

Mobile Termination Cost Model for Australia

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List of Abbreviations and Terms

2G	Second Generation of Global System for Mobile Communications
3G	Third Generation, is the generic term used for the next generation of mobile communications systems
3GPP	Third Generation Partnership Project
ABS	Australian Bureau of Statistics
ACCC	Australian Competition and Consumer Commission
ACMA	Australian Communications and Media Authority
All-IP Next Generation Network	All Internet Protocol Next Generation Network
AMPS	Analogue Mobile Phone System
Annualised CAPEX	WIK-Consult term for the sum of (i) depreciation on equipment and facilities and (ii) the return required by investors on their capital invested in such equipment and facilities; in the form of an annuity derived from the initial capital expenditure (CAPEX)
ANSI	American National Standards Institute
ATM	Asynchronous Transfer Mode
BH	Busy Hour
BHCA	Busy Hour Call Attempts
Bottom-Up	A cost modelling approach that models the network and cost structures of a hypothetical operator. This efficient operator employs modern technology and is not constrained by technology, systems and architectural decisions of the past. A bottom-up model identifies all components of the network necessary to produce the services in question. Based on engineering and economic experience and evidence, cost causation relationships are then defined to link the relevant quantities of network components with outputs and other relevant cost drivers.
BSC	Base Station Controller
BSCTREE	Base Station Controller Tree
BSC-BSC link	Link between one BSC and another BSC
BSC-BTS link	Link between a BSC and a BTS
BSC-MSR link	Link between a BSC and a MSR
BSS	Base Station Subsystem
BTS	Base Transmission Station
BTS hub	Centrally located BTS in a district with the largest traffic flow
BTS hub-BSC link	Link between a BTS hub and a BSC
BTS-BTS hub link	Link between a BTS and a BTS hub
Busy Hour	The period in a day experiencing peak network traffic volume
CAPEX	Capital Expenditure
CAPM	Capital Asset Pricing Model

CARS	Customer Acquisition, Retention and Service
CDMA	Code Division Multiple Access
CORE-DESIGN	A component of the core network module. The CORE-DESIGN task is divided into two parts: the first one is the logical design which ends with determining the required number of STM-1 DSG which connects the different MSC locations. The second part, named physical design, involves the determination of the corresponding physical topology, which connects the MSC locations, the routing of the STM-1 DSG demand on this topology and finally the determination of the transmission systems and medias.
CP	Central Processor
cpm	Cent Per Minute
CPU	Central Processing Unit
dB	Decibel
DCITA	Department of Communications, Information Technology and Arts
DEM	Digital Elevation Model
DI	Investment in Productive Network Asset (Direct Investment)
DIC	Debt Issuance Cost
District	Aggregated postal areas based on population and physical size. Districts are the basic geographical unit used for calculating cell deployment.
DP	Debt Premium
DS1	ANSI framing specification for the transmission of 24 64 kbps data streams
DSG	Digital Signal Groups
E1	ETSI framing specification for the transmission of 32 64 kbps data streams
EDGE	Enhanced Data Rates for GSM Evolution
EPMU	Equi-Proportionate Mark-Up
ETSI	European Telecommunications Standards Institute
EU	European Union
GHz	Gigahertz
GIS	Geographical Information System
GMSC	Gateway Mobile Switching Centre
GoS	Grade of Service
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
H3GA	Hutchison 3G Australia
HLR	Home Location Register
HSCSD	High Speed Circuit Switched Data
HSCSDS	High Speed Circuit Switched Data Service
Hw	Hardware
IC	Interconnection

IMT	International Mobile Telecommunications
ISDN	Integrated Services Digital Network
IT	Information Technology
ITU	International Telecommunication Union
Kbps	Kilobits Per Second
LRAIC	Long Run Average Incremental Cost
LRIC	Long Run Incremental Cost
Mbps	Megabits Per Second
mErl	Milli Erlang
MHz	Megahertz
MMS	Multimedia Message Service
MNO	Mobile Network Operator
MS	Mobile Stations
MSC	Mobile Switching Centre
MST	Minimal Spanning Tree
MTAS	Mobile Terminating Access Service
N1	Number of BTS Sites in a Urban Zone
N2	Number of BTS Sites in a Suburban Zone
N3	Number of BTS Sites in a Rural/Residential Zone
OC	Operating Cost
Ofcom	Office of Communications (United Kingdom) formerly Oftel
Oftel	Office of Telecommunications (United Kingdom) now Ofcom
OMC	Operations and Maintenance Centre
OPEX	Operating Expenditure
OPTA	Onafhankelijke Post en Telecommunicatie Autoriteit (The Netherlands)
Optus	Together Optus Mobile Pty Limited and Optus Networks Pty Limited
POA	Postal Area
PSTN	Public Switched Telephone Network
PTP	Point to point
PTPRAL	Point to Point Radio Links
PTS	Postal och Telestyrelsen (Sweden)
QoS	Quality of Service
RAF	Regulatory Accounting Framework
RFT	Request for Tender
RL	Radio Link
RNC	Radio Network Controller
SGSN	Serving GPRS Support Nodes
SLA	Statistical Local Areas

SMS	Short Message Service
SMSC	Short Message Service Centre
SNPT	Strategic Network Planning Tool
SP	Signalling Processor
STM-1	Synchronous Transport Module -1
Sw	Software
TDM	Time Division Multiplexing
TDMA	Time Division Multiple Access
TELRIC	Total Element Long Run Incremental Cost
Telstra	Telstra Corporation Limited
Top-Down	A cost modelling approach in which actual (historical) accounting data (e.g. capital employed, traffic volumes, etc.) of a specific carrier entity are taken as a starting point for parameterisation of the model. After certain efficiency adjustments and a proper asset valuation the historical cost-volume relationships of costs are projected forward to develop forward looking incremental costs. Top-down modelling approaches rely on actual network architectures and configurations and (at least implicitly) assume their efficiency.
TRAU	Transcoder and Rate Adaptation Unit
TRX	Transceivers
TSLRIC	Total Service Long Run Incremental Cost
TSLRIC+	Total Service Long Run Incremental Cost Plus, where the Plus represents an equi-proportionate mark-up on TSLRIC as a contribution to common organisational-level costs
UK	United Kingdom
ULLS	Unconditioned Local Loop Service
USL	Universal Service Levy
USO	Universal Service Obligation
UTM	Universal Transverse Mercator
VLR	Visitor Location Register
Vodafone	Vodafone Pty Limited
W	Watts
WACC	Weighted Average Cost of Capital
W-CDMA	Wideband Code Division Multiple Access
WDM	Wavelength Division Multiplexing
WIK	WIK-Consult
WIK-MNCM	WIK Mobile Network and Cost Model

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1 Introduction

1.1 The ACCC's RFT

On 31 March 2006 the ACCC released a request for tender (RFT) to seek assistance in constructing a bottom-up engineering-economics cost model of the Total Service Long-Run Incremental Cost plus (TSLRIC+) of providing the termination of voice calls on mobile networks in Australia. The model required by the ACCC needed to provide a tool for the assessment of the efficient costs of providing termination by a hypothetical operator under different scenarios. The model was required to simulate differences in inter alia

- market shares,
- technologies,
- geographical/population coverage, and
- extent of integration with a fixed-line carrier.

To avoid reliance on commercial-in-confidence information the ACCC did not require an assessment of the cost of termination of any particular mobile carrier operating in Australia. The model structure and model parameter inputs needed to be based on publicly available information in Australia, on modelling exercises in other jurisdictions and the expert knowledge of the consultant. This approach brings two benefits:

1. Development of a model consistent with a hypothetical efficient operator in an Australian context, and
2. Enable an open and transparent consultation process about the model and model outcomes that would inform future regulatory processes.

The ACCC requested a functional empirical model in electronic form with the flexibility to derive estimates using different input parameters and scenarios. Furthermore, the final report of the project was to contain a comprehensive discussion of the structure of the model, its inputs, crucial modelling assumptions and the model results under different scenarios. Besides these general requirements the ACCC specified a number of core issues to be addressed in the modelling exercise and the report. These are set out below:

- (1) The output increment,
- (2) Common network costs,
- (3) Routing factors,
- (4) Current costs/changes in equipment prices,
- (5) Spectrum costs,
- (6) Operational costs,
- (7) 'Busy hour' considerations,
- (8) Subscriber acquisition and retention costs,
- (9) Risk and WACC,
- (10) Working capital,
- (11) Integrated fixed-line/mobile carriers,
- (12) Implications of 3G and other emerging technologies, and
- (13) Common organisational-level costs.

Each of these core issues is further specified in the RFT and is further discussed in the relevant sections of this report.

1.2 Structure of this report

This report develops and describes the conceptual framework which has guided WIK-Consult in developing its modelling approach to meet the complex and challenging tasks of the RFT. Furthermore, the report describes the engineering and the economic principles and assumptions which are the basis for the modelling approach adopted. In addition it documents the basic assumptions and input parameters including the sources of information underlying these assumptions and input parameters.

Section 2 of the report characterises different modelling approaches applied in the regulation of access prices and provides details on WIK-Consult's overall modelling approach. In section 3 basic conceptual economic issues as outlined in the RFT are discussed. Section 4 of the report describes the two model components – the Strategic Network Planning Tool and the Cost Module of the WIK Mobile Network and Cost Model (WIK-MNCM). In section 5 relevant information sources are outlined. Section 6 applies the model to calculate the costs of the Mobile Termination Access Service

(MTAS) for various scenarios representing different conceptions of an efficient hypothetical operator in an Australian context. For expositional purposes WIK-Consult has chosen a reference case of a stand-alone mobile network operator (MNO) with a 25 per cent market share and with a population coverage for its service of 96 per cent. The reference case is then compared with other market scenarios and parameter variations. Annex A provides a detailed list of the economic input parameters and Annex B describes the technical parameters.

The WIK-MNCM is available in electronic form. This deliverable will consist of an executable model using C++ software language.

2 The role of bottom-up cost models in regulatory practice

2.1 Top-down vs. bottom-up modelling

In its RFT for this study the ACCC¹ asked for construction of a bottom-up engineering-economics TSLRIC model for providing the termination of voice calls on mobile networks in Australia. This requirement already defined the basic modelling approach to be taken. Given this requirement, WIK-Consult outlines below why a bottom-up rather than a top-down modelling approach best fits with the regulatory requirements to identify the relevant TSLRIC of the MTAS.

Cost models are constructed either under a top-down or a bottom-up approach. Under a top-down modelling approach actual (historical) accounting data (e.g. capital employed, traffic volumes, etc.) of a specific carrier entity are taken as a starting point for parameterisation of the model. After certain efficiency adjustments and a proper asset valuation the historical cost-volume relationships of costs are projected forward to develop forward looking incremental costs. Top-down modelling approaches rely on actual network architectures and configurations and (at least implicitly) assume their efficiency. Because top-down approaches only imperfectly deal with the efficiency requirement, at best they provide an upper bound estimate for the TSLRIC for supply of the MTAS. A bottom-up approach models the network and cost structures of a hypothetical operator. This efficient operator employs modern technology and is not constrained by technology, systems and architectural decisions of the past. A bottom-up model identifies all components of the network necessary to produce the services in question. Based on engineering and economic experience and evidence, cost causation relationships are then defined to link the relevant quantities of network components with outputs and other relevant cost drivers.

Each of these approaches has specific strengths and weaknesses. The top-down approach reflects by definition and by construction the current cost level of a specific carrier. There are no costs ignored or not included. Top-down approaches, in particular when developed as fully allocated costing approaches, are usually weak when the core objective is to calculate the long-run incremental cost of a specific service. Model results are in particular usually not very robust when significant volume or cost (structure) changes emerge over time. This is a specific shortcoming of top-down modelling when the costs of scenarios have to be calculated and the parameters diverge from those of the actual operator(s). Furthermore, network and cost inefficiencies of specific operators are generally embedded in the modelling approach and can only partially and imperfectly be eliminated.

¹ ACCC (2006c), p. 3.

A bottom-up approach on the other hand models an efficient network structure, efficient operations and efficient costs. Therefore, its output generates directly the relevant efficient costs. The cost-volume relationships are transparently defined and modelled according to engineering and economic best practice. A bottom-up model therefore more flexibly accounts for the changes of parameters and costs over time, and can also be employed under various scenarios of regulatory decision making. Because of these inherent properties bottom-up models do not necessarily reflect the cost structure and level of a specific operator in the market at that point in time. But they do reflect an efficient cost structure relevant to that market.

There is one more major difference between the two types of modelling approaches which is important within the incentive structure of regulatory policy and decision making: Top-down models inherently rely on carrier-specific information which is usually supplied by the carriers operating in that market, which provides the opportunity for bias in the outcomes. On the other hand bottom-up models rely on all available market (or regulatory) information. This is regarded as a strength compared with the top-down modelling approach. Another benefit is that experience from other jurisdictions can also flexibly be included and made use of.

In comparing these strengths and weaknesses of each modelling approach the ACCC (2006a, p. 29) concluded that 'the most appropriate method for estimating the "efficient costs" of an MNO providing the MTAS is via a "bottom-up" model'. WIK-Consult shares and supports this view. This approach is also supported by many carriers and is best practice applied by most regulators around the world. Vodafone has acknowledged this in its own undertaking process, in which it suggested that a 'first best' approach to determining forward-looking efficient economic costs is likely to be a TSLRIC+ model calculated on a 'bottom-up' basis and then reconciled with top-down accounting data.² Despite giving credit to top-down modelling approaches Telstra also considers bottom-up costing of the network of a hypothetical efficient MNO to be the optimal approach to determining efficient MTAS prices.³

In general, by using certain approaches of model calibration it is possible to combine the strengths of both of these approaches. Such a hybrid approach first develops a bottom-up model and calibrates the outcomes of that model with the network element and cost components of specific network operators. However, different approaches to model calibration can sacrifice the efficiency aspects of the bottom-up costing elements of a hybrid model when it adopts the cost structures and the cost levels of specific operators. WIK-Consult considers that the approach to calibration adopted by Ofcom⁴ used in its current mobile modelling exercise is at risk of such a compromise. Ofcom

² See Vodafone (2004), p. ii.

³ See Telstra (2005).

⁴ Ofcom (Office of Communications) is the regulator of telecommunication services in the United Kingdom. It was formerly known as Oftel (Office of Telecommunications).

calibrated its bottom-up model 'by adjusting the unit cost levels and cost causality relationships of each cost component, until the model achieves in aggregate the same level of costs as a top-down approach would achieve in historical years'.⁵ In WIK-Consult's view, the aim of calibration is to ensure that all relevant costs, but only those, are included in a bottom-up modelling approach and to explain the cost differences projected by the model and the costs of a specific carrier. It should not be the aim of the calibration exercise to sacrifice the efficiency merits of bottom-up modelling by inflating and/or averaging cost model results to the cost 'realities' of specific carriers, particularly, if these realities reflect inefficiencies. The ACCC also qualifies the reconciliation by considering 'that the reconciliation of a bottom-up model with a top-down model is likely to further strengthen the credibility of the model results, provided that the reconciliation is performed in a transparent and reasonable manner'.⁶

Bottom-up models have been employed for more than a decade as a tool that assists regulatory authorities in the determination of cost-based interconnection rates. Initially they were used in the context of fixed (telecommunication) networks but have in the past few years also been increasingly applied in the determination of the cost of terminating calls on mobile (telecommunication) networks. Bottom-up models provide an independent and objective methodology for the determination of relevant efficient costs. A TSLRIC framework is usually the standard that companies in a competitive market have to adhere to in order to be able to successfully withstand competitive pressure. As a result this efficient cost framework is favoured by regulatory authorities when regulating termination rates.⁷

2.2 WIK-Consult's overall modelling approach

The WIK Mobile Network and Cost Model (WIK-MNCM) is a bottom-up cost model, using a Total Service Long-Run Incremental Cost framework.

The WIK-MNCM is able to determine the costs of all services provided by a mobile network, in particular the cost of terminating a call on it. The network can flexibly be configured to a hypothetical operator based on different assumptions regarding coverage and market share and for scenario applications to existing networks. The WIK-MNCM has been constructed by relying exclusively on information and data that are available in the public domain or are derived from WIK-Consult's experience with similar modelling exercises. Data inputs and assumptions regarding parameter values are selected to provide reasonable estimates of input parameters from verifiable sources.

⁵ Ofcom (2006), p. 141.

⁶ ACCC (2006b), p. 29.

⁷ See for example PTS (2003), OPTA (2006), Ofcom (2006).

2.2.1 Model description

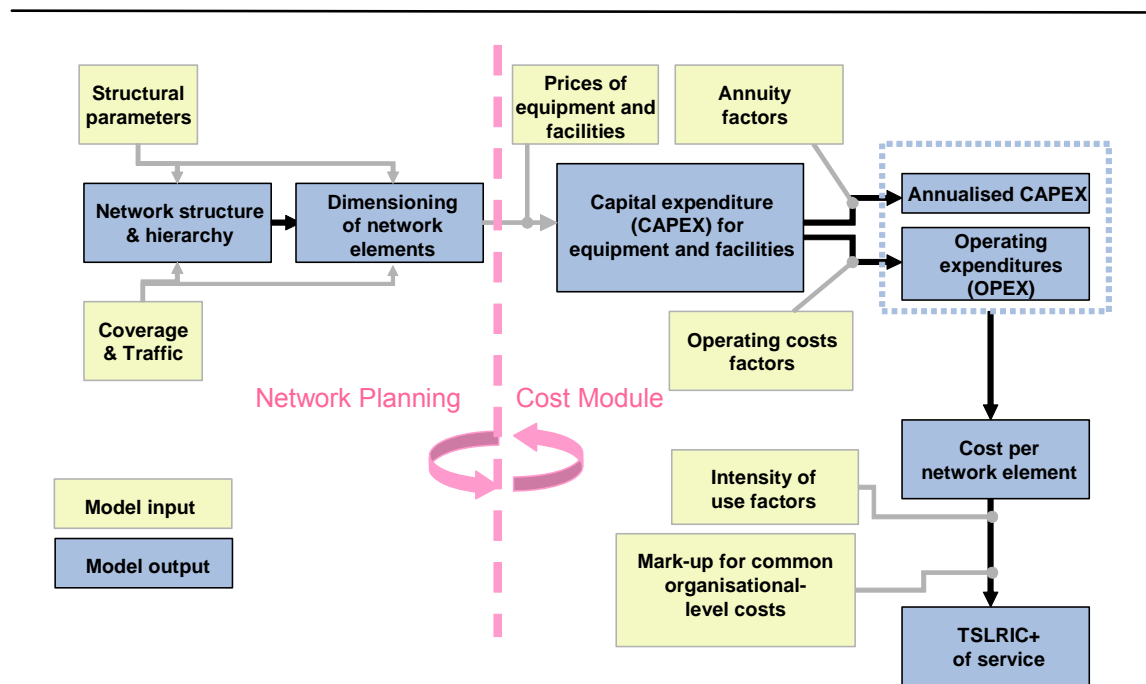
For a given demand of traffic the key cost driver in a mobile network is the number of base transceiver stations (BTSs). Accordingly, the emphasis in modelling has been on the optimisation of the number of BTSs for each of the areas to be covered. The upper network elements are then determined such that they connect the optimised network of BTSs. This approach guarantees a truly bottom-up modelling in the sense that there is no predetermined BTS structure to influence relevant network costs and it reflects the network planning decisions of a hypothetical efficient operator (which may also mirror that of a new market entrant).

Accordingly, network modelling consists of the following main two steps (see Figure 2-1 below):

- Mobile network design and dimensioning carried out by the Strategic Network Planning Tool (SNPT), and
- Calculating the costs of the various network elements carried out by the Cost Module.

Each of these modules will be briefly discussed in the following sections.

Figure 2-1: Schematic view of the WIK-MNCM modelling process



2.2.2 Mobile network design and dimensioning

Network design and dimensioning requires at the outset definition of the areas (in terms of population and geography) to be covered by the network. This is of particular importance in the Australian context, given its population distribution and topography. The SNPT of the WIK-MNCM carries out the following tasks:

- Calculates the optimal cell radius and cell deployment for each relevant area,
- Determines the network hierarchy, and
- Determines the capacity requirements of the link structure.

The network elements will be determined on the basis of optimising algorithms. For their concrete implementation the values for a large number of parameters as outlined need to be known:

- (1) Information on topography and population,
- (2) Demand parameters for the different services, such as territory to be covered, total mobile penetration, market share of modelled operator, average traffic demand per subscriber,
- (3) Technical data, prices of the equipment as well as operating and maintenance cost factors, and
- (4) Network design and configuration data.

2.2.3 Determining the cost of network services

In this report, the term 'services' generally refers to the services marketed by MNOs to customers (including other operators) or 'marketed services'. In some cases the report references other services such as network services which relates to the set of services provided by the network elements on the network, which are the inputs into marketed services.

Once the network structure and all network elements have been determined as described above, the costs of the services provided by the network (network services) can be determined. The relevant total costs using a TSLRIC framework essentially consist of the annualised capital expenditure on equipment and facilities (annualised CAPEX) and the cost of operations and maintenance (OPEX) plus, as the case may be, the cost of leased facilities. In addition, common organisational-level costs are added as a 'plus' on the TSLRIC estimate.

Annualised CAPEX

The first step towards determining annualised CAPEX consists in the valuation of all equipment items and facilities at current prices (which reflects the value of a new network being constructed now). The values of these equipment items and facilities need to be transformed into annual cost amounts over the estimated years for which they are expected to provide services. These amounts should cover the depreciation of the equipment over time as well as the return that investors require on their invested capital. This requires calculation of annual amounts of amortisation (recovery of the invested capital) according to what is known as economic depreciation. In the framework of a bottom-up model this type of amortisation is most suitably accomplished through the application of a capital recovery factor determined on the basis of the annuity formula. In the remainder of the report the resulting annual amounts are always referred to as annualised CAPEX.

The simple annuity formula, however, does not take account of two developments that will normally intervene during the economic lifetime of an item of equipment. The first is that for a large part of its economic lifetime the equipment item will be underutilised and only be fully used as service volumes grow. The second factor is the observation that equipment prices change over time and that this will change the costs that new entrants will face in the future. Both these factors change the value of the installed equipment of an operator today which needs to be taken into account in future pricing decisions – when a potential new entrant may be expected to enter the market. Both developments can be incorporated in the annuity formula on the basis of two parameters. These parameters can reflect the average annual impacts of the projected average growth of services (primarily call minutes), and the average rate of change of the price of the equipment item projected during its lifetime.

This approach is known as the ‘tilted-annuity’ approach as it implies that amortisation amounts vary over the life of the asset according to developments in the volume of services and the price of the asset.

The annualised CAPEX calculated in the WIK-MNCM is based on benchmark prices for equipment and facilities that are known from the European Union (EU) regulatory context,⁸ originally expressed in Euros (€) and converted into Australian dollars (A\$).

