capital price trends, as there is no specific price trend in the model applied to O&M expenses, and a static mark-up calculated on the basis of historical maintenance cost is applied in all years. This presents a risk of over-estimating the cost of operating and maintaining the assets, as it does not recognise efficiency improvements in O&M for the modern equivalent assets in future years. If asset costs are rising (which is the case for conduits in the 'model case' shown in Exhibit 16), this effect is compounded with a rise in O&M costs commensurate to the rise in capital prices.

Conclusion

Two different sets of price trends have been put forward by Telstra in its Undertakings, and in the PIE II model v4.4.2. The ACCC should obtain clarifications on which trends have been used to derive the results presented in the Undertakings.

The pegging of O&M costs on capital costs (as a static mark-up percentage) also presents the risk to inaccurately estimate the future cost of operating and maintaining the asset base deployed by the PIE II model. Developing specific O&M trends based on the change in O&M mark-up for the MEA would limit this risk.

4 Identification of additional issues

As part of our review of the PIE II model, and the documentation surrounding the presentation of the model in the context of Telstra's 2005 Undertakings, we have identified additional issues that could be investigated further. Some of these issues are directly related to the model algorithms or inputs; some are linked to inputs to the ULLS costs outside the model.

Modelling issues:

- deployment of RAUs, in particular their geographic location and connections to SIOs)
- methodology used to determine the appropriate amount of costs shared between CAN and IEN, linked to the shared trench length
- choice of copper as the MEA over fibre or radio in most areas, impact on costs.

Other issues:

- carrying forward holding losses in a forward- looking, efficient cost model
- recovering ULLS-specific costs only through unbundled loops, not including self-provided loops
- higher WACC for ULLS-specific costs.

5 Conclusion and next steps

Our review of the PIE II model shows that a number of the issues that have already been raised in past review remain significant. The impact of most issues presented in this report, while uncertain, may be reasonably material and warrant additional information, as well as the investigation of possible alternatives by Telstra. In summary:

- The use of an uncorrected rectilinear distance may overestimate trench distances by as much as 2%. This distortion is likely to be larger in rural areas.

- Clustering algorithms are available and could be employed in designing the DA layer. This could result in more efficient, lower cost infrastructure, in particular in low density areas. We are also unconvinced that the RAU deployment is adequately optimised.

- Trench sharing, in particular between the CAN and the IEN, is under-estimated for an efficient new entrant. Such a new entrant could also accrue the benefit of free access to trenches in new estates over a longer period than currently assumed.

- Telstra has not provided information supporting the rules the model uses to deploy the network in remote areas. Moreover, a network deployed using the current MEA may be substantially lower cost than the assets modelled in PIE II, due to the time elapsed since the start of the model's development.

- Estimating O&M in a top-down fashion for long-lived assets risks significant over-estimation of the efficient O&M charge. Evidence of bottom-up O&M expenses would provide a more robust end result.

- Provisioning for future uncertain and heterogeneous demand appears reasonable. An economic form of depreciation would explicitly link the recovery of the extra capacity provisioned to the future demand. However, the impact may only be quite small given the maturity of the network.

- It is unclear which of the two sets of price trends we have outlined in Section 3.3 has actually been used to support the Undertakings. Moreover, the rollover of O&M costs is directly linked to the evolution of capital costs, which is simplistic and does not recognise the separate evolution of operation and maintenance costs. This could be remedied by setting specific O&M price trends for different asset classes.

We also note that the limits imposed by Telstra on the manipulation of the PIE II model, and the time and resources required to run the model make it difficult for an external party to improve the model.

Should the ACCC wish to further the investigation of any of these issues, including the potential additional issues presented in Section 4, this could be covered by the optional tasks outlined in our proposal dated 7 April 2006.

Annex A: Provisioning and location of RAUs in the PIE II model

A.1 Documentation of the RAU deployment process

Very little information was available in the documentation available to us with regard to the algorithms employed to determine the location of remote access units.

Bridger Mitchell qualitatively addresses this point in his 2003 and 2005 documents in favour of Telstra's PIE II model:

> 58 – 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.

Then:

> 124 – 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.

The documentation provided by Telstra itself in support of its Undertakings does not address this issue.

A.2 How the model works

The deployment of RAUs is carried out inside the 'CAN A-F', 'CAN G-M' and 'CAN G-M' databases, by a procedure of the 'ProvisionRAUs' module called 'ProvisionAUs'.

As far as we have been able to assert within the bounds of our Confidentiality Undertaking, the procedure works as follows:

- Select all DAs that are not yet connected to a RAU, sorted by decreasing ALR SIO numbers.
- If this list is empty then exit, as all DAs are linked to a RAU; otherwise, select the first of these.
- Create a new RAU at the location indicated by the coordinates of the current DA, and mark the current DA as being linked to this RAU.
- Reserve enough capacity to serve the current DA.
- Select all remaining DAs with no RAU, ordered by distance from the current RAU.
- Working down this list, assign DAs to the current RAU until capacity[15] runs out.
- Iterate until all DAs are linked to a RAU.

The location of the RAU coincides with the 'focal point' of the DA, which is typically in the centre.

15 The RAU capacity used is this of an above ground housing