OPEX

In telecommunications bottom-up modelling exercises, it is common practice to express OPEX as a percentage mark-up on the investment value of the network elements where the value is expressed in current prices. This is not only current best practice in bottom-

⁸ We mainly refer to modelling exercises in Sweden (PTS (2003)), Germany (WIK-Consult (2006)), The Netherlands (OPTA (2006)), and the United Kingdom (Ofcom (2006)).

up cost modelling but also the approach used by many operators in their own business case planning processes.⁹

Total costs and cost per service

Adding up annualised CAPEX and OPEX provides the total annual cost of running the network and providing all network services. Information gained during the planning stage is then used to determine to what extent the various network elements are on average being used for the delivery of the particular services under study. This information comes in the form of intensity-of-use (routing) factors on the basis of which the costs of the network elements are distributed to the various services provided. Dividing a particular service's share of total cost so derived by the number of units delivered, usually minutes of calling, one obtains the per-unit average cost of this service (more precisely the per-unit average of TSLRIC). Adding an equi-proportionate mark-up for common organisational-level costs to the TSLRIC estimate then provides the basis for establishing cost-based prices.

2.2.4 Determination of the costs of the MTAS

This section describes the framework outlined above for estimating the efficient cost of the supply of the MTAS.

In Figure 2-2 below, a simplified schematic view of the network module of the WIK-MNCM is presented. For a call being delivered from one network and being terminated on another network, there are essentially two possibilities.

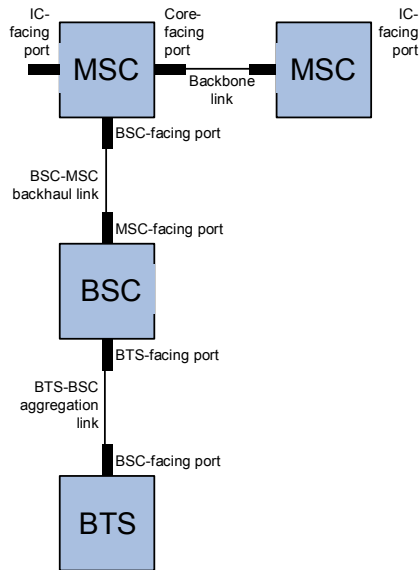
In the first case, the call is delivered to the mobile switching centre (MSC) to which the BTS belongs that serves the user receiving the call. The call then uses each of the network elements on the way to this user once: MSC, home location register (HLR), link between MSC and base station receiver (BSC), the BSC, the link between BSC and BTS, and the BTS. From the process described above, the per minute cost of using the network is calculated for each of these network elements, so that the total per minute cost of delivering the call is arrived at by simply adding up the per minute costs for each of the six network elements listed.

In the second case, the call is delivered at the level of another MSC not serving the BTS of the receiving user. To determine the cost in this circumstance, the cost of the MSC receiving the call and the cost of the link between this MSC and the MSC that serves the BTS in question is added to the cost derived in the first case. In order to arrive at a

⁹ In its PIE II model, for example, which is used to calculate the TSLRIC of fixed network services, Telstra calculates OPEX as a percentage of the asset values of the network elements (see Mitchell (2003), pp. 36-40).

single cost figure for termination, the costs of the two ways of delivering the service are calculated as a weighted average of the costs of each way where the weights are determined by the relative number of minutes of each way.

Figure 2-2: Schematic view of the network module of the WIK-MNCM



2.2.5 Flexible use of the WIK-MNCM

As pointed out, the WIK-MNCM is parameter-driven. This means that various scenarios can be modelled from different parameter values selected. The most important parameters that inform the WIK-MNCM in this way and can be applied to different scenarios, are:

- Threshold in terms of minimum population per basic geographical area to determine the degree of coverage. This way the WIK-MNCM could design a network that, say, covers 92 per cent, 94 per cent, 96 per cent or 98 per cent of Australia's total population,
- Market share achieved by the modelled operator in the area covered by its network,
- Shares of various services (voice On-Net, voice Off-Net outgoing, voice Off-Net incoming, Short Message Service (SMS), High Speed Circuit Switched Data, etc.) in the total network load, and,
- Prices of equipment and facilities.

The interface of the user with the model software is structured in a way that parameter values can easily be introduced. It can be done in two ways:

- In case that it is the value of a single parameter that needs to be changed, by just entering a new value of that parameter, and
- In case that the values of a list of parameters need to be changed, revised data can be entered into a data file that can be referred to by model algorithms to carry out updated calculations for the model.

2.2.6 Scenarios

Given the flexibility in application, the model can be used to calculate the cost of services for networks serving markets with different degrees of population coverage and market shares, traffic and subscriber growth. The WIK-MNCM can be applied to estimate the cost of the MTAS for the following scenarios:

- A hypothetical operator, say, covering 96 per cent of population with a market share of 25 per cent, and/or
- Networks with their individual coverage and market shares.

The WIK-MNCM for Australia models a 2G GSM operator which applies the current best-in-use technology. For estimates of call termination cost tendencies under 3G, WIK-Consult provides for a selected and limited number of representative districts the cell deployment for a 3G W-CDMA network operating in the 2,100 MHz band and in the 850 MHz band under the same service scenarios as in the 2G study. The resulting number of Nodes B will provide a first indication of the possible differences between the cost of a 3G and a 2G network.

3 Conceptual issues

3.1 The output increment(s)

The ACCC uses a forward looking long-run incremental cost (FL-LRIC) concept to determine the appropriate level of cost of access services. TSLRIC is a forward looking measure of costs which means that the referable costs are the ongoing costs of providing the service in the future using the most efficient means possible and commercially available.¹⁰ In practice this often means basing costs on the best-in-use technology and production practices available today and valuing inputs using current prices.¹¹ It includes the costs an efficient firm would necessarily incur in providing the service, or alternatively, the costs that would be avoided if the service was no longer provided in the long-run.¹² Specifically, the ACCC relies on a 'Total Service' approach of applying the economic principles of FL-LRIC. In a TSLRIC approach fixed costs of the network or of certain network elements, if any, are part of the TSLRIC because they vary in the long-run with the volumes of the relevant services. These costing aspects are further discussed in section 3.3.

Most of the costs of a mobile network are driven by the traffic which is transmitted or routed by the network. This means that the vast majority of the costs are causally related to the volume of traffic and are treated as being incremental to traffic. This also means that capacity costs are treated to provide geographical coverage as incremental costs of traffic. Some network costs are driven by the number of subscribers. These costs include typically the HLR which is mainly a database of subscribers and their location. Subscribers, however, indirectly drive network costs through their traffic generation, so it is justified to allocate them to traffic.

Consistent with the TSLRIC costing approach is a single traffic output increment approach. Under a single traffic increment approach all costs arising at the level of network elements, which are not directly subscriber-driven, are incremental to traffic; this includes the costs which are common to several or all network elements. A single

¹⁰ ACCC (1997), p.29.

¹¹ 'Best-in-use technology may often be best-in-commercial-use. This may exclude unique production technologies and practices specific to one firm. In most cases, using forward-looking rather than historic costs will result in the more efficient use of, and investment in, infrastructure. Historic costs guarantee a normal commercial return to the access provider independent of the quality of its investment decisions. Cost valuation based on the best-in-use technology (rather than historical costs) provides stronger incentives for appropriate investment decisions through rewarding/penalising the access provider for good/poor investment decisions. Using historic costs also increases the scope for access providers to shift costs from competitive segments of the market to less competitive segments. This can deter entry and inhibit efficient competition in dependent telecommunications markets. Finally, efficient 'build or buy' decisions will be based on whether a firm can provide the service at a lower cost using the best-in-use technology. As historic costs may not represent costs using the best-in-use technology, access prices based on these costs may result in inefficient 'build or buy' decisions.' (ACCC (1997), p. 29).

¹² Ibid. p.38.

traffic increment approach does not treat each type of service or call (e.g. termination, origination or On-Net) as a separate increment. It is the total of all traffic volumes which drives the cost. Certain traffic services (types of calls, data services) use different network resources or elements to a greater or lesser degree. The WIK-MNCM endogenously generates service usage factors (also called routing factors) which allocate all the network element costs to the individual services which use the network. These usage factors are then decisive in determining the service specific incremental costs. Although traffic is a homogeneous cost driver at the level of network elements, there are relevant differences among services (e.g. differences exist between termination services, origination services, On-net voice calls or SMS services) according to which network elements they actually use. Certain network elements can for instance only be used for specific services. A SMS router for example is not used by voice services. A near-end handed over call uses less transmission elements than a far-end handed over voice call. This allocation procedure generates the TSLRIC which is incremental to each particular service. Applying a single traffic increment compared to service specific increments also requires the model to calculate equivalent traffic volumes as a homogeneous cost driver of the network elements. The WIK-MNCM treats voice minutes as a homogeneous traffic representative. Therefore, SMS messages or General Packet Radio Service (GPRS) megabytes (Mbytes) have to be converted into capacity equivalents for voice minutes.

A single traffic increment modelling approach does not identify any fixed common costs. These costs, if any, are directly allocated to network elements. The unit costs of the network elements then include all network costs. In this way there are no fixed or common costs that remain at the network level which have to be allocated according to an EPMU or a Ramsey-Boiteux approach.

MNOs often differentiate a multiplicity of increments in the form of services. As a general rule, the more disaggregated the service increments the more common costs that emerge and need to be allocated to the cost increment.

3.2 The costs of mobile operations

The total costs of an MNO can broadly be attributed to network and non-network costs. Network costs are directly related to the operation of the network and directly associated with enabling voice calls (or other types of mobile services) to be made. Non-network costs are costs of all activities that are not directly associated with (technically) enabling mobile services. Non-network costs fall into three broad categories:

- (1) Costs of retail activities,
- (2) Business overheads or common organisational-level costs, and
- (3) Other costs including mainly interconnect and international roaming charges.

Although 'other costs' might represent a relevant share of total costs they are irrelevant in the context of determining the costs of the MTAS because they relate to the costs of other networks, none of which are part of the costs of the MTAS.

WIK-Consult is not aware of publicly available information on the distribution of the various cost categories relating to MNOs in Australia. Therefore, for illustration purposes Table 3-1 refers to the overall cost structure of British MNOs recently published by Ofcom (2006). Network costs accounted for 26.1 per cent of total costs of an average MNO in the UK in 2004. If 'other costs' are excluded, network costs represent 35 per cent of total costs.

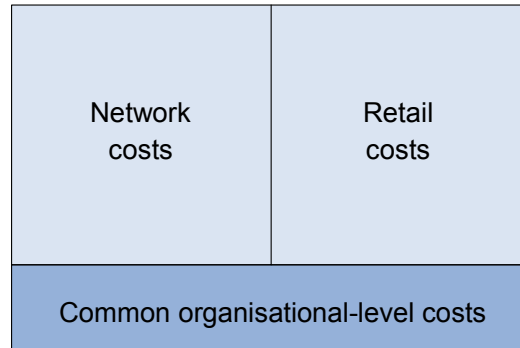
Table 3-1: Distribution of total costs to cost categories for British MNOs in 2004

Cost categories	Average costs ¹ (£ million)	Proportion of total costs (%)
Network costs	972	26.1
- Network depreciation	377	(38.8)
- Network OPEX	340	(35.0)
- Cost of capital ²	255	(26.2)
Non-Network costs	2,757	73.9
- Total costs of retail activities ³	1,534	(55.6)
- Business overheads	275	(10.0)
- other costs	948	(34.4)
Total costs	3,729	100
¹⁾ Representing four MNOs and excluding H3G. ²⁾ Based on a pre tax nominal WACC of 14.1 per cent. ³⁾ Comprising total CARS costs before taking account of offsetting revenues, such as the proceeds of handset sales and any part of periodic subscriptions from contract customers.		

Source: Ofcom (2006), derived from Figures A 15.1 and A 15.2

Business overheads are common organisational-level costs relating to all activities or services an MNO is providing. Therefore, these costs should be recovered across all the MNO's business activities, namely from the wholesale network services and retail services. Therefore, the cost categories shown in Figure 3-1 remain relevant for the costs of the MTAS.

Figure 3-1: MNO's cost categorisation relevant to the supply of the MTAS



3.2.1 Network costs

Network costs comprise capital and operating costs associated with mobile network equipment including in particular:

- Radio network equipment,
- Aggregation network equipment,
- Backhaul network equipment,
- Core network transmission and switching equipment, and
- Central network systems like VLR, HLR, network management system.

Systems which are used for providing retail services such as billing¹³ and other IT systems are regarded as retail and not network costs.

Network costs can either be incremental to specific services or they can be common to all the services. A typical example for common costs is the cost of a mobile switch handling the traffic caused by all services. Network service costs, including the costs of common production, are derived by allocating all the costs identified to different services by using service routing factors.

¹³ The costs for providing billing for wholesale services are small compared to the billing costs of retail services. Therefore, billing is not explicitly modelled in the WIK-MNCM. Network service related billing costs are treated as part of the common organisational-level costs.

3.2.2 Retail costs

Retail costs as part of the non-network costs are not directly associated with technically enabling calls to be made. WIK-Consult regards all customer acquisition, retention and service costs, the so-called CARS as retail costs. CARS comprise advertising and marketing, discounts, promotions and incentives, customer care, billing and bad debts¹⁴ expenses. These costs are mainly driven by retail customers and retail customer subscription. This does not exclude as we have stated in another study¹⁵ that CARS may be indirectly influenced by prices and quantities of On-Net and Off-Net calls and the MTAS. The customer acquisition cost function is likely to shift downwards if mobile call prices or MTAS charges are reduced. CARS, however, are not incremental to the provision of network (wholesale) services and MTAS in particular. CARS are also not common to wholesale (network) and retail services but can and have to be allocated to retail services. CARS costs are incurred because MNOs provide mobile retail services and are a function of the number of (new) subscribers and therefore related to supplying subscription services.

There may be the argument that customer care services such as call centre costs cannot comprise retail costs only as these costs should be partially attributed to incoming calls. In this respect, it is expected that the proportion of customer care services related to incoming calls will be minimal. Furthermore, such costs (if any) are caused by mobile customers of the respective MNO and not by the access seekers or their customers. Therefore, such costs should be covered by mobile users of the terminating network and not by the access seeker or its customers.

It remains important to note that retail services like On-net or Off-net calls do of course use the network and cause network costs by demanding wholesale network services. Retail costs are only characterised as those costs that are caused by retail services.

3.2.3 Common organisational-level costs

Business overheads are those costs that emerge at the company level of the whole organisation. They are common to both network and retail activities. At a functional level business overheads are related to administrative functions like accounting, financing, management, IT (as far as IT is not service-specific like billing which primarily relates to retail services), human resources and legal services for instance. Common

¹⁴ Using consolidated group accounts for all Australian MNOs, the data show that bad debt expenses represent around 1 per cent of external revenue. In general, bad debts may also be a relevant cost for wholesale services. It is, however, appropriate to assume that there is no bad debt risk for termination payments of the MNOs themselves and of the larger fixed-line operators. Therefore less than 10 per cent of the termination revenues may face a bad debt risk. To the extent there are appreciable relevant costs, they are treated as part of the common organisational-level costs.

¹⁵ See WIK-Consult (2005), p. 12.

organisation-level costs should be recovered across all business activities or services that they are supporting.

WIK-Consult proposes an EPMU approach in the WIK-MNCM to allocate business overhead costs. Under this approach business overheads are allocated in proportion to the incremental costs of each business activity or service. The TSLRIC of a particular service is then increased by a certain percentage mark-up to cover business overheads.

In its current MTAS costing exercise Ofcom¹⁶ has followed a similar approach. Ofcom has used accounting information of the MNOs to derive the total value for business overheads. Ofcom identified a mark-up of 11 per cent on network costs for total business overheads using an EPMU approach. Based on the WIK-MNCM construct, i.e. using historic cost accounting information to inform this analysis, this would reflect a conservative estimate of the mark-up if applied in an efficient operator context.

Given that the WIK-MNCM is not calibrated with carrier-specific accounting information to identify and value the level of business overheads relative to network costs, for conceptual reasons WIK-Consult applies a percentage mark-up approach to the relevant TSLRIC of the MTAS.

Ofcom for example, assumes that the absolute level of business overheads would remain relatively constant with changes in traffic. This is not WIK-Consult's view. In particular when considering MNOs of different sizes and market shares¹⁷ WIK-Consult regards it as more plausible to assume that the central functions of the business organisation are scalable and are scaled according to the size of the company. WIK-Consult would therefore assume that the absolute level of business overheads is not constant but varies with the size of the business.

As regards to the value for the mark-up, WIK-Consult has relied on international benchmarks that are applied in costing exercises for networks of comparable size. As has already been stated on a different occasion,¹⁸ and as is maintained here, there are no good reasons for the application of the Ramsey-Boiteux allocation mechanism in determining these mark-ups.

3.2.4 The costs of the MTAS

MTAS is a wholesale service which should not bear any retail costs. As any other wholesale service the MTAS causes mainly network costs which are attributed to this

¹⁶ See Ofcom (2006), pp. 218-220.

¹⁷ Because Ofcom is only considering one hypothetical operator at a specified market share it is de facto not considering different scales of operation.

¹⁸ See WIK-Consult (2005).

service by using the element-based approach which we describe in more detail in section 3.3. Any MTAS-specific costs that were not network related would be directly allocated to the MTAS. Besides bearing service-specific costs, if any, the MTAS has to bear the costs for using the network and its appropriate share of business overheads or common organisational-level costs.

The WIK-MNCM only includes network costs and business overheads. The latter are marked-up as a percentage to the relevant network costs. No retail services costs are included in the calculated costs of the MTAS.

3.3 The concept of TSLRIC

3.3.1 The approach in the WIK-MNCM

For the determination of the cost of the MTAS, the WIK-MNCM applies the cost standard of 'total service long-run incremental cost' or TSLRIC which is in agreement with the ACCC's access pricing framework outlined in its *Access Pricing Principles – Telecommunications of 1997*:

'TSLRIC is the incremental or additional cost – on an annual basis – the firm incurs in the long-run in providing a particular service (or production element) as a whole, assuming the scale of its other production activities remain unchanged.'¹⁹

In the MTAS Final Report of June 2004, the ACCC compares TSLRIC with other concepts stating that:

'TSLRIC stands for total service long-run incremental cost. Where it contains a contribution to organisational-level costs the Commission calls it "TSLRIC+". Other jurisdictions use TELRIC ("E" for "element"); LRIC (long-run incremental cost); LRIC + EPMU (equi-proportionate mark up) or LRAIC (long-run average incremental cost). This different terminology is the cause of some confusion, but in all cases reference is being made to essentially the same thing.'²⁰

While it is agreed that the various terms essentially refer to the same thing it is nevertheless useful to relate these terms to each other thereby hopefully reducing any confusion that has arisen by their use and facilitating the subsequent discussion:

¹⁹ See ACCC (1997), p. 28.

²⁰ ACCC (2004), p. 230, footnote 566.

- The above quote introduces the term 'TSLRIC+', which as mentioned is the fundamental approach adopted by the ACCC to telecommunications access pricing, and identifies it as the TSLRIC that includes common organisational-level costs which are not included when the '+' is not added. It is thus made clear that the latter is meant to exclude only the common organisational-level costs and, by implication, includes all network relevant costs of providing the service in question. In particular, TSLRIC includes also the cost due to lumpy investment that over certain ranges of traffic volumes do not change but of which each service is allocated an appropriate share,
- The term 'LRAIC' in the above quote could mean one of two things. The 'A' may indicate that the total cost is divided by the relevant measure of volume to get an average figure, i.e. a per-unit cost figure. But all the relevant cost terms actually refer to a per-unit cost, so this interpretation would not really differentiate the term from other ones. Alternatively, another interpretation of 'A' is that a cost component is included due to a lumpy cost, i.e. a cost that over the relevant range of volumes does not change and would have to be included on the basis of some averaging procedure. If this is the case then LRAIC, except for the specific averaging procedure, is equivalent to TSLRIC,
- The term 'LRIC + EPMU' has mainly been used in the UK context. In a particular application by the UK regulator (however, not in the most recent Ofcom consultative document on mobile termination)²¹ the LRIC excludes some cost items due to lumpy investment, which are then together with common organisational-level costs rolled into the EPMU. It thus stands for a procedure for arriving at a cost figure that like TSLRIC+ covers all relevant cost items and the total cost of the service, and
- The final term is TELRIC. The ACCC's definition of TSLRIC by itself does not specify the procedure by which lumpy costs are to be accounted for. TELRIC, in fact, does. It says, these costs should be assessed at the level of network elements and then, like the non-lumpy traffic-sensitive parts of these elements' costs, be allocated to services by factors (routing factors) reflecting intensity of

²¹ See Ofcom (2006), p. 143, paragraph A5.18: 'Service costs are arrived at by allocating all the costs identified to different services according to service routing factors. To the extent that common costs exist, these are allocated to service increments according to routing factors. The model does not explicitly identify or estimate the level of common costs. The outputs of the model are unit costs that exhaustively include all network costs. Therefore the model outputs and in particular the cost of termination is an incremental cost and an implicit mark-up for an allocation of any potential common costs. This is a particular form of network common cost allocation. Allocation of common costs is discussed in more detail Annex 17.' This is in contrast to Ofcom (2004), p. 63, paragraph 6.68 which states: 'Consistent with the approach described in paragraph 6.4 above, the LRIC model incorporates an EPMU for network common costs.' Ofcom's approach to network common cost at that time had previously been set out in detail in Ofcom (2002).

use of the network elements by these services. This is, as will be shown below, consistent with the ACCC's preferred approach to access pricing.

Note that in the above discussion of the various terms no reference is made to the terms 'fixed' and 'common' costs. The reason is that they play no specific role in the determination of network costs of relevant services. In respect of fixed cost, there are actually very few cost items that are truly fixed. Cost items that are often referred to as fixed also change when scales of operation change enough to make it necessary to either increase the scale of investment or decrease it. A licence fee paid once upfront, in order to be able to enter the business at all, is the only example of what could be termed as a truly fixed cost.²² From this, it follows that what is often addressed as being a fixed cost is actually a cost of lumpy investment as discussed above.

In respect of common costs, two things need to be noted. First, there are hardly any network costs that are not common to several or all services in a mobile telecommunications network. Virtually all the services provided by such a network are produced in common by the same set of network elements, i.e. BTSs, MSCs, transmission systems, and so on. There are only a few and isolated examples of network elements that are truly dedicated to only one service and are therefore not common to other services; one such example is the SMS centre which is a service-specific network element which is only used to generate SMSs and is not used for any of the voice services provided in a mobile network. Second, the fact that most marketed services are produced in common by the various network elements does not mean that the drivers of these costs cannot be identified and that these costs cannot be properly allocated according to cost causation principles. These cost drivers are the minutes of traffic of the various marketed services for which the network elements have to provide the component parts. In other words, the total cost of each network element varies depending on the volumes of the network services that are demanded of it to produce the various marketed services. So the allocation of the costs of these network elements to the various marketed services must be in relation to the intensity with which the latter services use these network elements and thereby cause their costs. There are common costs for which cost drivers cannot be identified, but this is essentially only at the level of organisational-level costs.

The ACCC's *Access Pricing Principles – Telecommunications of 1997* require that the total cost of providing the relevant service (TSLRIC) should not exceed the stand-alone cost, and that common costs (to the extent that they occur) must in fact be common to the relevant service and should not be over-recovered.²³ The WIK-MNCM addresses this by implementing a TSLRIC framework in the form of TELRIC. With the application of TELRIC it is assured that each service is allocated the shares of the costs of network

²² The relevance of upfront licence fees for the costing of mobile termination is considered in section 3.9.

²³ See ACCC (1997), p. 40.

elements in agreement with its relative use of these elements, both in respect of the immediately traffic-sensitive parts and the parts of costs that are due to lumpy investment. This ensures for one that the resulting cost figure will be below a stand-alone cost. What is more important, it ensures that common costs, i.e. the cost of joint production, are included in exact proportion to the relevant service's use of the various network elements thereby fulfilling the requirements stated in ACCC's principles that these common costs are indeed common to the services in the cost of which they are included, and that they are not be over-recovered. TELRIC provides that economies of scale achieved by the various network elements are shared by each of the marketed services in relation to the intensity with which each service uses the element.²⁴ In doing this, it in particular fulfils the exigency of efficiency according to which a service should bear the cost of an input in relation to its use of that input. Using TELRIC, the common cost for which the drivers cannot be identified is allocated on the basis of an equi-proportionate mark-up; as is also contemplated by the ACCC.²⁵ As mentioned, the WIK-MNCM recognises this kind of common cost only in the form of common organisational-level costs.

Turning from points of principle to the concrete steps of implementation, the procedure by which the WIK-MNCM determines the cost of the MTAS is described.

As already noted, a mobile telecommunications network produces jointly a number of services demanded by end-users or other carriers (marketed services): On-Net calls, outgoing Off-Net calls, incoming calls (MTAS), SMS and other data services. All these services are produced by distinct network elements, most of which are engaged - in different proportions - in producing all of the mentioned marketed services.²⁶ Thus, each of the marketed services is to be regarded as a combination of the various network services. From this follows that determination of the cost of MTAS requires determination of the costs of the various network services that arise in the provision of MTAS and then that these need to be added up.

Therefore, for determining the costs of the MTAS, the WIK-MNCM first designs and dimensions a network of the requisite capacity to provide all services the operator is offering, determines the cost of running this network, which means the total cost of all network elements. The following steps are then undertaken:

²⁴ WIK-Consult understands that in its latest consultative document on mobile call termination Ofcom, in contrast with the approach in previous proceedings, is also proposing to allocate all network costs to services on the basis of routing factors. See Ofcom (2006), Annex 5, A5.18.

²⁵ The approach preferred by the ACCC to the allocation of common organisational-level costs is the EPMU over directly attributable costs. This involves measuring the directly attributable costs (directly attributable costs exclude common costs that cannot be directly traced back to variations in traffic) of each service within the group and allocating the common costs based on each service's proportion of the total directly attributable costs. Refer to ACCC (1997), p. 39.

²⁶ This general statement includes the special case where a network element is exclusively used for one service, as for example is the case with an SMS centre.

- (1) Network elements the services of which are required to produce MTAS are identified,
- (2) The cost per unit of service (i.e. in most cases per minute) of each relevant network element by dividing the total cost of this network element by the total units of service produced by it is determined. (In the cases where services are normally measured in units other than minutes, the total volume of these services is in this instance expressed in terms of equivalent minutes. There are standard formulas establishing this equivalence. See section 5.2 for more detail.),
- (3) The amount of service of each of the network elements that are needed for one minute of MTAS is determined,
- (4) Each of the amounts of service by network elements determined under (3) are multiplied by the cost per unit of that network service determined under (2), and
- (5) The resulting cost components for each service are added up to derive the cost of the service.

Step (2) is crucial to being able to properly allocate the cost of lumpy investment. All costs of the lumpy investment are distributed equally over all units provided by dividing the total cost of a network element by the volume of network services rendered by it, to arrive at the per-unit cost of that network service. Implied in this procedure is the assumption that this lumpy investment cost should be allocated without any special regard to what marketed service the network service is used for. In particular, the cost of a unit of service by a network element used for determining the cost of MTAS necessarily includes the same proportion of lumpy investment cost as such a minute used to produce any other minute of a another marketed service.

3.3.2 Appraisal of other approaches to the determination of the TSLRIC

In the approach based on TELRIC, the TSLRIC for each marketed service is arrived at on the basis of the TSLRIC figures for the various network elements where the cost contributions of the several elements are then added up in an appropriate way. The criticism concerns an approach where the cost of some important parts of lumpy investments are treated as fixed and common costs and then allocated according to a mechanism that ignores the relationship between the actual cost driver and the lumpy investment. The prime example for a fixed cost in this sense is the cost of coverage. This approach has, for example, been followed in the 2003 proceeding by Ofcom (then

Oftel) concerning wholesale mobile voice call termination²⁷ and in undertakings by mobile operators regarding mobile termination in Australia²⁸ as well as elsewhere.

In this approach the cost of coverage is regarded as a business-wide fixed cost, similar to a licence fee, and should, therefore, be recovered as a mark-up to be added to the LRIC figure in which no cost attributable to coverage is yet included. The first error in this reasoning consists in not realising that the cost of coverage is not a fixed cost. It varies with the degree of coverage that an operator chooses and is, therefore, as far as this argument goes, a variable cost and not a fixed cost. Taking this reasoning further, if there was a service called 'coverage' and there were people demanding it, the cost per unit of coverage, say per household covered, would make sense and be a useful piece of information. There is, however, no such service. The variable cost of coverage in fact turns out to be a cost of a lumpy investment in the form of BTSs that assure the availability of the network to make calls in the areas in question. The lumpiness of this investment is due to the fact that it needs a minimum configuration of BTSs to be in a position to offer services at all. From this follows that the corresponding costs are caused by the necessity of actually providing BTS services. Operators provide for coverage to such an extent that they think is necessary to attract subscribers that make calls, i.e. from and to areas with high density of traffic as well as from and to areas where traffic is low in volume. Thus, the so-called cost of coverage is part of the lumpy investment costs that arise due to the need to have BTSs over which to provide network services as an input to traffic. Accordingly, these lumpy investment costs need to be allocated in their entirety to the costs of the relevant network element, i.e. BTSs, and these, in turn, are to be allocated to the various marketed services according to their relative use of this network element.²⁹

3.3.3 Appraisal of the criticisms of the TELRIC approach to estimating the TSLRIC

Gans and King (2003) argue that there are risks of using the TELRIC approach. At the empirical level the risk would be that too much fixed and common cost (cost of lumpy investment in the present analysis) could be allocated to regulated services given that the cost of certain network elements were wholly or in large part allocated to the regulated service although this element is also used for the production of other services which are, however, disregarded. This problem cannot arise with the WIK-MNCM as it models a network that carries all the traffic that the operator would offer and allocates the costs of network elements to all services using them.

²⁷ See Oftel (2003), Annex F.

²⁸ See for example Vodafone (2004) and Optus (2004).

²⁹ As pointed out in an earlier footnote, Ofcom has abandoned the approach criticised here in its most recent consultative document on mobile call termination. See Ofcom (2006), p. 143.

The other risk would be conceptual in that fixed and common costs would be allocated according to a different method than is socially optimal. This reasoning has the following flaws: (1) it does not recognise that the fixed costs considered would be costs of lumpy investments, as discussed in the text. Since these investments are lumpy they change for sufficiently large increments or decrements in volumes, hence they are driven by traffic. (2) in addition, it does not recognise that common costs can arise from (a) using lumpy investment or (b) using investment that closely moves in line with traffic. In both cases the cost driver is traffic to which these costs need to be allocated, where each of the services causing that traffic should bear a share in proportion to the service's use of the network element. Only in the case of common costs, which cannot be traced to individual drivers – such as organisational-level overheads – is such an allocation not possible and an alternative method such as a mark-up approach is required. In summary, Gans and King overlook that there are few truly fixed costs, with one possible exception being an expense like a one-off licence fee paid on entry to the market, and in effect that needs to be recovered by the activities of the firm over its entire time of operation. They also do not recognise that many common costs, i.e. costs of common production, do have identifiable cost drivers. This is also true for the examples used in their paper where X is a link and that is used as a fixed cost, but where the number of links changes when the scale of operations changes; and where Y is a switch used in common by two services, but where the cost of a switch is driven by the minutes of switching provided by that switch and is used by both services so that if there is enough growth in traffic there will need to be another switch and this change would, of course, be driven by the additional minutes brought about by the increase in demand in both services.

There has in the past been substantial criticism directed at the concept of TELRIC as well as TSLRIC. Some criticism focused on what was seen as the *practical* risk that the application of these concepts would not allow operators to recover all relevant costs. In contrast, Gans and King consider the risk of using a TELRIC approach to be that it may allow an operator to recover too much of its cost from regulated services. In relation to the issue of the recovery of relevant costs, as has been pointed out above, the WIK-MNCM takes great care to ensure that all relevant costs, but no more, are taken into account and are appropriately allocated to the various services. In respect of the *conceptual* criticism of the TELRIC approach this seems to have arisen more recently in the context of the regulation of the charges for the termination of calls on mobile networks, and appears to be peculiar to an Australian context. Using a TELRIC approach fixed and common costs would be inefficiently allocated by *not* allocating them to services on the basis of a mark-up. In the past, Ofcom (although not in its latest consultative document on mobile call termination) has accepted that there exist so-called network fixed and common costs and has used an EPMU to allocate these costs. This, however, was not associated with an explicit criticism of TELRIC. As is consistently argued in this report, there are very few items that qualify as fixed and common costs and that therefore exist without a clear cost driver. The implication is that

virtually all relevant costs can properly be allocated to services using the mechanism provided by the TELRIC approach.

3.3.4 Example to compare the TELRIC and mark-up approaches

In section 3.3.1 it was shown that all the costs of network elements should be allocated based on intensity of use of the marketed services. In contrast, the approach criticised in section 3.3.2 relies on a mark-up approach to allocate so-called fixed and common costs of coverage, which is actually a cost of lumpy investment in BTSs. This section demonstrates that, although the issues are important in terms of what cost principles to apply, the practical difference between using the one or the other approach is very likely to be small.³⁰

The example, while simple, nevertheless allows an appreciation of the basic difference between the two approaches. We assume that there are two marketed services, On-Net (o) and terminating (t), and two network elements, BTSs (bs) and MSCs (ms). The use of each network element results in two types of costs – lumpy investment costs which are not traffic sensitive within a certain range (L_{bs} , L_{ms}) and volume-dependent costs which are formed by the product of quantities of network service (V_{bs} , V_{ms}) produced by the two elements times their per-minute costs (k_{bs} , k_{ms}).³¹

The equations determining the total cost due to running the two network elements are:

$$(1) \quad C_{bs} = V_{bs} * k_{bs} + L_{bs}$$

$$(2) \quad C_{ms} = V_{ms} * k_{ms} + L_{ms}$$

The average costs per unit of service for the two network elements are then:

$$(3) \quad c_{bs} = k_{bs} + (L_{bs}/V_{bs})$$

$$(4) \quad c_{ms} = k_{ms} + (L_{ms}/V_{ms})$$

In this simple example it holds that for each minute of On-Net service two minutes of BTS service are needed and one minute of MSC service while for one minute of terminating service one minute each of BTS service and of switching are used. Thus the per-minute costs of these two marketed services are as follows:

³⁰ As has also been pointed out by Gans and King (2003).

³¹ A simplification in the example is that the per-minute cost of each network element remains constant when there are changes in volume; these per-minute costs usually change with variations in volume due to economies of scale. This simplification does not diminish the generality of the results derived.

$$(5) \quad C_o = 2 * C_{bs} + C_{ms}$$

$$= 2 * [k_{bs} + (L_{bs}/V_{bs})] + [k_{ms} + (L_{ms}/V_{ms})]$$

$$(6) \quad C_t = C_{bs} + C_{ms}$$

$$= [k_{bs} + (L_{bs}/V_{bs})] + [k_{ms} + (L_{ms}/V_{ms})]$$

As can easily be verified, the per-unit cost of each marketed service consists of the sum of the per-unit costs of the two network elements used, each weighted by the intensity of use of the network element by the marketed service. Each per-unit cost of a network element, in turn, is the sum of the per-unit volume-dependent cost and the average lumpy investment cost arrived at by dividing the element's lumpy cost by the volume provided by it.

The above is the procedure using the TELRIC implementation of TSLRIC.

In the approach whereby lumpy investment costs are allocated according to a mark-up, the costs of marketed services that are considered volume dependent (k_o , k_t) are the weighted sums of the costs of the network elements excluding the lumpy cost elements:

$$(7) \quad k_o = 2 * k_{bs} + k_{ms}$$

$$(8) \quad k_t = k_{bs} + k_{ms}$$

Note that in the above equations the lumpy investment costs of the network elements are not included. The total volume-dependent cost (K) for the two marketed services combined is then:

$$(9) \quad K = V_o * k_o + V_t * k_t$$

The mark-up to account for the total lumpy cost ($L = L_{bs} + L_{ms}$) has then to satisfy the following equation:

$$(10) \quad L = m * K$$

or

$$(11) \quad m = L/K$$

$$= L / (V_o * k_o + V_t * k_t)$$

Total costs (C) are then:

$$\begin{aligned}
 (12) \quad C &= K + L \\
 &= (1+m)*K \\
 &= (1+m)*(V_o*k_o + V_t*k_t) \\
 &= (1+m)*k_o*V_o + (1+m)*k_t*V_t
 \end{aligned}$$

From (12) it follows that the per unit-costs for the two marketed services are:

$$\begin{aligned}
 (13) \quad c'_o &= (1+m)*k_o \\
 &= (1+m)*(2*k_{bs} + k_{ms})
 \end{aligned}$$

$$\begin{aligned}
 (14) \quad c'_t &= (1+m)*k_t \\
 &= (1+m)*(k_{bs} + k_{ms})
 \end{aligned}$$

In (13) and (14), the per-unit costs of the marketed services are differentiated from the corresponding ones derived using the TELRIC implementation per (5) and (6).

It is useful to express the per-unit costs according to (13) and (14) also as functions of the costs of the lumpy costs to make them comparable with equations (5) and (6). This results in:

$$(15) \quad c'_o = 2*\{k_{bs} + L/[V_{bs} + (k_{ms}/k_{bs})*V_{ms}]\} + \{k_{ms} + L/[(k_{bs}/k_{ms})*V_{bs} + V_{ms}]\}$$

$$(16) \quad c'_t = \{k_{bs} + L/[V_{bs} + (k_{ms}/k_{bs})*V_{ms}]\} + \{k_{ms} + L/[(k_{bs}/k_{ms})*V_{bs} + V_{ms}]\}$$

These equations can be compared to equations (5) and (6) derived using the TELRIC approach:

$$(5) \quad c_o = 2*[k_{bs} + (L_{bs}/V_{bs})] + [k_{ms} + (L_{ms}/V_{ms})]$$

$$(6) \quad c_t = [k_{bs} + (L_{bs}/V_{bs})] + [k_{ms} + (L_{ms}/V_{ms})]$$

In each of equations (5), (6), (15) and (16) the per-minute cost of either marketed service is expressed as the sum of the costs of the relevant network services weighted by the number of minutes that each network element is needed. In the simple example, one minute of On-Net service needs two minutes of BTS service and one minute of MSC service, and one minute of terminating service needs one minute each of BTS service and MSC service. The cost per-minute of each network element consists of the variable per-minute cost, k_i , and a share of the lumpy cost. The difference lies in the determination of the applicable share of the lumpy cost. In the case of the TELRIC approach, the per-minute cost of each network element includes a share of that part of

the lumpy cost that is due to that particular network element, where this share is determined by dividing the relevant lumpy cost by the volume of the service provided by the network element, i.e. L_{bs}/V_{bs} and L_{ms}/V_{ms} . In the case of the mark-up approach, the lumpy cost share consists of the total lumpy cost, i.e. the sum of the two lumpy costs at the level of the network elements, divided by a weighted sum of the volumes of services provided by the two network elements, i.e. $L/[V_{bs}+(k_{ms}/k_{bs})*V_{ms}]$ and $L/[(k_{bs}/k_{ms})*V_{bs}+V_{ms}]$.

For illustrative purposes a numerical example using arbitrary volumes and costs is presented below:

$$V_o = 2 \text{ billion minutes}$$

$$V_t = 5 \text{ billion minutes}$$

$$V_{bs} = 9 \text{ billion minutes} \quad (\text{NB: the 2 billion On-Net minutes each use 2 minutes of BTS service.})$$

$$V_{ms} = 7 \text{ billion minutes}$$

$$k_{bs} = 0.03 \text{ cent/min}$$

$$k_{ms} = 0.01 \text{ cent/min}$$

$$L_{bs} = \text{A\$135 million}$$

$$L_{ms} = \text{A\$17.5 million}$$

Plugging in above values in equations (5), (6), (15) and (16), one obtains:

$$c_o = 10.25 \text{ cent/min}$$

$$c'_o = 10.14 \text{ cent/min}$$

$$c_t = 5.75 \text{ cent/min}$$

$$c'_t = 5.79 \text{ cent/min}$$

The differences lie well within the margin of reliably acceptable cost estimation exercises.

Note, though, that under the mark-up approach the cost of a terminating service is higher than under the TELRIC approach ($c'_t > c_t$) and vice versa for On-Net calls ($c'_o < c_o$). The reason for the higher cost of termination under the mark-up approach is that the traffic sensitive costs of termination (to which the mark-up is applied) contains a higher share of similar costs from other network elements and the mark-up is added to this higher cost base. Under the TELRIC approach the lumpy cost is allocated to the two

services strictly in relation to their use of BTSs which means that it is also strictly allocated in relation to the traffic sensitive costs on account of BTSs only.

3.4 Annualised CAPEX and the WACC

Annualised CAPEX in this report, the WIK-MNCM User Guide and the WIK-MNCM refers to depreciation plus the (required) return on the invested capital over the period of investment where this return consists of the return on equity and the return on debt capital. The return on invested capital is operationalised as a weighted average of the returns on equity and debt capital, i.e. the so-called 'Weighted Average Cost of Capital' or WACC.

3.4.1 The WACC

The WACC used by the ACCC in its regulatory decisions is expressed in the so-called vanilla form, i.e. the sum of the return on equity capital and the return on debt capital, weighted by their shares in the capital structure of the company in question:

$$(1) \quad WACC = E \cdot r_e + D \cdot r_d$$

where

r_e = return on equity capital

r_d = return on debt capital

E = share of equity capital

D = share of debt capital

The WACC in this form is used as an intermediary entity to facilitate cash flow calculations. It is a hybrid entity in that the return on equity represents a post-tax return required by investors and the return to debt is a pre-tax cost of debt. Because the WACC comprises the weighted shares of debt and equity multiplying the WACC by the total investment in the asset indicates the required return on capital over one year. The cash-flow consequences of tax liabilities are then considered separately as part of expenses. The issue of taxes is considered in section 3.4.3 in respect of the way total capital return is recovered.

The ACCC determines the variables r_d and r_e according to the following two equations:

$$(2) \quad r_e = r_f + \beta_e \cdot (r_m - r_f)$$

$$(3) \quad r_d = r_f + DP + DIC$$

where the r_e as determined in (2) follows the standard formula of the capital asset pricing model (CAPM), and where

- r_f = the risk-free interest rate
- β_e = the company's equity beta
- r_m = the equity market return
- $(r_m - r_f)$ = the market risk premium
- DP = the debt risk premium
- DIC = the issuance cost of debt

The equity beta, β_e , the risk-free interest rate, r_f , and the market premium, r_m , are the central parameters of the capital asset pricing model. They are determined as discussed in the following paragraphs. Two other variables that are used in the WIK-MNCM are sourced from a recent ACCC decision³² as listed in Table 3-2.

Table 3-2: Parameter values for the WACC as used in the ACCC's ULLS decision of August 2006

Parameter	Values used by ACCC (%)
Debt premium (DP)	1.02
Debt issuance cost (DIC)	0.083

As regards the risk-free interest rate, the ACCC has in previous proceedings used the rate on Australian government securities with a 10-year maturity on the conservative assumption that the regulated operator is a wholly owned Australian entity. Telecommunications operators in a substantial number of countries are actually subsidiaries of overseas-based global companies. This is in particular true for mobile telecommunications, and in fact three of the four mobile operators in Australia are either majority or wholly owned by foreign entities. Generally, the WIK-MNCM assumes that all the mobile operators in Australia have access either to group-based financing or financing available from international capital markets. Therefore, WIK-Consult considers that it is appropriate to use a risk-free interest rate referable to international risk-free securities. In order to capture the rates available in relevant capital markets, a weighted average risk-free interest rate is used based on 10-year government securities

³² See the ACCC's Final Decision regarding ULLS (ACCC, 2006d).

observed in the capital markets of the United States, Europe and Singapore (30 per cent weight each), with the remaining weight (10 per cent) referenced to the Australian 10 year government bond.

Interest rates for the past eight years were averaged and weighted to derive the rate used in the WIK-MNCM. This period for averaging is chosen, to reflect a longer term reference point for interest rates to account for interest fluctuations that may occur. As regards to the risk-free interest rate, this should be the rate that – independent of current short-run business cycle and monetary policy influences – represents the willingness of capital providers to lend and of businesses to borrow capital. The average value over an eight-year period from the fourth quarter of 1998 to the third quarter of 2006 is used as the estimator for the relevant risk free rate. As a consequence, the value for the risk-free interest rate used in the WIK-MNCM is 4.434 per cent. The quarterly values covering the 32 quarters from 1998/IV to 2006/III are shown in Annex C.

A similar international perspective is taken for determining the market risk premium. Recent extensive studies conclude that the value for this premium ranges between 3 per cent and 5 per cent.³³ As a conservative choice from this range, a value of 4.5 per cent was selected.

The beta values β_a and β_e used in the WIK-MNCM are also identified with reference to international benchmarks. In principle, the observed values for the existing mobile operators operating in the Australian market should be used. This, however, is not a feasible approach. Two of these operators, Telstra and Optus, are integrated fixed and mobile operators for which the beta values might be expected to be different than for a stand-alone mobile operator. Further Optus and Vodafone, are wholly owned subsidiaries of foreign based companies and are not quoted separately on the Australian capital market.

There are two sources for the benchmarks used, first, beta values published by Professor Aswath Damodaran³⁴ for comparable mobile operators, and second, publicly available values used in recent regulatory decisions, as discussed below.

Table 3-3 presents the beta values for five mobile operators published by Damodaran (2006). The table also includes the corporate tax rate and the share of debt relative to market value for these mobile operators so that the implied value of the asset beta can also be derived. The latter value has been derived on the basis of the other variables using the following relationship between asset and equity betas:

³³ See Ofcom (2005), New Zealand Treasury (2005), Dimson, Marsh and Staunton (2006).

³⁴ Damodaran (2006a); regarding his general approach to valuation, see Damodaran (2006b).

$$(4) \quad \beta_a = \beta_e/[1 + (D/E)*(1-T)]$$

where

D, E = shares of debt and equity capital in total capital

T = the effective tax rate

Note that in this conversion the debt beta is set equal to zero, consistent with the assumption used by the ACCC in its ULLS decision. Further, there is no consideration of tax credits that investors may be entitled to on account of corporate taxes that the companies in which they hold shares have paid. This point is elaborated on in the last paragraph of Section 3.4.3.

Table 3-3: Beta estimates for mobile operators from Damodaran

Company	Estimated equity beta	Tax rate* %	Market debt share %	Implied asset beta
Cosmote Mobile	0.51	35.9	5.3	0.49
Mobistar	1.35	29.4	5.6	1.30
O2	1.81	2.6	7.5	1.68
Telefonica Moviles	1.31	35.8	22.3	1.11
Vodafone	1.31	0.0	13.4	1.13
Average	1.26	20.7	10.8	1.14
Average excluding outliers	1.32	21.7	13.8	1.18

* The tax rate figures are presumably derived from the financial reports of the companies and would thus reflect actual taxes paid relative to a proxy of the relevant taxable income and would therefore represent very rough estimates of the effective tax rate. The low and zero rates of tax for O₂ and Vodafone, respectively, appear to be due to impairment losses that have been recognised by tax authorities.

Table 3-3 includes values for two companies that are considered as outliers, i.e. the estimated equity betas of 0.51 for Cosmote, which appears too low, and of 1.81 for O2, which appears too high. From a more fundamental perspective the large variance in the estimates shown reflects the inherent difficulties with deriving estimates of these beta values using the CAPM. Leaving aside the outlying observations, an average value of 1.32 for the equity beta and an average value of 1.18 for the asset beta is derived.

Given the dearth of data available for mobile only operators in the Damodoran study, the values for these parameters were also sourced from recent regulatory decisions relating to mobile termination rates. Table 3-4 lists the values for the betas and the market debt share for these cases.

Table 3-4: Parameters of the WACC formula used by overseas regulatory authorities

Regulatory authority	Source	Year of proceeding	Asset beta	Equity beta	Market debt share (%)
Norwegian Post & Telecom Regulatory Authority	Johnson (2006)	2006	1.0 -1.6	1.04-1.67*	20
Ofcom, UK	Ofcom (2006)	2006	0.9 - 1.45	1 - 1.6	10
OPTA, The Netherlands	OPTA (2006)	2006	1.08*	1.27	20
Ficora, Finland	Ficora (2005)	2005	1.1 - 1.3	1.4 - 1.43	10 - 30
PTS, Sweden	Marsden Jacob Associates (2004)	2003	1.0 - 1.1	1.08 -1.3	10 - 20
An EU country known to WIK (information considered confidential)	N/A	2006	1.0	1.16	18
Average**			1.13	1.28	17.2

* Not provided in the source. Value derived from the beta value provided (asset beta in case of the Norwegian, and equity beta in the case of OPTA) using equation (2) in the text.

** Where a range instead of a single figure is to be included in the average, the lower and the upper values are each taken as an individual observation.

Table 3-4 indicates that the average figure for the asset beta is 1.13 (range 0.9 and 1.6); for the equity beta 1.28 (range between 1.0 and 1.67); and the average debt share is 17.2 per cent, (range of 10 per cent and 30 per cent). These values are broadly consistent with those identified by Damodaran and shown in Table 3-3, with the additional advantage of having been scrutinised by six regulators in the context of determining the cost of mobile termination.³⁵ On this basis, the values of 1.13 for the

³⁵ A case in point are the observations by Ofcom (2006) p. 248. In its most recent consultation document, after referring to a range of equity betas between 0.69 to 1.26 estimated recently for Vodafone and O2, Ofcom acknowledges the inherent difficulties of estimating these values: "These estimates are broadly lower than the ones used to support the 2004 statement (see Table 2 and Table 3 of the December 2003 Consultation). Equity betas (and implied asset betas) calculated using one year of daily data for both Vodafone and O2 have fallen fairly significantly. Based on this evidence there may be reason to revise the top end of Ofcom's previous range of 1.0 to 1.6 down to reflect the change in more recent estimates. However, given that beta estimates are subject to volatility and change over [time] it may be appropriate to continue to use the same range as the previous market review. It is not possible to judge whether the lower betas measured today reflect a long term trend or a short term market fluctuation." The authors of the present study concur with Ofcom as regards the problems of properly interpreting estimates of beta values. It should be noted again, however, that when the values actually used for the model calculation were selected, the basis for this choice were not only the values Ofcom used but in addition those used by five other regulators.

asset beta and of 17.2 per cent for the market debt share are used in the WIK-MNCM. The equity beta of 1.32 is derived using equation (4). The effective tax rate of 20 per cent used in the WIK-MNCM is discussed in section 3.4.3.

Table 3-5: Parameter values for the WACC as discussed in the text

Parameter	Values
Risk-free interest rate (r_f) (%)	4.434
Market risk premium (r_m) (%)	4.5
Equity beta (β_e)	1.32
Market debt share (D) (%)	17.2

Table 3-5 summarises the parameter values used in the WIK-MNCM.

Using the values identified in Table 3-2 and Table 3-5 results in a vanilla WACC of 9.53 per cent (per equations (1) and (3)). As will be derived in section 3.3, the WACC before taxes amounts to 11.68 per cent.

3.4.2 Recovering CAPEX on the basis of the tilted annuity formula

In calculating annualised CAPEX (inclusive of both depreciation and the required return on investment), the WIK-MNCM proceeds on the assumption that this cost is assigned to the various time periods on the basis of an annuity. This approach assures that the time path of the allocation of total capital returns is consistent with a pricing policy that both remains stable over time – meaning that it does not change in line with idiosyncratic cost allocating procedures – and is in step with underlying cost developments. At the same time it applies the principle of economic depreciation.

The annuity approach accomplishes this in that it

- (i) defines a time series of amounts of capital returns, i.e.

$$(5) \quad A_1, A_2, \dots, A_i, \dots, A_n$$

where 'n' is the number of periods of the lifetime of the capital item in question,

- (ii) assures that the A_i s reflect developments in, both the price and the utilisation rate of the capital item, and

(iii) discount each of these amounts back to the time of investment such that the sum of these discounted amounts equals the value of the investment at the time of installation.

If the only concern were that the discounted sum of the annuities add up to the initial outlay for the asset, the profile of the returns over the 'n' periods could be arbitrary. In fact, without any concern to allocative efficiency, the A_t s have in the past often been determined such that they were equal to each other. Now, from a regulatory perspective, using the principle of economic depreciation, the (real) cost *share* of an asset assigned to a *unit* of network service produced should be the same irrespective of when the unit of network service is produced on the basis of that asset. If then the value of the asset changes from period to period because of changes in its market price, if in addition the number of units provided by the asset change from year to year, for example due to growth of demand, then the time profile of the A_t s becomes a matter of relevance. To ensure the principle of an equal share of real cost assigned to each unit of network service produced, the A_t s must change from year to year consistent with (i) the expected annual change in the price of the asset, and (ii) the expected growth in volume of network services provided by the asset. The first factor has already routinely been incorporated when the annuity approach to capital recovery is used, the second factor is usually not incorporated.

The simple annuity approach assumes that the return on investment is calculated on the basis of a constant capital return amount in each year of the economic life of the asset. That is where $A_1 = A_2 \dots = A_i \dots = A_n$. In this case, the A_t s in (5) remain constant and the cost of the capital item in each year is equal to A . Without any time discounting, the purchase value of the capital item would only have to be divided by 'n' in order to obtain its annual amount of capital recovery.

Since an amount in the future is worth less than the same amount at the present time, each amount in the series (5) needs to be appropriately discounted. The amount of A can then be derived from equation (6) in which the purchase value of the capital item is equated with the sum of the 'n' amounts of A and where each of these amounts is divided by the discount factor that is applicable in the corresponding year:

$$(6) \quad I = A/(1+r) + A/(1+r)^2 + \dots \dots + A/(1+r)^n \\ = A * [1/(1+r) + 1/(1+r)^2 + \dots + 1/(1+r)^n]$$

where

I = the amount invested in the network element

A = the amount of the annual amortisation

r = the return on capital (the WACC)

n = the length of the economic lifetime of the network element measured in years

Using (6) to solve for A, the following results:

$$(7) \quad A = I / [1/(1+r) + 1/(1+r)^2 + \dots + 1/(1+r)^n]$$

In an unchanging world the revenue stream represented by A would be appropriate regardless of when the infrastructure was put in place and the services commenced. However, technological change is persistent as are the changes in the prices of equipment and their utilisation, hence the simple annuity stream can not hope to capture the impact of continuing changes in the industry.

The WIK-MNCM's use of the annuity formula is consistent with the principle of current cost accounting. In line with this framework, the annual amounts of the annuity in any one year are in proportion to the prevailing (current) price in that year. Assume that one expects an average rate of price increase of 'Δp' over the lifetime of the asset, then, in the second year the asset will have a value of '1+Δp' relative to its value at the time of installation. This means that for the annuity for this year, i.e. A₂, to remain referable to the value of the asset, it will have to increase in line with the price difference (i.e. 'Δp'). The same then holds for the third year meaning that the initial price of the equipment and therefore also the initial amount of amortisation will be increased by multiplying the initial amount with '(1+Δp)²'. Repeating this process for all years (i.e. 1 to 'n') then leads to the following adjusted form of equation (6):

$$(8) \quad I = A*[1/(1+r) + (1+Δp)/(1+r)^2 + (1+Δp)^2/(1+r)^3 + \dots + (1+Δp)^{n-1}/(1+r)^n]$$

The solution for A is then obtained in the same way as with equation (7). Note that the amounts A_i for each year of the series in (5) are now different from year to year and can be obtained using the following relationships:

$$(9) \quad \begin{aligned} A_1 &= A \\ A_2 &= A*(1+ \Delta p) \\ A_3 &= A*(1+ \Delta p)^2 \\ &\dots\dots \\ A_n &= A*(1+ \Delta p)^{n-1} \end{aligned}$$

The solution value for A derived from equation (8) is lower than that derived from equation (6) if price changes 'Δp' are positive and the opposite if the price changes are negative. The reason for this result is that equation (8) has the effect that windfall profits (or losses) arising due to the fact that prices of investment goods will in future years be higher (or lower) than the actual purchase price will not benefit (or burden) an entity or MNO, as any windfall profit (or loss) will be passed on to the users – at least in the case of regulated entities – in the form of different prices for marketed services.

The following paragraphs outline the consequences if the assumption of a constant utilisation rate of the equipment or facility is relaxed. This assumption may be realistic in those cases where capital items are not lumpy, are always near full utilisation, and the numbers of which change more or less linearly with volume of network service; in other cases it is manifestly unrealistic as, given expected growth of mobile services, network elements will in future periods provide a greater volume of network services than at present. An example is a BTS site being able to accommodate more BTS equipment than at present and thus also able to provide more services. Under the principle of economic depreciation where each unit of service – here each unit of the service provided by the network element – should bear an equal share of the cost of the equipment or facility, the amount of the annuity attributable to the various periods must reflect this fact. The argument is analogous to the one used in relation to expected price changes. Assume that one expects an average annual growth rate for the service to be provided by the network element over its lifetime of ‘g’, then in the second year the utilisation of the item will be greater by the factor of ‘1+g’. This means that for the annuity to reflect the growth rate ‘g’, it will have to be increased relative to the amount in the preceding period by this factor as well. The same then holds for the third year meaning that the initial price of the equipment and therefore also the initial amount of amortisation will be increased by multiplying the amount with ‘(1+g)²’. Repeating this process for all years then leads to the following adjusted form of equation (8):

$$(10) \quad I = A \left\{ \frac{1}{(1+r)} + \frac{[(1+\Delta p)(1+g)]}{(1+r)^2} + \frac{[(1+\Delta p)(1+g)]^2}{(1+r)^3} + \dots \right. \\ \left. + \frac{[(1+\Delta p)(1+g)]^{n-1}}{(1+r)^n} \right\}$$

As before, the solution provided by equation (10) is in terms of A which can then be used to determine the amounts for each year of the series in (2) as follows:

$$(11) \quad A_1 = A \\ A_2 = A[(1+\Delta p)(1+g)] \\ A_3 = A[(1+\Delta p)(1+g)]^2 \\ \dots\dots \\ A_n = A[(1+\Delta p)(1+g)]^{n-1}$$

It should be noted that the factor ‘g’ varies from network element to network element based on the expected growth of the services to be delivered by the element in the future. For a number of network elements, such as those that are expected to linearly increase in number with the volume of marketed services, the value of ‘g’ is zero.

For reasons of transparency, the use of the standard form of the annuity formula which is equivalent to equation (8) above is avoided. When equation (8) is transformed accordingly, the following is obtained:

$$(8') \quad A = r / [1 - 1/(1+r)^n]$$

Using this standard form of the annuity formula would have made it difficult to trace the effects due to price changes and changing utilisation rates. The solution for A following from equation (11) is in the form equivalent to equation (8):

$$(12) \quad A = 1 / \{ 1/(1+r) + [(1+\Delta p)^*(1+g)]/(1+r)^2 + [(1+\Delta p)^*(1+g)]^2/(1+r)^3 + \dots \\ + [(1+\Delta p)^*(1+g)]^{n-1}/(1+r)^n \}$$

In the standard form this becomes

$$(12') \quad A = (r - \Delta p - g - \Delta p * g) / \{ 1 - [(1+\Delta p)^*(1+g)/(1+r)]^n \}$$

3.4.3 Providing for corporate taxes

Taxes apply to the return on equity capital. In the WIK-MNCM the return on equity capital is a portion of the total return on investment which, in turn, is a part of the annual stream of capital recovery in the form of the amounts of 'A_i' discussed in the preceding subsection.

From the discussion in section 3.4.2 each 'A_i' of the series of annual amounts of amortisation contains an appropriate amount of depreciation as well as an appropriate amount to cover the return on invested capital to satisfy demands of investors. This part of 'A_i' depends on the value of the WACC as discussed in section 3.4.1. The WACC used to determine the relevant operator's return on investment is – consistent with the ACCC's usual approach – the vanilla form, reflecting the return on capital after the deduction of corporate taxes. That means the *pre-tax* cash flows necessary to generate the 'A_is' as post-tax cash flows will in general be greater in magnitude than the values given by the 'A_i' formulae in the preceding section where 'r' is based on the vanilla WACC. In principle, it is possible to apply Australian Taxation Law to deduce a modified 'A_i' inclusive of tax liabilities that must be paid.

In order to determine the cost of a service, it is of no particular interest to determine the corporate tax as a separate cost item. The important point is that the present value of the cash flows (total capital returns) must equate to the initial capital costs as in equations (6), (8) and (10) above. This is achieved for the post-tax cash-flows with the discount rate set equal to the vanilla WACC. An equivalent return is available from a pre-tax cash-flow stream based on a pre-tax WACC.

For this purpose the WACC is specified to include the effect of corporate taxes which leads to the following form:

$$(13) \text{ WACC} = E*[r_e/(1-T)] + D*r_d$$

This differs from the vanilla form of the WACC in equation (1) by the term '1-T' by which the return on equity, 'r_e', is divided. Here the 'T' is not the corporate tax rate but a number termed the effective tax rate which depends on the discounted value of tax liabilities relative to the discounted value of income achieved.

In the context of the WIK-MNCM calculations, the conceptually most straightforward way to determine the effective tax on the return on equity capital over any period 'i' is to calculate the cash flows that generate the 'A_i' as a post-tax outcome. Then calculate what value of 'T' in the pre-tax formula generates a present value equivalent to the present value of 'A_is' (post-tax cash flows) computed on the basis of the vanilla WACC. Then, using the pre-tax WACC formulation (13) for 'r' in the formula derived for 'A' calculated above will generate a pre-tax set of capital returns equivalent in present value terms to the post-tax based approach. The effective tax rate given the composition of assets in the WIK-MNCM amounts to 20 per cent which is the rate used in the calculation.

The usual approach is thus followed by applying the WACC before taxes which ensures that taxes the relevant operator is obliged to pay are calculated as part of the total cost that arise on account of successfully operating a mobile network. On the basis of an effective tax rate of 20 per cent and the values of the other parameters entering into its determination (see the discussion in section 3.4.1), the value of the WACC covering taxes amounts to 11.68 per cent.

When in prior decisions the ACCC based the determination of the WACC on the assumption of 100 per cent Australian ownership, the effect of taxes on the WACC had to be different from that shown here. Australian investors are entitled to tax credits for the corporate taxes that the companies in which they hold shares have paid. Depending on the imputation factor, which typically would be 50 per cent, the impact of the corporate tax rate on the WACC would be correspondingly reduced. As discussed in section 3.4.1, the assumption is made here that the operator is mainly owned by overseas investors for which the possibility of tax credits granted according to Australian Taxation Laws does not exist. It is also assumed that such tax credits are not available in the countries where the relevant investors are based. Accordingly, no such effect has been incorporated into the present derivation of the value of the WACC.

3.5 Cost of spectrum

Mobile operators offering GSM services use spectrum from two ranges of the frequency band, i.e. from the 900 MHz and the 1,800 MHz bands. The availability and the arrangements governing the use of the spectrum in the two frequencies are different as described below.

- In the 900 MHz band the three GSM operators share about equally a band of 25 MHz paired, i.e. Telstra and Optus each have 8.4 MHz (paired) and Vodafone has 8.2 MHz paired of spectrum. The cost for that spectrum is A\$2,451,922 per MHz paired per year.
- In the 1,800 MHz band operators obtained varying amounts of frequencies as the result of auctions that were held during the years 1999 and 2000.

Table 3-6 below shows the amounts of spectrum available to each of the operators as well as the amounts that they paid for it.

Table 3-6: 1,800 MHz spectrum available to 3 GSM operators and amounts paid for it

Operator	Amount paid A\$	Range and availability of spectrum
Telstra	135,637,230	20 MHz paired spectrum in Brisbane, Adelaide and Perth 15 MHz Paired in Sydney, Melbourne and regional Australia (excl. Cairns and TAS and SA) 12.5 MHz paired spectrum in Cairns and regional SA 10 MHz Paired in Darwin, Tasmania and Canberra
Optus	51,145,600	15 MHz paired spectrum in Sydney, Melbourne, Brisbane, Adelaide and Perth
Vodafone	102,789,240	15 MHz paired spectrum in Sydney, Melbourne, Brisbane, Adelaide and Perth 5 MHz paired spectrum in Darwin, Tasmania and Canberra

* Hutchison is not included in this context because this operator does not use its 1,800 MHz spectrum to provide mobile services.

Source: ACMA (2000), *Prices paid for Lots of PCS Auctions*, Spectrum Auctions, URL: http://auction.acma.gov.au/auction_results/3rd_pcs_results_page/pcs_lot_prices.pdf. Accessed on 1 June 2006.

The WIK-MNCM assumes that a hypothetical operator is provided with spectrum in the 900 MHz band that is comparable to what the three existing operators currently have, which means that it has at its disposal one third of a paired 25 MHz band, or 8.33 MHz, available in each location throughout Australia. Given the annual fee per MHz stated

above, this means that the annual cost for this type of spectrum is A\$20,432,602. Modelling shows that this range of frequencies in the 900 MHz band is more than sufficient to serve the capacities of all the BTSs that use it. There is therefore no scarcity of this spectrum. The above annual expenditures for this spectrum are therefore lump-sum amounts that need to be recovered each year by the operator. Since spectrum is exclusively used by BTSs, the volume of minutes to which this amount is to be allocated is the total number of minutes handled by all BTSs in the network.

For determining the amount to be recovered for the 1,800 MHz spectrum, a different approach is adopted. The WIK-MNCM shows that the 1,800 MHz spectrum that the current operators are holding is generally more than is required to meet demands placed on it by overlay cells. It is also assumed that a hypothetical operator will have available in this band an amount of spectrum that is comparable with what the other operators have on average. Further, it is assumed that a given initial outlay for the acquisition of this spectrum is required to be amortised over the years of the duration of the licence for this spectrum.

The estimated parameter values used to calculate the annual amounts of spectrum to be amortised are listed in Table 3-7.

Table 3-7: Parameters used for the calculation of the annual cost of 1,800 MHz spectrum

Parameter	Value
Value of spectrum, as represented by initial outlay	A\$96,524,023
Length of period over which amortisation is to be carried out	15 years
Discount rate (WACC) (%)	11.68
Annual average growth rate of mobile services (%)	5
Annual change in the value of the spectrum (%)	0

The value of the spectrum used in the WIK-MNCM is the average of the amounts that the existing operators paid for their spectrum as result of the auctions in 1998 and 2000. This amount should be considered as a conservative estimate as it lies above the amount paid for radio spectrum in Australia in 2006.³⁶ An alternative approach would be

³⁶ An amount of about A\$80 million has been mentioned as the sum that two Australian railroad companies are paying for 1,800 MHz spectrum. The sale context is a liquidation sale of OneTel's radio spectrum which could be interpreted in isolation as representative of the current market value of the 1,800 MHz spectrum in Australia. It must be noted, however, that the spectrum was purchased under

to use the lowest amount paid by the existing operators for spectrum. Optus paid the lowest amount for this spectrum, i.e. A\$51,145,600. The rationale for this would be that the value for spectrum achieved at auction as listed in Table 3-4 was referenced to a time of ebullient expectations regarding the future prospects of telecommunications and these market conditions may have changed since then. So the lowest amounts paid at auction could reasonably be expected to represent the most appropriate current reference point for spectrum value. Notwithstanding this fact, the higher average amount has been included in the WIK-MNCM.

As regards to the length of period over which this investment in spectrum is to be amortised by a hypothetical operator, a licence period of 15 years is assumed consistent with the licence periods of existing operators. The value of the WACC (before taxes) used as discount rate is 11.68 per cent as applied to all annualised capital cost derivations used in the WIK-MNCM.

It is assumed that the value of the spectrum reflects the underlying value of the volume of services that the spectrum will carry over the lifetime of the licence. The annual amounts of spectrum amortised are in proportion to the relevant volumes in any one year. In this way, any amount amortised in a given year reflects the assumed growth rate or 'g' for mobile services. As a conservative estimate the WIK-MNCM sets the annual average growth rate for mobile services over the licence period of 15 years at 5 per cent. It is further assumed that the current valuation of the spectrum, as represented by the amount of the initial outlay, will not change over the lifetime of the licence so that in the formulae below, calculating the annual cost of spectrum, no tilt is introduced that would reflect such a change in value.

Given the parameter values in Table 3-7, the annualised cost of this spectrum is calculated using the annuity formula developed earlier. The sum of the annual amounts of spectrum costs amortised over 15 years should equal the initial outlay of A\$96,524,023. This is expressed by the following equation:

$$(1) \quad A\$96,524,023 = A_1 + A_2 + \dots + A_{15}$$

In (1) the amount of spectrum costs amortised each year, represented by the 'A_is', need to be discounted to reflect the fact that future amounts of income are always worth less than if they were currently received. This is expressed for each term in (1) by dividing it by the corresponding discount factor of '1 + 0.1168' as follows:

$$(2) \quad A\$96,524,023 = A_1/1.1168 + A_2/(1.1168)^2 + \dots + A_{15}/(1.1168)^{15}$$

exceptional circumstances where the liquidator was unable to sell the spectrum for a number of years. This potentially gave prospective buyers substantial bargaining power and as a result it is possible the spectrum was heavily discounted. The ultimate buyers also purchased the spectrum for purposes other than cellular mobile services and as a result a railroad corporation may value the spectrum differently when compared to a mobile operator.

If the annual amount of amortisation was the same each year, the 'A_s' in equation (2) could be replaced by a static value for 'A' and its value could be determined simply as shown below:

$$(3) \quad A\$96,524,023 = A \cdot [1/1.1168 + 1/(1.1168)^2 + \dots + 1/(1.1168)^{15}] \quad \text{and}$$

$$(4) \quad A = A\$96,524,023 / [1/1.1168 + 1/(1.1168)^2 + \dots + 1/(1.1168)^{15}]$$

This calculation would, however, be incorrect insofar as there is growth in the services using the spectrum. The annual amortised amount would change on the principle that each unit of service, independently of when it is delivered, should bear as a cost the same amount of amortisation. This requires that one estimates the amounts of amortisation due for each of the 15 years. Using the framework above, an average of 5 per cent (as assumed) can be factored in so that equation (2) becomes

$$(5) \quad A\$96,524,023 = A_1/1.1168 + A_1 \cdot (1.05)/(1.1168)^2 + A_1 \cdot (1.05)^2/(1.1168)^3 \\ + A_1 \cdot (1.05)^{14}/(1.1168)^{15}$$

In (5), the amount of amortisation in the first year, 'A₁', is now multiplied by '1 + 0.05', i.e. representing the incremental amount required to be recovered to account for growth in the volume of services each year. On the basis of (5), one can simply solve for the amount of 'A₁', i.e. the amount of amortisation in year 1:

$$(6) \quad A_1 = A\$96,524,023 / [1/1.1168 + 1.05/(1.1168)^2 + (1.05)^2/(1.1168)^3 + \dots \\ + (1.05)^{14}/(1.1168)^{15}]$$

According to equation (6) the amount of amortisation in year 1 is A\$10.68 million. This amount will be used in the current parameterisation of the WIK-MNCM as the cost of spectrum in the 1,800 MHz band. As in the case of the cost of 900 MHz spectrum, this amount will be treated as an annual lump-sum amount and allocated to the total number of minutes handled by all BTSs.

3.6 Working capital

In the RFT the ACCC required a detailed estimation of the reasonable working capital and of what portion of the opportunity cost of this working capital can reasonably be allocated to a mobile termination service.

Conceptually, the most efficient operator with perfect foresight would not face a demand for working capital because it would organise its business processes such that there are no timing differences between cash payments for inputs and cash receipts for output on account of current operations. For that reason bottom-up modelling approaches often

assume that the need and therefore the cost of working capital is negligible or even zero. Under a more realistic consideration of business operation even an efficient operator cannot avoid the need for a certain amount of working capital. The cost of working capital therefore is a legitimate cost item to be covered by all business activities of the MNO.

The WIK-Consult modelling approach assumes that the relevant working capital costs, which are the opportunity costs of using the working capital at a relevant interest rate, are part of the common organisational-level costs. Through the mark-up approach being applied to account for the organisational-level costs, the total costs for the MTAS then is covering a share of that cost which is in proportion to the TSLRIC of the MTAS. WIK-Consult does not see the possibility of directly identifying and modelling working capital according to relevant cost drivers at the level of network elements or the services using the network elements. Therefore, explicitly adding and modelling working capital at the level of network assets would lead to a double counting of costs. WIK-Consult's approach to attributing working capital costs to the cost of the MTAS is conservative in the sense that it is overestimating the relevant amount of working capital cost the MTAS should recover compared to an approach which would be able to directly identify the relevant amount of costs at the service level.

If the user of the WIK-MNCM is able to identify a certain amount of working capital or working capital costs at the company level and intends to allocate these costs to retail services and network services, the MTAS should cover an underproportionate share of these costs for the following reasons:

- (1) There are only slight differences of production-related working capital needs for retail and wholesale services if they exist at all,
- (2) There are significant differences of demand-related working capital needs in the wholesale business compared to the retail business. In retail services there are relevant differences between debtors and creditors due to billing cycles and customer payment behaviour. Insofar as wholesale services are demanded inside the MNO e.g. for On-Net terminating calls, there are no working capital requirements as the MNO is both the debtor and the creditor. There is by definition no difference between debtors and creditors because the transactions are handled efficiently in the internal cost accounting system of the company, and
- (3) The potential working capital needs should only reflect the net traffic flows. In the circumstances of terminating services between two mobile (or integrated) operators, the relevant working capital needs to reflect the traffic imbalances i.e. the net flow between the two carriers.

These arguments support the conservative approach taken regarding working capital.

3.7 Fixed-mobile integration

Presently, in the Australian telecommunications market two types of MNOs offer mobile services. Telstra and Optus operate as integrated fixed-line/mobile carriers and are simultaneously offering mobile and fixed-line services. Vodafone and Hutchison on the other hand operate as mobile-only operators. In the following sections WIK-Consult will firstly develop the argument why from a normative point of view a stand-alone mobile operator should define the regulatory reference point for efficient mobile operations. In section 3.7.2 the nature and potential extent of economies of scope that could arise from simultaneously operating a mobile and a fixed-line business are discussed. Then the report discusses how the WIK-MNCM would factor in a scenario for an integrated fixed-line/mobile carrier.

3.7.1 Mobile-only as reference case

A stand-alone mobile network operator, in WIK-Consult's view, should be the reference case for a hypothetical efficient mobile operator because it represents the likely characteristic of a new market entrant. If there are economies of scope from operating a fixed and a mobile network, modelling stand-alone costs will result in a higher (more conservative) unit cost. A carrier-specific modelling approach to reflect any economies of scope would be dependent on the structure and scale of the fixed-line business of the relevant integrated mobile operator. The (potential) cost advantages therefore become carrier-specific and dependent on the business model of the relevant carrier, as well as the business activities and performance of an integrated mobile operator in their fixed-line business. Assume that the hypothetical efficient mobile operator can minimise the cost of its mobile operations if, say, it is operating a nationwide fixed-line network with a market share in the fixed-line business of (significantly) more than 50 per cent. In WIK-Consult's view, this scenario is not an appropriate reference point for an efficient mobile operator, because it is impossible for every mobile operator to reach such a market position in Australia.

Correctly determining and taking stand-alone costs as a reference point does not imply that the benefits from economies of scope are ignored; it only means that costs are referenced to that of a stand-alone operator. It also means that determining the costs of the MTAS on a stand-alone basis identifies an upper limit of the relevant cost. In determining the MTAS of a specific mobile operator the cost advantages arising from the integrated business of that specific carrier needs to be factored in if that specific carrier integrates both types of business.

3.7.2 The potential cost savings of integration

WIK-Consult's overall conclusion is that the amount of economies of scope between fixed-line and mobile operations under current technology is limited. Its reasoning is set out as follows. A major candidate of cost advantages is the transmission cost of the various types of links used in a mobile network. For the bulk of the transmission links, the BTS-BSC links, WIK-Consult generally assumes that the efficient mobile operator is using its own microwave links. For these links there are by definition (nearly) no cost advantages associated with integration. For all other links, the WIK-MNCN models MNOs' leased lines rented from fixed-line operators. Benefits from integration may occur if the leased line prices WIK-Consult is assuming are not based on efficient costs and do not represent a price reflective of an effectively competitive market for leased lines. An integrated operator could internally provide leased lines at the cost of production which may be lower than the corresponding price it can command in the market.

Further cost savings may be attributable to site sharing opportunities for BTS sites with fixed-line microwave sites; or MSC sites or buildings with switching sites for the fixed network.

Under current technology integrated operators do not share the entire core network to operate their mobile and fixed-line networks. This structure may change in the future due to the development of All-IP Next Generation Networks because of integration capabilities of this technology at the core network level. Also WIK-Consult notes that fixed-line operators have announced their intention to integrate mobile and fixed core networks over the next few years. Integration of networks at the core network level would need to be modelled explicitly and cannot be addressed on the basis of changing parameters in the WIK-MNCN.

Cost sharing between the mobile and the fixed-line business may also occur at the level of business overheads. The fixed-line and the mobile business may share certain business functions at that level. WIK-Consult expects that these potential savings are small, because of the assumption that business overheads are scalable according to the size of the business. In the industrial organisation literature there is even the argument that business overheads may be a source of diseconomies of scale at the organisational level of the company. Given the dichotomy of views that exists in relation to this issue, WIK-Consult has adopted the approach of ignoring any potential benefits of integration related to business overheads that could arise.

3.7.3 Integration benefits at the modelling level

Integration benefits can be considered in the context of the WIK-MNCM using carrier-specific information, Regulatory Accounting Framework (RAF) data or other confidential market sources and adjusting the following parameters:

- (1) assuming a lower level of leased line prices,
- (2) assuming lower BTS, BSC, repeater, and MSC site costs due to site sharing, and
- (3) assuming a lower percentage mark-up for business overheads.

3.8 Integration of 2G and 3G mobile networks

In its June 2004 MTAS Final Report the ACCC extended the existing declaration of the MTAS to include voice services terminating on 3G mobile networks.³⁷ Despite the technological differences between 2G and 3G networks the ACCC considers that the nature of the supply of 3G voice services is largely the same as the supply of 2G voice services.³⁸ Voice call services provided on 3G networks compete with voice call services provided on 2G networks. Similar to most European regulators the ACCC considers mobile calls utilising 2G and 3G networks are sufficiently substitutable to be considered as part of the same mobile services market.³⁹ For that reason there is no reason to treat voice termination in 2G networks differently from termination in 3G networks from a regulatory point of view. In the MTAS Final Report and reflected in the indicative prices in its MTAS Pricing Principles Determination, the ACCC also noted 'that there should be no presumption that the Commission would set a different price for termination of voice call on 3G networks as it would set for termination of voice calls on any other digital mobile technology'.⁴⁰

De facto the Australian MNOs have introduced different mobile technologies and are operating networks of different generations. Three carriers operate second generation cellular mobile networks in Australia. Telstra, Optus and Vodafone launched their 2G (GSM) networks already in 1993. All three GSM carriers operate in the 900 MHz band. In 1998 and 2000 further 2G spectrum in the 1,800 MHz band was made available through a spectrum auction. In addition to the existing three GSM carriers, several other operators acquired 1,800 MHz spectrum which is currently not being used to provide mobile services.⁴¹ Until August 2006 Hutchison was operating a 2G network based on

³⁷ See ACCC (2004), Appendix A.

³⁸ See ACCC (2004), p. 22.

³⁹ See ACCC (2004), p. 61.

⁴⁰ See ACCC (2004), p. 211.

⁴¹ See ACCC (2004), p. 76.

the CDMA standard. At present, in addition to its GSM network Telstra is operating a CDMA network with nationwide coverage, but this is scheduled to be replaced by its 3G 850 MHz network from 1 January 2008 as outlined below. This CDMA network was launched following the closure of its Analogue Mobile Phone System (AMPS) network in 2000. All four MNOs have in the meantime rolled out 3G networks based on the W-CDMA standard and on spectrum in the 2,100 MHz band. After closing down its CDMA network, Hutchison is only offering mobile voice services on its 3G network and complementing this voice service by roaming onto other carriers' networks.

Since 2005 Telstra is following a new and somewhat innovative 3G network deployment strategy. Telstra has rolled out a new 3G network using spectrum in the 850 MHz band and a W-CDMA technology. The network is reusing much of the core infrastructure of the existing CDMA network. This new 3G network has the potential to supersede all three mobile networks Telstra currently operates, namely the 900 MHz 2G network, the CDMA network and the 3G network in the 2,100 MHz band.⁴² Telstra has indicated that over time it will migrate its customers from its old networks onto its new 3G 850 network⁴³ and will continue to offer 3G services over its existing 3G 2,100 network co-shared with Hutchison. The intention of the new network is according to Telstra to reduce its level of network costs and complexity and to enable it to provide customers with faster speed, better coverage and a greater range of services than on the basis of its old networks.⁴⁴

Any cost modelling approach has to answer three different conceptual questions regarding network technology:

- What is the best-in-use technology which should form the basis for modelling?
- Should a migration path from a best-in-use technology to a next generation technology be modelled?
- How to deal with the sharing of functions or elements of various networks or technologies?

⁴² Greg Winn put this context in a Telstra Technology Briefing into the following words: 'So what we will be doing is installing 3GSM equipment into over 5000 base station sites in Australia which is the sum of our existing GSM sites and our CDMA sites including the overlay minus a few minor micro cell sites that don't provide any coverage at all. We will be upgrading and migrating to a single soft switch based core system serving our entire GSM ecosystem, which is our 3G and our current 2G network which we will continue to operate. We'll upgrade all of our legacy equipment in our 2G network which at the same time will enable edge capability which is enhanced data for GSM evolution which is a higher data throughput capability for GSM frequency devices. So this will totally deliver us 1.6 million square kilometres of CDMA capability, of 3G capability equal to our current CDMA footprint, and they will deliver collectively voice, video and High Speed Circuit Switched Data.' (see Telstra (2005a)).

⁴³ See Telstra: Annual Report 2006 (2006), p. 15.

⁴⁴ In its Director's Report 2006, Telstra made the following statement: 'Our transformation has already resulted in our national 3GSM 850 network build being more than 60 per cent complete. Savings have been achieved by consolidating office space, vacating existing leases and sourcing mobile devices through global supply-chain specialist, Brightstar.' (Telstra Corporation Limited and controlled entities Directors Report 2006, page 6).

The production technology an efficient operator applies in the network should be the best-in-use technology. This is the one which is most cost-effective in current networks and at current levels of demand. WIK-Consult's modelling approach is based on the assumption and the RFT requirement that the 2G generation of mobile network technology is the 'best-in-use technology'⁴⁵ representing the technology an efficient forward-looking operator would apply today under the current level of demand. 2G is a mature technology with well-known characteristics and is optimised for carrying voice traffic. The latest evolution of mobile technology is 3G. This technology is currently being employed by all four mobile operators in Australia under different roll-out strategies. 3G is optimised for carrying data traffic. The technology is, however, also capable of conveying voice traffic and in reality 3G networks are also used for conveying and terminating voice traffic. Operators expect 3G technology to become the dominant network technology, in the long-run integrating voice and data traffic in an efficient manner. It should be noted that at relevant volumes of traffic, 3G technology is regarded as the more efficient technology (compared with 2G technology) resulting in lower unit costs of delivery. This is at least the quantitative result of the latest modelling approach Ofcom has generated in calculating 3G costs in the United Kingdom, if the licensing (spectrum) costs were ignored. In spite of this conclusion there is, however, sufficient uncertainty with regard to network structure, demand / traffic and costs of 3G networks to model the 3G network costs referable to the same level of reliability as for 2G network costs. For similar reasons Vodafone in its submission supporting its undertaking in 2004⁴⁶ presented a top-down modelling approach based on a 2G stand-alone network. In its decision on the undertaking the ACCC outlined its view that 'over the long-term, the per unit costs of supplying the MTAS on 3G networks have the potential to be lower than on 2G networks'.⁴⁷ The ACCC, however, accepted the view that there is some uncertainty about the future demand for 3G services and the migration path from 2G to 3G networks.

Although WIK-Consult is modelling a mobile network based on the 2G technology, it will test the hypothesis as to whether 3G technology is a more efficient technology given the current level of demand. WIK-Consult's approach to meet the ACCC's RFT requirement is to model for a selected and limited number of representative districts the cell deployment for a 3G W-CDMA network under the same service scenarios as for the 2G network. The results of this approach are presented in section 6.6.

WIK-Consult considers that 2G and 3G voice call termination can be viewed as an analogous service, at least from the point of view of the end-user of that service. 2G remains the dominant technology for the delivery of voice services. If carriers have the discretion to choose a certain technology to deliver voice calls, it is fair to assume that the introduction of 3G as a new technology should therefore not increase the cost and

⁴⁵ This criterion is set in the ACCC's Access Pricing Principles. See ACCC (1997), p. 29.

⁴⁶ See Vodafone (2004).

⁴⁷ ACCC (2006b), p. 41.

price of the MTAS. If in this environment carriers decide to migrate traffic from 2G to 3G networks, regulators should assume from this market behaviour that the costs of traffic migration (if any) are equal to or lower than the cost differences of delivery of voice calls between 2G and 3G.

What this means is that conceptually regulators should not be concerned with migration paths of call volumes between different technologies and the associated costs. There is at any point in time a best-in-use technology that provides the relevant demand of the services in question at minimal cost. In WIK-Consult's view, the reference point for determining the costs of a hypothetical efficient operator is a new market entrant, whose network represents the best-in-use technology. The new operator makes a clear decision about the optimal technology to use. This reference point is not consistent with path-dependent investment decisions. The investment decision of an efficient operator does not depend on past decisions and existing networks or technologies. This concept and reference point does not know migration or migration costs. Setting the MTAS at the level of 2G costs and not modelling migration would generate an upper limit of the efficient MTAS costs in the phase of migration. This approach should accelerate the path of migration and should enable an earlier switch to the (potentially) lower costs of the MTAS at a 3G technology. WIK-Consult sees less incentives to migrate using the approach, recently proposed by Ofcom. In its recent consultation documentation, Ofcom proposed that the MTAS charges should be determined with reference to a blended 2G/3G benchmark. This benchmark should be based on an average of 2G costs and 3G costs weighted according to the respective volumes of terminated voice minutes in each year.⁴⁸ This approach explicitly takes into account the cost of migration. Its outcome significantly depends on a (highly uncertain) forecast of data traffic and of traffic migration.

Operators providing mobile services on both 2G and 3G networks can share economies of scope between the two networks. BTSs and other sites may be shared between 2G and 3G networks. Modern MSCs as well as network management systems are capable of supporting 2G and 3G networks. As already discussed in the context of fixed-line/mobile integration⁴⁹ it has to be decided whether the hypothetical efficient operator being modelled should be treated as an operator applying a stand-alone single mobile technology or whether it may also benefit from economies of scope with 3G networks. The RFT gives a clear answer to the later point: 'The ACCC requires detailed analysis of the implications of the introduction and development of 3G services for the cost of providing 2G voice termination, with sufficient information for it to make a quantitative assessment of the impact on 2G termination cost.' With this perspective in mind, network sharing costs (and potential economies of scope) between different mobile

⁴⁸ See Ofcom (2006), p. 102.

⁴⁹ See section 3.8.3.

network technologies would have the potential of reducing the cost of termination on 2G networks.

To address this issue and to identify and quantify the implications of 3G on the cost of 2G termination, the WIK-MNCM is a 2G stand-alone network and cost model. As a second stage consideration, the network elements which can be shared under a 2G/3G network modelling approach are identified and the sharing of these network elements can be modelled under plausible assumptions. Comparing the costs of termination on a stand-alone 2G network with those resulting in a network sharing scenario informs the ACCC of the implications of 3G developments on 2G costs.

3.9 Licence and other regulatory fees

3.9.1 Licence fees

MNOs in Australia like other telecommunications carriers are subject to annual licence fees. In addition to these annual licence fees, Vodafone and Optus were subject to one-off licence fees when they originally entered the Australian market. The original licence fee payments are considered to be historical licence fees and their relevance to the modelling exercise is considered below. Subsequent sections deal with the annual licence fees.

3.9.1.1 Historical licence fees

In November 1991 the Australian Government partially deregulated the telecommunications market by awarding a fixed and mobile carrier licence to Optus to compete against the former monopolist Telecom-OTC (now Telstra) in a duopoly market structure. Optus received its licence in a competitive bidding process and within a complex deal structure.⁵⁰ The successful bidder was required to purchase the AUSSAT satellite operations which had A\$740 million of debt in its balance sheet. Optus paid A\$800 million in total to the Australian Government to secure its entry in the market.

Given the value of the debt AUSSAT carried on its books one might attribute a maximum of A\$60 million to the fixed and mobile licences acquired by Optus as an implicit licence fee at that time.

⁵⁰ See The Age Newspaper, 20 November 1991.

The third mobile licence was also awarded in a competitive bidding process in 1992. Arena, an alliance between Vodafone and AAP Telecommunications, paid A\$140 million for its mobile licence.⁵¹

In 1991 the Australian Government made it clear that from 1997 the new telecommunications legislation would operate and supersede these earlier restrictions. One of the consequences of the 1997 Telecommunications Act was to substantially reduce the costs (and barriers to entry) of obtaining a carrier licence to operate in the Australian market.

The historic licence fees need to be regarded as the price for the economic rent of operating in a market characterised by regulatory entry restrictions, even if only for a limited period. When the entry restrictions were lifted in 1997, the forward-looking opportunity costs for the historic licences became zero and the licence fees became a sunk cost investment. Efficient prices are based on forward-looking opportunity cost considerations. From this perspective the historical licence fees should have no impact on prices including regulated cost-based prices; they are no longer relevant costs for the determination of the costs of the MTAS. This view is supported by reference to the costs borne by a new entrant today. It does not bear such costs.

3.9.1.2 Annual carrier licence charge

MNOs are required, like other telecommunications carriers, to pay annual carrier licence charges, which are determined by the Australian Communications and Media Authority (ACMA) each year. The carrier licence fee charged is determined with reference to the following formula.⁵²

$$MFC + \left[(MCA - OTC - (MFC * TNC)) * \frac{ER}{TER} \right]$$

MFC	Minimum Fixed Charge
MCA	Maximum Charge Amount
OTC	Other Telecommunications Charge
TNC	Total Number of Carriers
ER	Eligible Revenue
TER	Total Eligible Revenue

The most recent (and publicly available) licence charges for Vodafone and Optus Mobile using this formula are shown in Table 3-8. The basic drivers for the value of the licence fee include the revenue and market share of the respective carrier.

⁵¹ See Australian Financial Review, 16 December 1992.

⁵² Australian Communications and Media Authority (2006).

Table 3-8: Annual carrier licence fees for Vodafone and Optus⁵³

	Vodafone A\$ million	Optus Mobile A\$ million
2004	1.060	1.702
2005	1.315	2.749
2006	1.150	2.738

This annual licence fee is a relevant cost for providing the MTAS. An MNO cannot run its business without a carrier licence or without paying licence charges. It is related to the whole mobile business of an MNO and should therefore be treated in the same way as common organisational-level costs. The amount of the annual licence fee actually used in the model as a parameter is derived in section 5.3.12 of this report.

3.9.2 Universal service levy

As with all other licensed telecommunications carriers, MNOs are required to contribute to universal service subsidies. Telstra is currently the sole universal service provider and receives payments as a compensation for the net cost of providing universal services. The USO levies imposed on MNOs are a relevant cost of providing the MTAS, similar to annual licence fees they are a regulatory obligation which cannot be avoided when operating a network. The universal service levy is related to the entire mobile business of an MNO.

The USO subsidies are determined by the Minister based on advice from the ACMA on an annual basis. These subsidies have fallen consistently in recent years as Table 3-9 shows.

⁵³ Calculated from Australian Communications Authority (2004), (2005) and from Australian Communications and Media Authority (2006).

Table 3-9: USO subsidies⁵⁴

Period	USO subsidies (in A\$ million)
2004 – 2005	211.3
2005 – 2006	171.4
2006 – 2007	157.7
2007 – 2008	145.1

The licensed carriers are required to contribute to the USO subsidies according to their eligible revenues. Table 3-10 shows the universal service levies (USLs) imposed on Vodafone and Optus Mobile in the last few years based on their respective universal service assessments by the ACMA.

Table 3-10: USLs for Vodafone and Optus Mobile (in A\$ million)

Period	Vodafone	Optus Mobile
2005/2006	8.6	20.5
2004/2005	11.1	23.3
2003/2004	12.1	19.6

In the WIK-MNCM the relevant USLs for a hypothetical operator is calculated with reference to the 2005/2006 levies for Vodafone and Optus for the period.⁵⁵ This is considered a conservative forward looking assumption given the continuing trend of lower USO subsidies. The amount of the USL actually used as a parameter in the model is derived in section 5.3.12 of this report.

3.9.3 Annual numbering charge

According to the Telecommunications Numbering Charges Act of 1997 MNOs have to pay annual numbering charges. These charges are specific to mobile phone numbers, as fixed-line phone numbers are exempted from numbering charges. The annual numbering charge per 10-digit number is A\$0.91 and is required to be paid for the total digital mobile service numbers operated by each of the carriers. This is usually larger

⁵⁴ http://www.acma.gov.au/ACMAINTER.1572992:STANDARD::pc=PC_2483.

⁵⁵ The parameter value for the universal service levy used in the model is derived in section 5.3.12.

than the number of customers attributable to a carrier. According to the 'Register of Allocated Numbers'⁵⁶ as at 3 July 2006 the MNOs hold mobile phone numbers as shown in Table 3-11.

The demand for mobile phone numbers is driven by the number of subscribers. The more subscribers an MNO can attract the more phone numbers it needs. Therefore, these costs for mobile phone numbers are related to and need to be attributed to the retail business of an MNO. This is not considered a cost relevant to the supply of the MTAS.

Table 3-11: Mobile phone number holding and charges by carrier

Mobile carrier	Amount of numbers	Annual numbering charge (in million of A\$)
Telstra	14,000,000	12.7
Optus	12,100,000	11.0
Hutchison	2,200,000	2.0
Vodafone	8,800,000	8.0

3.10 Governmental subsidies for mobile networks

Australian MNOs do not have an explicit licence condition to provide a certain degree of geographic or population coverage of their networks. Although competition has generated a high degree of population coverage which is not too much different from mobile coverage in Europe, the geographical coverage of cellular mobile services is of particular importance from a policy perspective in Australia. This concern can be highlighted by the specific population distribution characteristics of Australia whereby a mobile network which is capable of providing services to 96 per cent of Australia's population, covers physically only about 20 per cent of Australia.

The Australian Government has provided over time various programmes and subsidy schemes as incentives for MNOs to expand the scope and coverage of their networks in regional and remote areas. Table 3-12 lists the most important programmes the Department of Communications Information Technology and the Arts has administered or is administering. Telstra has been the beneficiary of most of these subsidies, because of the extent of its network and the cost relativities of increasing coverage of the CDMA network which has been significantly lower than that for GSM networks.

⁵⁶ <http://web.acma.gov.au/numb/openAccess/menuInquiry.do>.

Nevertheless, other MNOs have been eligible and also received some of these subsidies to improve their coverage.

Table 3-12: Governmental mobile coverage programmes

Name of programme	Intention	Subsidy volume	Subsidised MNO
Towns Under and Over 500 ⁵⁷	Improve coverage to 131 towns in regional Australia with population of over 500 and 55 towns with populations under 500	A\$58 million	Telstra
Regional Highway Programmes			
- Selected Regional Highways ⁵⁸	Improved CDMA coverage in segments of 34 regional highways	A\$19 million	Telstra
- Mobile Phones on Highways ⁵⁹	Facilitate continuous mobile service along a number of major Australian highways	A\$25 million	Vodafone
Extended Mobile Phone Coverage in Regional Australia ⁶⁰	Improve CDMA coverage to 62 locations within regional Australia	A\$16 million	Telstra
Networking the Nation ⁶¹	Specific projects to improve mobile coverage	N/A	N/A
Wireless West	Extending CDMA coverage in Western Australia	A\$14 million	Telstra

WIK-Consult is not aware of any net cost approach to calculating the efficient level of such subsidies which also takes into account the additional revenues MNOs may receive by expanding their coverage. Therefore, it remains unclear whether coverage was extended beyond a competitive level. Nevertheless, the subsidy programmes reduce the cost of network coverage to the participating MNOs. It is nevertheless not possible to allocate the subsidies to the cost of coverage as modelled by the WIK-MNCM because the subsidy programmes targeted specific areas of the country. It is

⁵⁷ http://www.dcita.gov.au/tel/mobile_telephone_services/funding_for_industry/mobile_phone_coverage_for_towns_with_a_population_of_500_or_more.

⁵⁸ http://www.dcita.gov.au/tel/mobile_telephone_services/funding_for_industry/mobile_phones_on_regional_highways.

⁵⁹ http://www.dcita.gov.au/tel/mobile_telephone_services/funding_for_industry/mobile_phones_on_national_highways.

⁶⁰ http://www.dcita.gov.au/tel/mobile_telephone_services/overview_of_mobile_telephone_services/extended_mobile_phone_coverage_in_regional_australia.

⁶¹ http://www.dcita.gov.au/tel/role_of_the_telecommunications_division_and_contacts/networking_the_nation.

also hard to identify what amount of coverage subsidy a hypothetical operator might receive.⁶²

WIK-Consult's approach with regard to the mobile network subsidies is to ignore them for cost calculation purposes in modelling the network cost. This is largely because of the practical problems of properly attributing the subsidies to the network cost. WIK-Consult's conclusion is that this results in a more conservative estimation of the relevant cost of the MTAS than might apply if the subsidies were incorporated into the cost estimate for a hypothetical operator.

62 A precise approach to calculating the effect of these subsidies would be to identify the net cost of the degree of coverage which is above the optimal level for the respective MNO and deduct any subsidies from those net costs.

4 The WIK Mobile Network and Cost Model

4.1 Introduction

This chapter consists of two discrete sections. The first section deals with the design and dimensioning of the network for which the cost of the MTAS is to be determined. The second section describes how the design and dimensioning of the network is used to determine the number of the network elements needed. It further identifies the required amounts of investment and discusses how the relevant costs are determined. Once these (network element) costs are identified they can be used to estimate the cost of the MTAS (i.e. the service using the network elements).

The WIK-MNCM is in a position to estimate the cost of the MTAS of a hypothetical mobile network operator that is operating in Australia. There are two general parameters that will characterise the modelled network for an Australian specific context. These are the area covered by the network, to identify the population to be covered, and the share of the market served by the network.⁶³ The WIK-MNCM has the flexibility to account for different coverage and market share scenarios. It is therefore important to note, that beside modules for cell deployment, switching and transmission contained in the SNPT presented in section 4.2 has the functionality to account for Australia's different population densities for any changes in coverage and market share. Section 4.2.1 considers this functionality in more detail while subsequent sections will present the design and dimensioning of the cells, the aggregation network, the backhaul network and the core network.

As has been pointed out before, by far the largest share of the services of a mobile network are the result of common or joint production by network elements. To ensure that the production – and thus also the cost – of the MTAS derives all the benefits arising from the economies of scale and scope of the production of similar services on a much larger scale by the various network elements than is possible for a single service, it is necessary to model the whole network of a hypothetical operator. The Cost Module then is applied to determine the cost of the MTAS, both for voice calls and SMS messages, such that all these services (including other data services) are assigned costs consistent with their share of use of the various network elements. Obviously, when there are service-specific network elements, related costs need to be allocated exclusively to those services for which they have been installed. This cost determination process is further described in section 4.3.

⁶³ The market served by the network is of course defined in terms of the overall penetration of the market with mobile services.

4.2 Network design by the Strategic Network Planning Tool

4.2.1 Data set up process

The first step in a network dimensioning process is to establish the data requirements. This process involves identification of the areas to be covered and the areas not covered (to establish the area of coverage) and the number of subscribers served in each of the areas covered and the demand arising from these subscribers in the covered areas (to establish the demand for services in the covered area). These processes involve aggregation of the basic geographical areas to sizes of districts that are relevant for cell deployment and the elimination of those areas (because of low population density) that will not be served. These two processes will be referred to as 'aggregation' and 'elimination'. There is an adjustment to the raw population data to take account of the fact that mobile subscribers, in particular the working population, move between locations and may thus contribute to demand during a typical day in more than one location (i.e. to account for the impact of the working population on covered areas).

One input for the data aggregation process is Postal Areas (POAs). Relevant POA information includes the population, number of employees working in the POA, the size of the POA in square kilometres (Km²) and the classification of population density and geographic size of the POA (urban/suburban/ residential).

As the demand during the busy hour in an area determines the capacity requirements of the network in that area, it is important to determine the impacts of a transient population in a POA. As mentioned above, the working population can impact the daily demand in a POA. A subscriber living in a specific POA may work in another POA and will normally as a consequence contribute to the busy hour in the POA in which the subscriber or user works rather than the one in which the user resides. Typically, this may mean that the subscriber contributes to the morning busy hour in the POA in which the subscriber or user works and to the evening busy hour in the POA in which the user resides. As a result, the first step in the data set-up process in the SNPT is to adjust the population for each POA for the working population impacts on busy-hour demand in the morning and then for the residential/working population changes in the evening.

The second step is to identify and eliminate the areas that will not be covered by the network. To do this an 'exclusion threshold' parameter is used to establish the minimum number of inhabitants in a POA required for coverage. This parameter determines the desired degree of coverage for the WIK-MNCM.

The third set-up step consists of the aggregation process which converts POAs into districts that are the basic geographical unit used for the cell deployment. The aggregation process is a mechanism to join several POAs (or smaller geographic units)

into districts. The aggregation process takes into consideration a POA's population and physical size (distance).

The aggregation process assumes that there are three types of POAs (rural, suburban, urban) classified according to their population density and their size. The size parameter is known as the aggregation radius and identifies the maximum distance between the centres of adjacent POAs that can be joined to form a district.

The aggregation process methodically works through all the POAs from high density POAs or urban POAs to lower density or rural POAs to aggregate and classify POAs into (urban, suburban and rural) districts.

This procedure may not result in all POAs being aggregated. There may be some POAs that will constitute districts by themselves. This would be the case with rural POAs which cover a large area, and would exceed the distance criterion for aggregation with other neighbouring POAs.

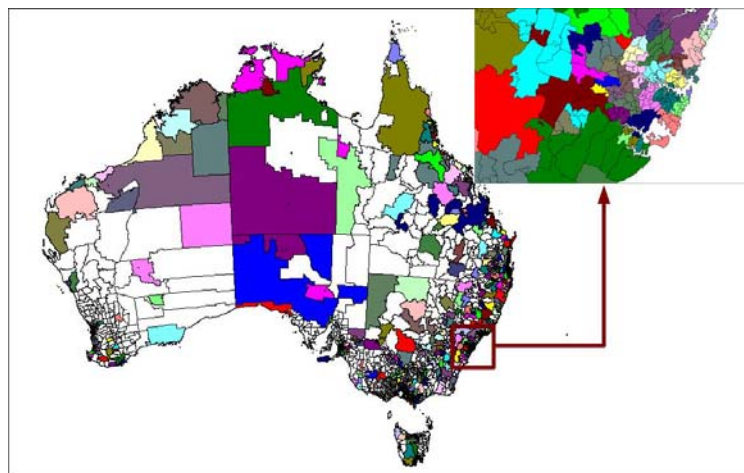
The aggregation process is best illustrated by an example. Consider Table 4-1 in which typical aggregation values for the three types of POAs are listed. The distance (aggregation) criterion indicates that a POA with a density of 750 inhabitants per Km² will be aggregated with another POA within a distance of 10 Km.

Table 4-1: Typical aggregation values

Thresholds	Inhabitant density (number/Km ²)	Aggregation distance (Km)
Rural	100	20
Suburban	500	10
Urban	1000	5

Figure 4-1 also illustrates an example of an outcome of the data aggregation process. The threshold for exclusion is an absolute number of 3,500 inhabitants and for the aggregation the values are taken from Table 4-1. The regions shown in white are the POAs that are excluded, and POAs with the same colour form one district as a result of the aggregation.

Figure 4-1: Representation of the results of the aggregation process in Australia and details of the area of Sydney



Note: Large remote districts that appear to be fully covered (by their areas being completely coloured) are in fact only served in a number of limited places.

The values for the parameters needed for the aggregation and exclusion process can be specified by the model user. The values in Table 4-1 and the 3,500 inhabitant threshold represent the aggregation and exclusion factors for a population coverage of 96 per cent. The output of the aggregation and elimination processes are the set of districts over which cell and BTS deployment will be designed.

The relevant population for each district, determined as a result of the basic data set-up procedure, also represents the demand input. This follows because:

- Market penetration is measured as a given percentage of total population,
- Market share of a hypothetical operator is a given percentage of market penetration. This determines the number of subscribers,
- Demand for traffic is expressed in terms of the average demand by a subscriber at the busy hour for all services considered by the WIK-MNCM, and
- The demand per subscriber is multiplied by the total number of subscribers to proxy total demand.

A more detailed discussion of some of the above mentioned points is presented in section 5.2.

4.2.2 Cell and BTS network deployment.

The cell and BTS deployment is the first step in the design of the mobile network and specifically in the Base Station Subsystem (BSS). It consists of two hierarchical steps: cell radius calculation and the determination of the number of sites for each district based on the classification of a district into an urban, suburban or rural district type.

4.2.2.1 The deployment procedure

The cell radius determination is the process that optimises the configuration of a cell from the point of view of coverage and capacity for traffic. The inputs for this process include: information about the set of services offered by the operator to its customers; the quality of service; technical parameters about the network equipment; topographic and demographic information about relevant districts; and additional design parameters.

In order to determine the cell radius, information about the radio coverage, i.e. uplinks (mobile station to BTS) and downlinks (BTS to mobile station), is required. A key factor for radio coverage is the maximum path loss, which is calculated with reference to: the transmission power of the equipment, the corresponding antenna gain, the noise figure of the receivers, and the margins to avoid fading.⁶⁴ Once these variables are identified, they are applied to an appropriate propagation prediction method to calculate the maximum range of the cell (cell radius). The WIK-MNCM adopts the Okumura-Hata (propagation) model⁶⁵ for frequencies below 1,500 MHz (GSM 900 MHz). For frequencies above 1,500 MHz the WIK-MNCM implements the modifications of the COST 231 project adapted to the Okumura-Hata model for these ranges.⁶⁶ This method is a good compromise between the requirements of cell radius accuracy and the flexibility in adapting to different environments under a limited number of input parameters. In actual operational planning, more sophisticated solutions are required, such as ray tracing.⁶⁷ Developing a more precise propagation model requires a large set of reliable and accurate data for virtually every street in every district to be covered by the network. However, WIK-Consult has found that the approach adopted in the WIK-MNCM provides sufficiently accurate results for purposes of cost modelling.

Once the cell radius using the propagation criteria is calculated, the SNPT considers the cell radius with reference to the traffic requirements. The first step is to calculate the value of the individual traffic per customer. As the set of services includes a mixture of voice, message and data services, each with their corresponding parameters, an

⁶⁴ See Rabanos (2004) and Freemann (1989).

⁶⁵ See Okumura et al (1968), pp. 825-873 and Hata (1980), pp. 317-325.

⁶⁶ European Cooperation in the Field of Scientific and Technical Research EURO-COST 231, Urban Transmission Loss Models for Mobile Radio in the 900 and 1,800 MHz Bands, Revision 2, The Hague, September 1991.

⁶⁷ See Coinchon et al (2001).

equivalent traffic flow must be established in order to calculate the required capacity for traffic. This conversion of the demand for different services to an equivalent traffic flow is carried out on the basis of a well-established technique of network design theory.⁶⁸ From the target blocking probability and the number of traffic channels available in the cell,⁶⁹ the value of the maximum feasible volume of traffic is determined using an adaptation of the traffic model described by S. Rappaport.⁷⁰ Based on the average value of the traffic per user, the WIK-MNCM estimates the maximum number of users. Finally, considering the customer density in the different areas of each district as well as the number of sectors of the BTSs, the cell radius for the given traffic demand is calculated.

The next step is to compare the results for the cell radius calculations (propagation modelling or traffic requirements). The cell radius selected will reflect the most conservative (smaller) cell radius for each district based on a comparison of the outcomes of both criteria and will be the more limiting criterion. In the circumstances where the radio propagation determines the cell radius in a zone, the site (BTS) will be coverage driven. However, where the cell radius in a district is driven by traffic load then the site (BTS) will be capacity driven, assuming that only 900 MHz spectrum is being used.

In case that the cell radius is limited by traffic, the network operator may install overlay BTSs using 1,800 MHz spectrum. In this case part of the users are then served by the 1,800 MHz BTSs. Therefore, a further optimisation of the sites is required considering the maximum radio coverage range of the 1,800 MHz BTSs, the number of users served by the 1,800 MHz BTSs, as well as the reduction of the number of users served by the 900 MHz BTSs. The use of 1800 MHz overlay cells will increase the capacity range of the 900 MHz BTSs and hence there needs to be a further optimisation. The final cell radius will be the more limiting criterion of the two criteria determined by radio coverage or capacity.

4.2.2.2 BTS classification and types considered in the WIK-MNCM

The discussion above highlights that the cell radius depends on the type of BTS considered. This section provides a brief overview of the different types of BTSs and their application in the WIK-MNCM.

⁶⁸ See Lindberger (1994), pp. 897-906 and Ariza (2001) pp. 47-48.

⁶⁹ The number of user channels depends on the number of TRX in the cell which also depends on the frequency planning.

⁷⁰ See Hong et al (1986), pp. 77-92.

The BTSs are usually classified according to the type of cell they are handling. A classical division is the following.⁷¹

- Macrocells: Coverage radius between 1.5 to 20 Km, mainly for rural areas with low traffic,
- Microcells: Coverage radius between 0.5 to 2 Km, for urban areas with high traffic, and
- Picocells: Coverage radius up to 0.5 Km, for dense urban areas with high traffic or to cover special places like malls and airports; which are usually traffic driven.

The WIK-MNCM considers a large set of parameters for modelling BTSs. The most relevant ones are transmission power, number of sectors, number of transceivers (TRXs) and number of channels for signalling.

Table 4-2 summarises the BTS types and main parameters used in the WIK-MNCM.

Table 4-2: Characteristics of different types of base stations

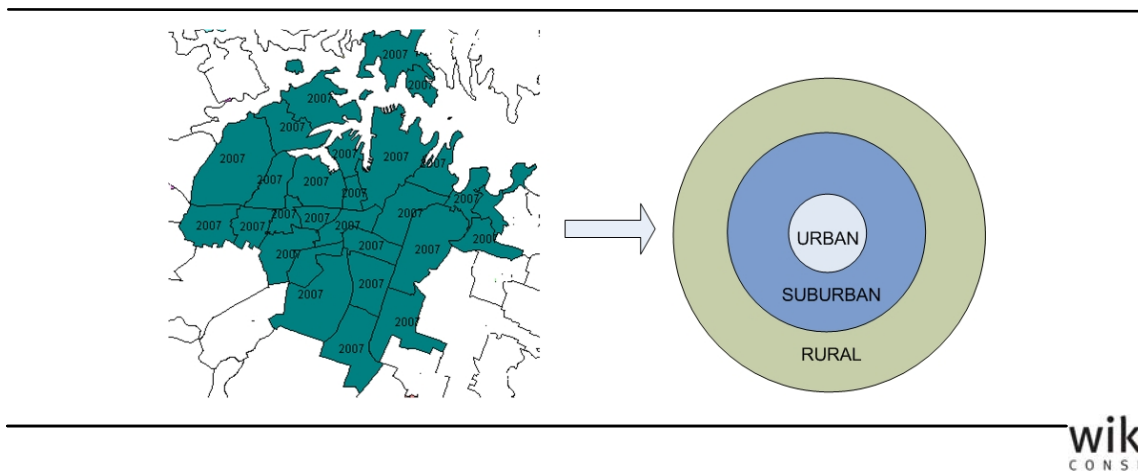
Type	Used for			Sectors	TRX	TRX Power
	U	S	R			
Macrocell	N/A			1-2	1-2	10
Microcell	N/A			3	1-3	1
Picocell		N/A	N/A	3	1-3	0.25

4.2.2.3 Determination of the number of sites and the number of BTSs

For each district obtained from the data aggregation process the cell deployment module calculates an equivalent district of the same size and with the same characteristics as the original one. An example is provided by Figure 4-2.

⁷¹ See Rabanos (1999) and Boucher (2000).

Figure 4-2: Artificial equivalent district conversion



The model considers that the population density and terrain characteristics remain the same within considered zones (urban, suburban or rural). Therefore all sites inside a particular zone will have the same characteristics, will cover the same area and serve the same number of users. Therefore, the number of sites can be calculated by dividing the area of the zone by the area covered by a site. Note that this value is calculated using the cell radius of the BTS in the 900 MHz band. As a result, the number of 900 MHz BTSs in the zone is equal to the number of sites. In cases where due to the traffic load the 1,800 MHz band is also required, the WIK-MNCM installs 1,800 MHz BTSs in all 900 MHz BTS locations. The number of 1,800 MHz BTSs is then the same as the number of 900 MHz BTSs.

For each district the WIK-MNCM estimates the number of sites and the numbers of the 900 MHz and 1,800 MHz BTSs. The resulting configuration produces the smallest number of sites for each district. However, due to the differences in topography and demography, this configuration will vary from district to district. For each district the optimal BTS configuration is selected so that cell deployment at the national level is optimised.

As pointed out the input for the cell deployment calculations considers the complete set of technical parameters (related to the BTS equipment, the mobile station parameters as well as to general radio propagation conditions), the service portfolio and the set of districts for which the network is being designed.

The output of the model is the number of sites as well as the number of BTSs with the corresponding equipment and traffic values per BTS type and per district. Note that the number of sites and BTSs in the WIK-MNCM can be different and de facto is different. Because of the dual band overlay structure of BTSs, BTS equipment, operating in the 900 MHz band and in the 1,800 MHz band is collocated at one site. With these values,

the SNPT can design the aggregation and core networks and can provide the information for the corresponding investment calculations.

4.2.3 Aggregation network

The main output of the cell (and BTS) deployment is the number of the sites and BTSs for all districts. Once this is known and the number of TRX frames are determined, the TRX frames must be multiplexed and transported to the BSCs to which the relevant BTSs are assigned.

In optimised mobile GSM networks a BTS is not directly connected to its BSC, rather the capacity requirements of all the BTSs installed in a district are aggregated at one BTS location in the district. This aggregation point or BTS hub is situated at a central (BTS) location in a district. The connection of the individual BTSs to this BTS hub, for cost effectiveness reasons,⁷² is realised by mini-link microwave systems that can transport up to several digital signal groups of E1.⁷³ A mini-link, originally developed to bridge only short distances, can bridge today a distance of up to 70 Km, and hence it can be assumed that each of the BTSs in a relevant district is connected to the BTS hub by an internal radio link using a mini-link microwave system. Further, it can also be assumed that one or a small number of E1 groups provide sufficient bandwidth for the capacity required by the BTSs.

The bandwidth resulting from the BTS aggregation in the BTS hub must be transported to the corresponding BSC location. Operators can decide to use either leased line Digital Signal Groups (DSGs) or to install their own long distance microwave systems in the form of Point to Point Radio Links (PTPRAL)⁷⁴ to do this. For longer link distances or in case of reduced leased line costs for DSGs due to competition, the application of leased lines for transmission must be considered.⁷⁵ Figure 4-3 shows a typical aggregation network topology composed of internal radio link connections and external radio or leased line links connecting the BTSs to its corresponding BSC forming the Base Station Controller Tree (BSCTREE).

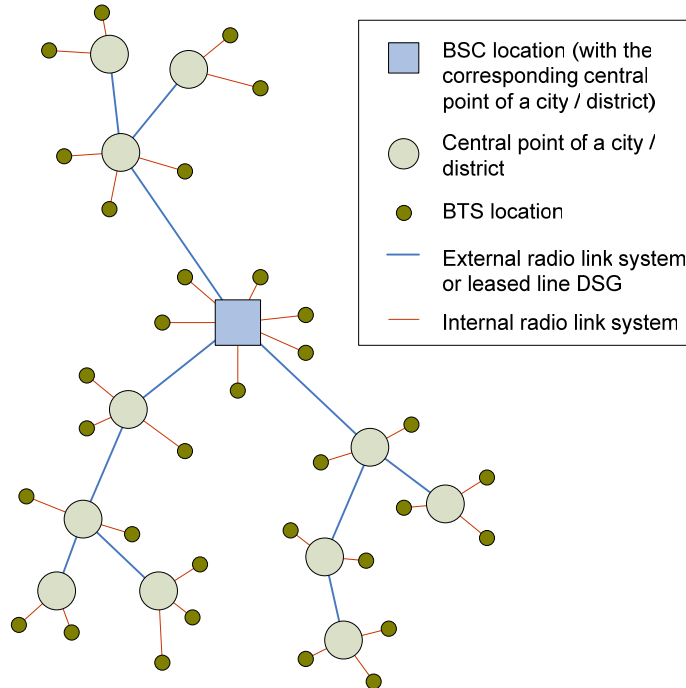
⁷² See Press Information February 2004 from L.M. Ericsson: Ericsson microwave transmission portfolio MINI-LINK offers more flexibility, efficiency and availability.

⁷³ E.g. see Boucher (2000), pp. 195-197 and for corresponding equipments the Data sheet MINI-LINK™ TN ANSI, from L.M. Ericsson, EN/LZT 110 5159 R3-2005.

⁷⁴ PTPRAL can bridge distances of up to 70 Km.

⁷⁵ For a cost comparison between leased line cost for DSG and microwave systems see Mobile Network Transmission Nokia's vision of evolution of the transmission capacities, medias and technologies in mobile networks GSM, EDGE, W-CDMA, Nokia code: 0582_EN_0400_1.0-2000. The main conclusion from this paper leads to the statement that the implementation of a microwave system is cheaper than DSG under leased line. We observed that at least this is valid for link lengths which lie inside of the distance bridged by the corresponding microwave system but might be doubtful for links of longer distance which requires the installation of a chain of microwave systems to bridge the total length. Additionally, we have to consider that the leased line tariffs for DSG decreased in the last years.

Figure 4-3: Example for the topology of an aggregation network connecting the BTS to its corresponding BSC



The SNPT considers all of these aspects and provides a network configuration for the aggregation network using the following steps:

- i. Selection of the BSC location and assignation of each BTS hub to a BSC,
- ii. Calculation of the BSCTREE, and
- iii. Routing the demand from each BTS hub to the BSC and determining the required bandwidth on each link of the BSCTREE in form of DSG in the level of E1.⁷⁶

For the selection of the BSC location the module uses an algorithm which selects the location at which most traffic is aggregated and with the additional restriction that the distances between each pair of BSCs is larger than a predetermined threshold (which is an input in the WIK-MNCM). The first condition ensures that the lowest bandwidth requirement in the BSCTREE is determined while the second condition allows the

⁷⁶ The DSG E1 is the smallest unit considered in telecommunication transmission networks. It provides a capacity for up to 15 TRX frames.

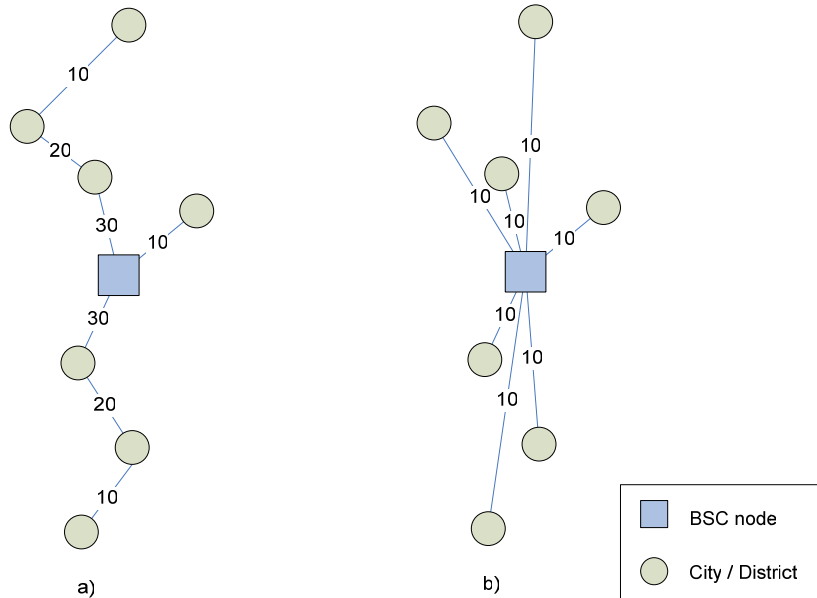
SNPT to derive a distribution of the BSC locations over the total area of coverage that minimises the length of the BSCTREE. The module assigns BTS hubs to a particular BSC on the basis of a shortest distance criterion but with the additional condition that the number of BTSs assigned to a BSC location is limited by a parameter which is an input to the WIK-MNCM. With this parameter it is possible to consider trade-offs between a better traffic distribution over BSCs on the one hand and traffic routed over shorter distances of the corresponding BSCTREES on the other hand.

The WIK-MNCM approximates the BSCTREE depending on the cost relationship between PTPRALs and the use of DSGs in form of leased lines. The SNPT considers that a large number of PTPRALs implies that the BSCTREE is formed by short links which leads optimally to the construction of a Minimal Spanning Tree (MST).⁷⁷ The trade off resulting from the MST is that the traffic from the BTS hub location must be routed over a chain of links and hence the bandwidth to be provided by the links increases. In contrast in the leased line case each BTS hub location is connected directly with the BSC location forming a star topology and hence the bandwidth is minimised. Figure 4-4 shows an example where the MST requires a total bandwidth over all links of 130 TRXs while the star topology requires only 70 TRXs. It also holds that the MST topology has in general a lower network resilience than the star topology, for example a failure of a link for 30 TRXs in the MTS topology implies a greater service degeneration than a similar failure in one of the star links (see Figure 4-4). Therefore, the SNPT bases the determination of the BSCTREE on a modified MST⁷⁸ in which a topology is selected with reference to cost and network resilient characteristics that approaches an optimal combination of leased DSGs and PTPRAL systems.

⁷⁷ This MST is a tree which connects a BSC location with its corresponding BTS hub locations minimising the length of the tree.

⁷⁸ The modified MST calculates a BSCTREE where the length of an added link is artificial incremented considering the total number of links in the path from the BTS hub to the BSC.

Figure 4-4: Example of a BSCTREE under a MST and a Star topology assuming a requirement of 10 TRXs from each BTS hub⁷⁹



For this purpose the corresponding algorithm considers a tree configuration parameter the value of which influences the topology of the BSCTREE. A zero value for this parameter implies that the topology is the original MST. With higher parameter values more direct links from BTS hubs to the BSC locations are introduced. For sufficiently high values of the parameter (in the example of an operator with 25 per cent market share the value of the parameter is 100) the topology of the tree converges to the star topology.

Once the BSCTREEs are determined the path over which the TRX demand is routed over the corresponding links to the BSC location is completely determined and the SNPT provides this routing and determines the TRX flow on each link.

With this calculation the design and dimensioning of the aggregation network is completed. It provides two values: the length and bandwidth requirements for each BSCTREE link. These values are the basis on which the Cost Module selects the transmission system that minimises the cost taking into consideration resilience aspects used in configuring the aggregation network.

⁷⁹ The values on the links express the required bandwidth in number of TRXs.

4.2.4 Backhaul network

In the design and dimensioning for the backhaul network an operator makes decisions regarding the topology which connects the BSCs with the corresponding MSC. Similar to the procedure for the aggregation network, decisions must be made about the number of locations where MSC equipment is installed and the selection of these locations. The number of MSC locations depends on the capacity of an MSC and on aspects of network resilience. The SNPT takes these values as input parameters. The basis on which MSC locations are determined is essentially the same as that used for BSC locations. It always co-locates an MSC with BSC equipment.

As in the case of BTS hub and BSC links, to connect BSC and MSC locations an operator has to select between installing its own PTPRAL system or using leased line DSGs. One of the considerations is that backhaul links aggregate a large volume of traffic and cover large distances so that a failure in a link would affect a large number of users. This means that a PTPRAL system installed by the operator, for network resilience purposes, may not need to rely on a star structure but has at least to install a ring or even a meshed topology which would probably exceed the bandwidth capacity of a PTPRAL system. Furthermore, due to the large distances in Australia the links between the BSC-MSC locations would often require chains of microwave systems. For this reason the WIK-MNCM considers the best solution for the backhaul network is connecting BSC locations with their corresponding MSC locations by a star topology implemented only by leased DSGs. These leased DSG connections are assumed to provide sufficient network resilience as will be discussed in section 4.2.6.

In conclusion, the backhaul module of the SNPT provides information used in the Cost Module about the lengths and the required bandwidth as well as the number of E1 DSGs for each BSC-MSC link.

4.2.5 Core network

The core network consists of the MSCs, the network topology connecting these MSCs, the various registers required mainly for mobility management (HLR etc.), the interconnection interfaces to other networks, the interfaces to the service platforms, and, in respect of one such service platform and the SMS centre. The SNPT provides the design and dimensioning of the core network links connecting the MSC locations known from the design of the backhaul network, the traffic routing and the corresponding number of E1 DSGs that are required to transport this traffic.

The equipment comprising an MSC is an upgraded circuit switch machine like the ones used in the PSTN/ISDN. This equipment provides high capacity for connecting E1 DSGs which allows aggregation of a large number of users and their traffic. From this follows that only a small number of MSC locations are required which are usually

located in large cities. In an Australian context MSCs should be located in the five main cities, i.e. Sydney, Melbourne, Brisbane, Adelaide and Perth. The number of MSCs can be adjusted in the WIK-MNCM if required. In line with current best practice, the SNPT provides that facilities supporting interconnection with other networks as well as the Visitor Location Registers (VLRs) are located at each MSC, while the HLR and service centres like the SMS server are installed only at the MSC location with highest traffic values.

The next step is the construction of a traffic matrix. The traffic matrix distributes the traffic aggregated in a particular MSC to: the users connected to the other MSCs (for On-Net and Off-Net incoming traffic); the MSCs where the interfaces to other networks are situated (for Off-Net traffic this will always be the originating MSC); or the MSC where a required server is installed (e.g. for SMSs). The WIK-MNCM calculates this matrix using the traffic weights given to the different MSC locations.

Because of the time zone differences between regions in Australia, the busy hour in Eastern Australia is earlier than the busy hour in Western Australia, which means that there is less demand for busy hour capacity in the core network than if the busy hour occurred simultaneously everywhere. The SNPT accounts for this through a parameter whereby total traffic in the core network is correspondingly reduced.

To arrange for physical transport the SNPT installs, as in the case of the backhaul network, a topology composed of leased line DSGs. For reasons of network resilience the SNPT provides for a fully meshed topology where each MSC is connected to other MSCs by direct leased line links, mainly at the level of STM-1.

4.2.6 Routing factors

In bottom-up cost models it is the network configuration that generates the entire set of routing factors required for the individual cost calculation for each service. In the GSM network, each service (a voice call, an SMS message) uses all network elements from the BTS to the corresponding MSC at least once. This is because there is a unique path from the bottom to the top of the GSM network architecture. It is important to realise that these 'neat' utilisation factors are not introduced as exogenous factors but are the result of the logic of the model configuration; they could not be introduced as exogenous factors if one wanted to. Note that for an On-Net call the utilisation addressed here is the one of either the up-link or the down-link; for an On-Net call the network elements would be used twice (up-link and down-link). The utilisation of the MSCs is generally more than once for an average call because a call initiated by a network subscriber will in general not stay within the district of the originating MSC, in addition it is likely that any incoming call will not enter the network at the MSC which serves the receiving party. The WIK-MNCM determines a corresponding traffic distribution in the form of a traffic matrix among the MSC locations and provides the routing as part of the core

network configuration. This will result in utilisation (routing) factors for On-Net and incoming calls, for MSCs of greater than one, and for MSC-MSC links of greater than zero. For an Off-Net outgoing call, in which case there are interconnection facilities at each MSC, the utilisation factors for MSCs are one and those for the core links (MSC-MSC) are zero.

4.2.7 Resilience aspects considered in the network configuration

When designing and dimensioning the network, the SNPT not only considers aspects of cost optimisation but also constraints in terms of network resilience requirements. Network resilience refers to limiting the negative effects of traffic increments which are much larger than estimated, short term overloads, and failures in equipment or even in whole parts of the network. The risks associated with large traffic increments and overloads can be mitigated with additional capacity. Protection against failures of equipment or more broadly parts of the network can be somewhat guaranteed by investment in quality equipment and network operation. The first is achieved through the provision of stand-by capacities and by distributing traffic over different systems,⁸⁰ and the second by regular inspection and maintenance programmes. Such measures for achieving network resilience necessarily have an impact on the level of investment and the costs of operation.

The WIK-MNCM provides for the required reserves by implementing limits on the rate of utilisation of the capacity for the equipment and transmission links which in general are below the actual capacity levels. For example, the SNPT provides that a maximum of 28 E1 groups are used from an available 30 DS0 circuits. Resilience in the electronic equipment is achieved through a set of capacity limitation parameters, for example the maximum number of BTSs which can be assigned to a BSC location. In the SNPT these values are in general input parameters.

The number of BSC and MSC locations and the corresponding spacing of these facilities also reflect a combination of network optimisation and network resilience. This is achieved through the implementation of minimal distances between locations which ensures a geographical distribution that is more in line with resilience requirements than if the locations were only selected on the basis of traffic concentration. This involves higher costs than would otherwise be the case because of a larger number of backhaul and core links but is reflective of the trade-off between cost minimisation and network stability.

As regards to the protection against network failures, WIK-Consult considers that current telecommunications network equipment is already engineered in a way that in

⁸⁰ A typical example is the well-known self-healing ring used under SDH transmission technology, see the Alcatel Telecom Review of 1998.

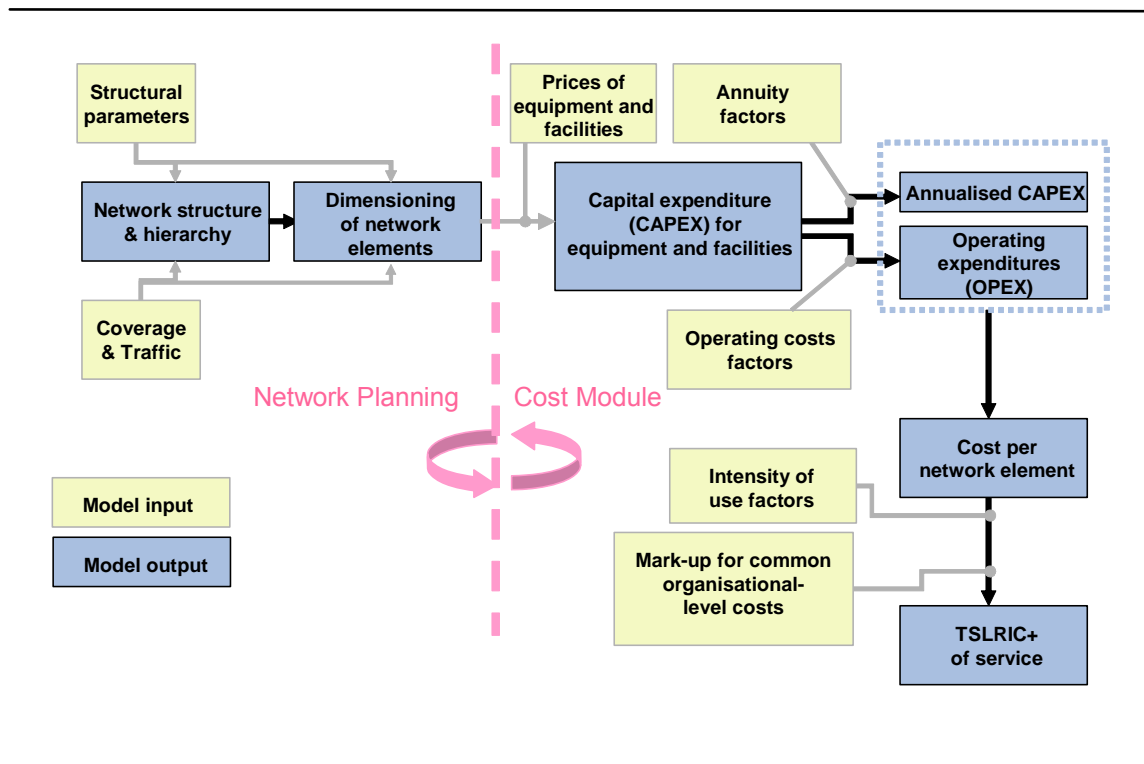
combination with network maintenance and testing the network availability can be considered to be very reliable. Concerning the availability of the transmission paths, network operators apply a combination of multi-path routing and stand by capacities. This requires in general a fully meshed transmission network or at least ring topologies excluding tree based topologies. As discussed in the sections on the backhaul and core networks, such topologies are implemented in the modelled network by the SNPT.

4.3 The Cost Module

Once the network structure and the network elements have been determined, the costs of providing services using the network can be determined. The quantities of network elements determined by the SNPT constitute for the MNO the investment in, or initial outlays for, the stock of equipment and facilities that make up its network. For the purpose of determining the cost per minute of the MTAS, these investments need to be translated into annual costs for each network element, then a cost per minute of service provided by each network element, and then per minute of the MTAS. The starting point for the cost determination will generally be the investment figure for a network element. Costs will consist of annualised CAPEX (depreciation and return on capital) plus the expenditure on operation and maintenance, commonly referred to as OPEX. Both annualised CAPEX and OPEX are calculated as a function of the investment value of the network element (or other asset). The method for deriving annualised CAPEX is discussed in section 3.4, and as previously outlined in section 2.2.3 OPEX is calculated as a percentage of the initial investment value of the equipment or facility. Finally, common organisational-level costs are added as an equi-proportionate mark-up on the annual network costs (annualised CAPEX and OPEX).

The process of deriving the cost estimate in the Cost Module is described in detail in the following sections. The SNPT estimates the quantities of each network element as the main set of inputs for the Cost Module. Additional inputs, such as equipment prices, operating cost factors, usage factors etc. are also relevant input parameters in the Cost Module.

Figure 4-5: Schematic view of modelling process



As outlined, the productive network assets are the BTSs, BSCs, MSCs, links etc. The investment calculation for these productive network assets is described in section 4.3.1.1. Other assets that are used for network support such as motor vehicles, office equipment etc. are network support assets which are also relevant to providing network services. In the WIK-MNCM the investment values for network support assets are determined as a mark-up on the investment values for the productive network assets rather than explicitly modelled. This approach represents common practice in modelling network support assets. The calculation of network support assets is described in section 4.3.1.2.

Annual operating expenditures or OPEX are treated in a similar way as network support assets, because OPEX is also derived on the basis of mark-ups. OPEX is considered for each group of network elements, including productive network assets and network support assets. Details about the way in which OPEX is modelled is described in section 4.3.2.

4.3.1 Investment calculation

4.3.1.1 Investment for productive network assets

Equipment prices for network elements reflect current replacement values. Investment volumes are derived on the basis of the corresponding quantities for each category of productive network assets (BTSs, BSCs, MSCs, links etc.).

4.3.1.1.1 BTS investment

The total investment value of a BTS comprises the investment value related to the

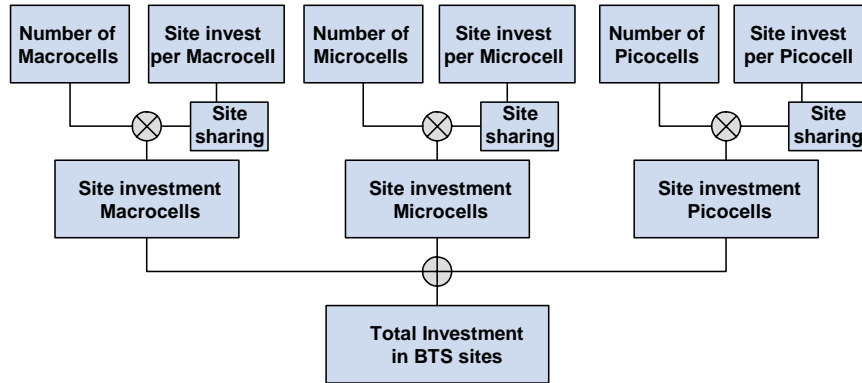
- BTS sites,
- BTS system equipment, and
- TRXs.

The BTS site investment value includes site acquisition, planning, construction as well as land and building costs. The WIK-MNCM assumes that sites or buildings are not leased. Different prices for BTS Macrocells, Microcells or Picocells are used in the WIK-MNCM as observed empirically.

In practice, BTS sites are often shared between several operators which has an impact on the relevant costs of the MTAS. This is particularly prevalent with respect of the shared 3G networks in Australia, but also common for 2G infrastructure. The WIK-MNCM can take account of the 'site sharing' impacts on the investment value of a BTS site. The relevant reduction in investment is quantified by a site sharing parameter.

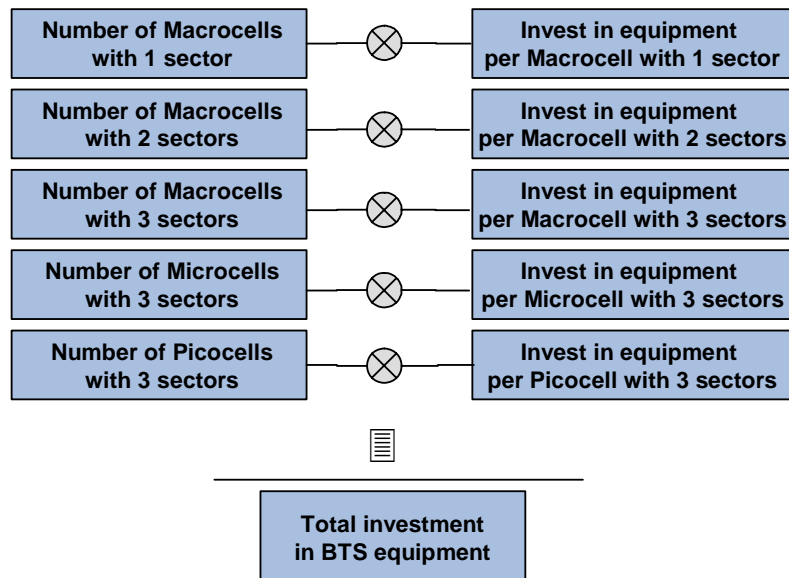
In the WIK-MNCM, 50 per cent of Macrocells and 30 per cent of Microcells are assumed to be shared. Picocells are typically not shared. If the reduction in the investment value for Macrocells and Microcells is assumed to be 40 per cent, this yields a net reduction in the investment value of 20 per cent and 12 per cent, respectively, for every BTS.

Figure 4-6: BTS site investment



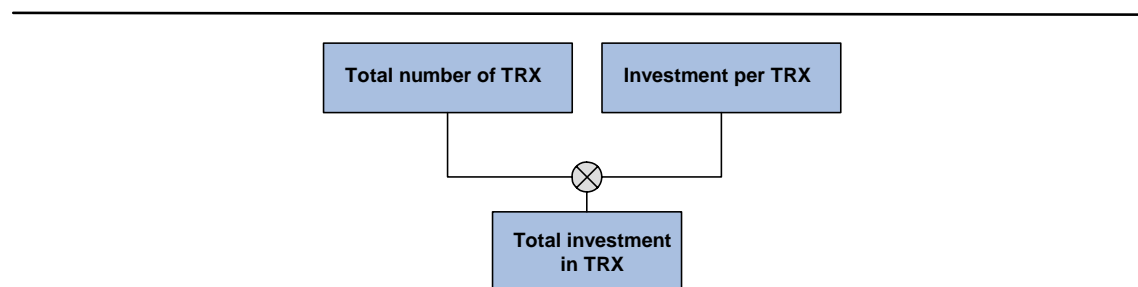
BTS system equipment covers network assets such as antennas, amplifiers, combiners, power supply etc. Investment for BTS system equipment differs with respect to the type of BTS (Macrocell, Microcell, Picocell) and the number of sectors each BTS is serving.

Figure 4-7: BTS system equipment



The last set of equipment comprising a BTS is the TRX. The total value of the investment of TRXs is driven by the number of TRXs in the network and the unit investment price for this network element. Since the equipment prices of TRXs are not a function of the BTS type, unit prices are assumed to be equal for each type of BTS.

Figure 4-8: Total investment in TRX



4.3.1.1.2 Links between BTSs and BSC

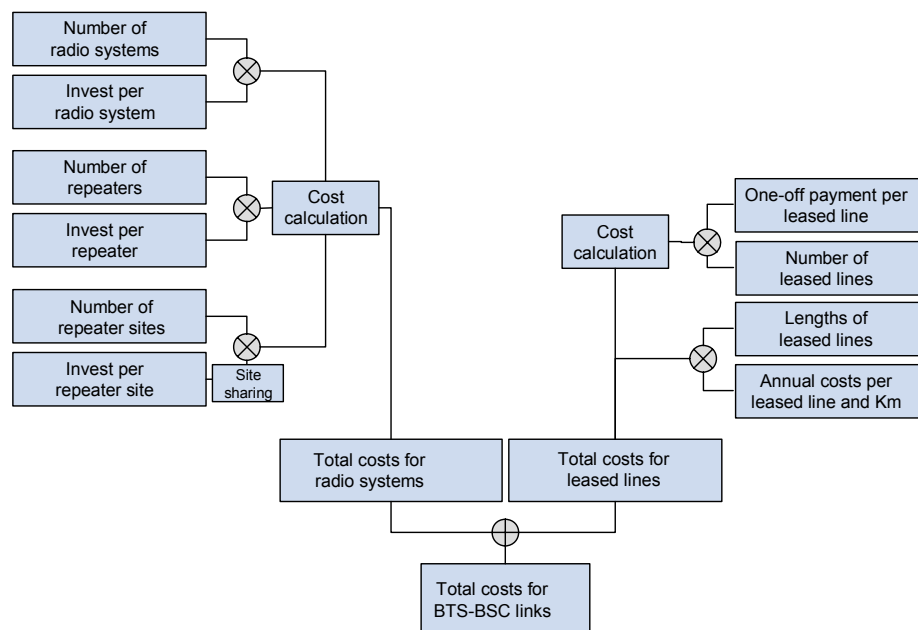
As described in the SNPT above, each BTS is connected to a BSC either directly or via a BTS hub in each district, by either a radio system or a leased line link. The links between BTS and BSC are regarded as network elements. Therefore, the cost modelling approach in this section is also applied in the case that the link is realised by means of a leased line despite the fact that it is of a different nature. In this case the link does not comprise an investment in physical network infrastructure of the MNO. The leased line costs are directly expressed as an annual cost. There is one exception to this rule: the pricing structure of leased lines comprises two basic elements - an upfront one-off payment for the provision of the leased line and an annual price component depending on the length of the leased lines. For the cost calculation, the upfront component is technically treated as an investment.

The segment between a BTS and a BTS hub is always implemented as a 2 Mbps radio system which does not require repeaters due to its short distance. For the links between the BTS hub and the BSC the SNPT generates the number of repeaters required for larger distances of a link. The SNPT also factors in the use of leased lines for network segments between the BTS hub and the BSC. Prices for leased lines are differentiated by length: the WIK-MNCM covers three classes of leased lines, 0 Km to 10 Km, 10 Km to 150 Km and greater than 150 Km. This segment of the link (BTS hub – BSC) may, however, be alternatively delivered using radio system links (2, 8, 34 or 155 Mbps). For both radio system links in the BTS – BTS hub segment and the BTS hub – BSC

segment the Cost Module considers the relevant equipment prices as well as frequency fees which are to be applied for point-to-point links in Australia.⁸¹

Hence, the BTS hubs may be connected to the BSC either via radio systems, leased lines or a combination of both. The efficient cost solution is calculated by the WIK-MNCM endogenously on the basis of relative input prices for both technologies.⁸² Repeaters are also costed into the WIK-MNCM in circumstances where radio based links exceed a certain distance. The investment in repeaters comprises investment in sites (which as mentioned are likely to be shared with other operators) and investment in equipment which will have different investment values depending on the radio system links used (2, 8, 34, 140 Mbps). It is assumed that 30 per cent of all repeater sites are shared and 40 per cent of the investment in the site can be saved by sharing. These assumptions lead on average to a reduction of investment per repeater site of 12 per cent.

Figure 4-9: BTS-BSC links



81 The numbers on fees for the radio links are taken from the ACMA apparatus licence fee schedule 2006.

82 For deriving the costs of leased lines the model refers to i) an upfront payment to be paid for the provision of the leased line and ii) an annual fee. Because the latter is a cost figure rather than an investment figure leased lines are only part of the investment calculation, as far as the upfront payment is concerned.

4.3.1.1.3 BSC investment

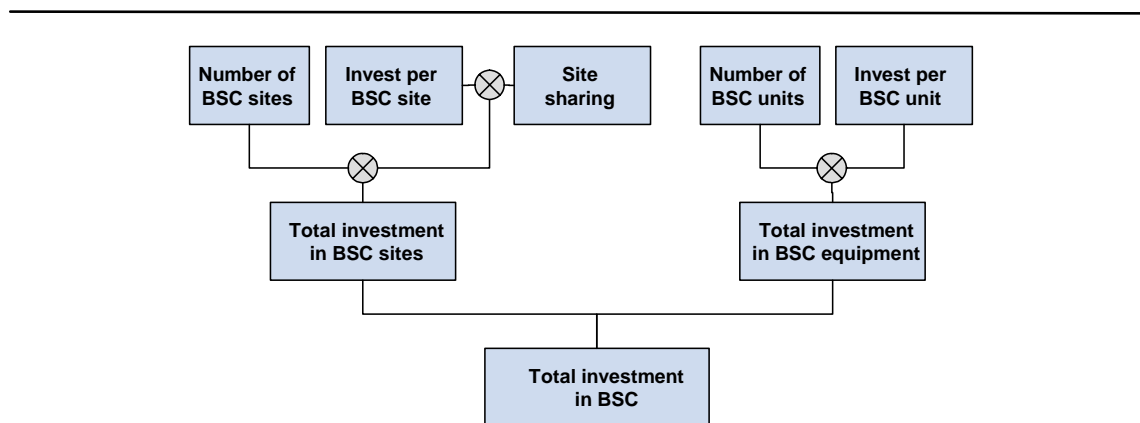
The investment in BSCs comprises:

- BSC sites, and
- BSC system equipment.

Each of these BSC investment elements has a different economic life. The number of BSC sites and the amount of BSC equipment deployed in the network is derived from the SNPT and is used as the basis for the investment calculation.

According to the possibility that some BSC sites are shared with other network equipment, the reduction in site related investment can be quantified as an input parameter.

Figure 4-10: BSC investment

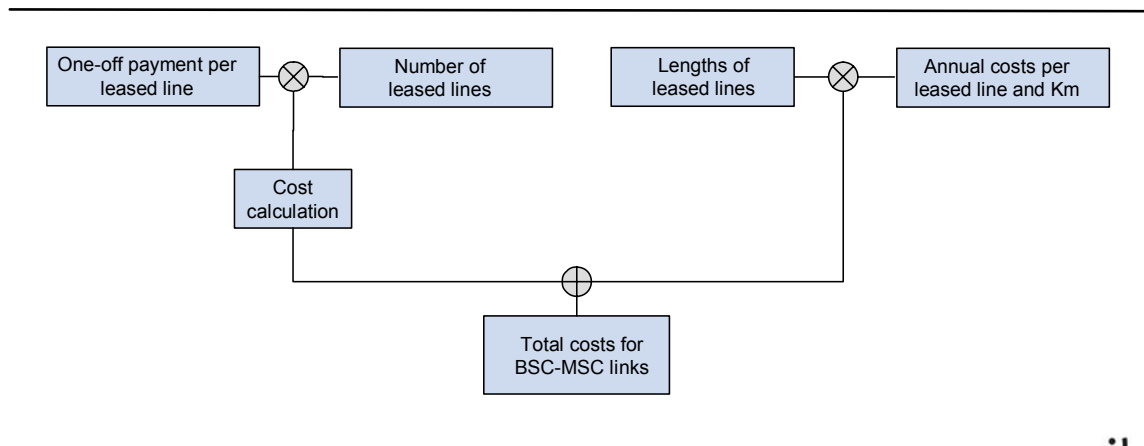


4.3.1.1.4 Links between the BSC and the MSC

Transmission between the BSCs and their corresponding MSC is realised via 155 Mbps leased lines due to the fact that these links concentrate volumes of traffic requiring several E1 groups.⁸³ The end points and lengths of all leased lines are an output of the SNPT. As outlined, leased line prices vary according to length.

⁸³ For considering a cost component instead of an investment component in this section we refer to the introductory remarks of section 4.3.1.1.2.

Figure 4-11: BSC-MSC links



4.3.1.1.5 MSC investment

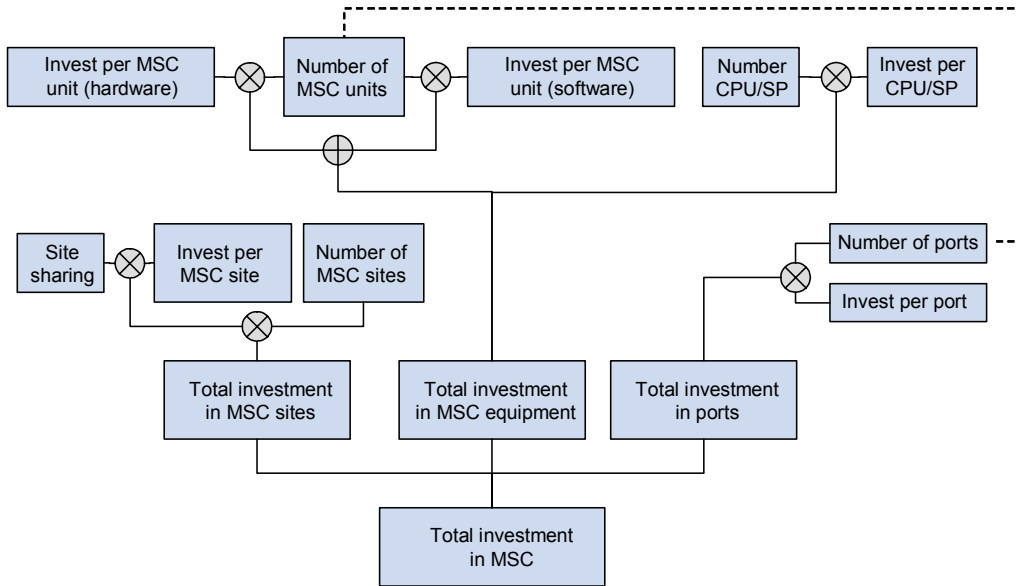
This section considers the investment for the MSC. MSC investment comprises:

- MSC sites,
- MSC equipment,
- Transcoder and Rate Adaptation Unit (TRAU) – which is assumed to be located at the MSC, and
- 2 Mbps ports.

Besides the site related investment, MSC investment is mainly driven by the amount of traffic and thereby by the number of ports handled by the MSC. As a result, the investment in the MSC is determined by the number of ports, a pre-defined utilisation ratio, and a pre-defined capacity limit. In general, several MSC units may be operated at a single MSC site.

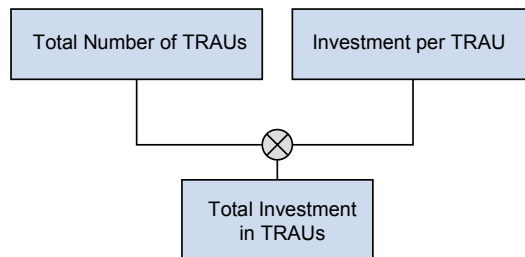
Processor equipment also comprises part of the MSC investment value. The investment in the central processor and signalling processor equipment is driven by the number of busy hour call attempts, a pre-defined capacity limit and a utilisation ratio.

Figure 4-12: MSC investment



The investment in TRAU is calculated on the basis of the number of TRAU which are deployed in the network and their unit price. TRAU functionality is required at each MSC.

Figure 4-13: TRAU investment



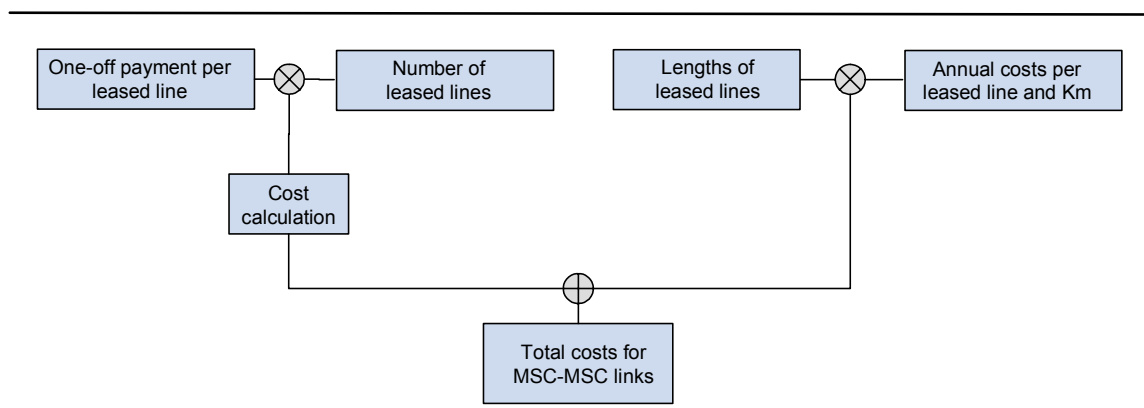
4.3.1.1.6 Links between MSCs

The capacity of leased lines for links between MSCs is assumed to be 155 Mbps. As for the other leased lines in the lower network segments, prices for leased lines in the core

network typically vary depending on their length.⁸⁴ Transmission links between MSCs are typically implemented on high capacity backbone routes of the fixed network. Their unit prices (per Km) are significantly lower than those of other links in the network.

The price structure for these types of leased lines are assumed to be categorised into i) prices which are given on a per Km basis and ii) annualised upfront payments to be paid for the provision of a leased line. Note that leased line prices per Km are classified as (recurring) annual amounts or costs.

Figure 4-14: MSC-MSC links



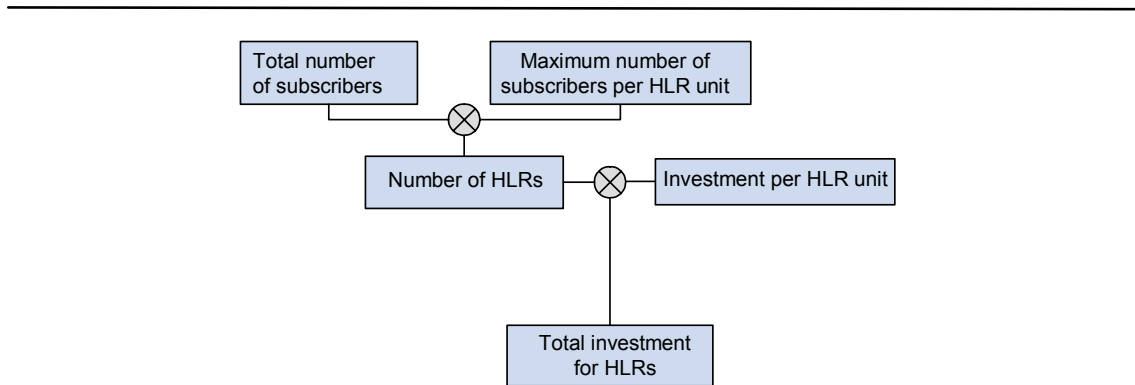
4.3.1.1.7 HLR investment

Information about the subscribers to a mobile network is stored on the HLR. The HLR provides information on the subscribers' mobile numbers as well as their activated services.

The value of investment for the HLR components is basically driven by the number of subscribers. As a result, the required number of HLR components is a function of the total number of subscribers in the network, a pre-defined capacity limit (in terms of subscribers) and a pre-defined utilisation ratio.

⁸⁴ For considering a cost component instead of an investment component in this section we refer to the introductory remarks of section 4.3.1.1.2.

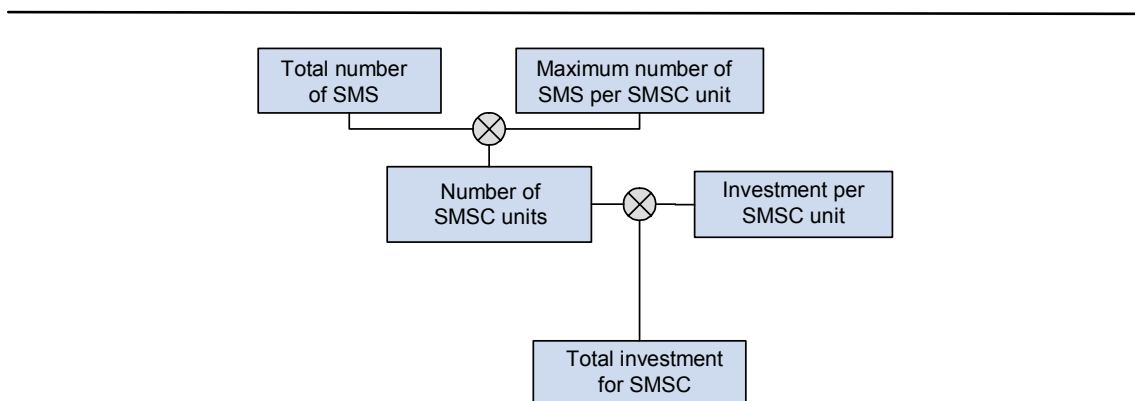
Figure 4-15: HLR investment



4.3.1.1.8 SMSC investment

SMS demand is routed over the SMSC. The SMSC investment is a function of the required number of SMSCs for a network, which reflects the SMS demand, a pre-defined capacity limit and a pre-defined utilisation ratio.

Figure 4-16: SMSC investment



4.3.1.2 Investment for network support assets

Investment in productive network assets is complemented by network support assets. Network support assets comprise:

- Motor vehicles,
- Workshop tools and small items equipment,
- Office equipment,
- Network related IT and computers,
- Network management systems, and
- Buildings for network support equipment.

Network support asset investment is modelled as a percentage of productive network asset investment in the particular (group of) network element(s). These percentage mark-ups are fixed as input parameters in the WIK-MNCM.

Figure 4-17: Investment in network support assets allocated to BTS

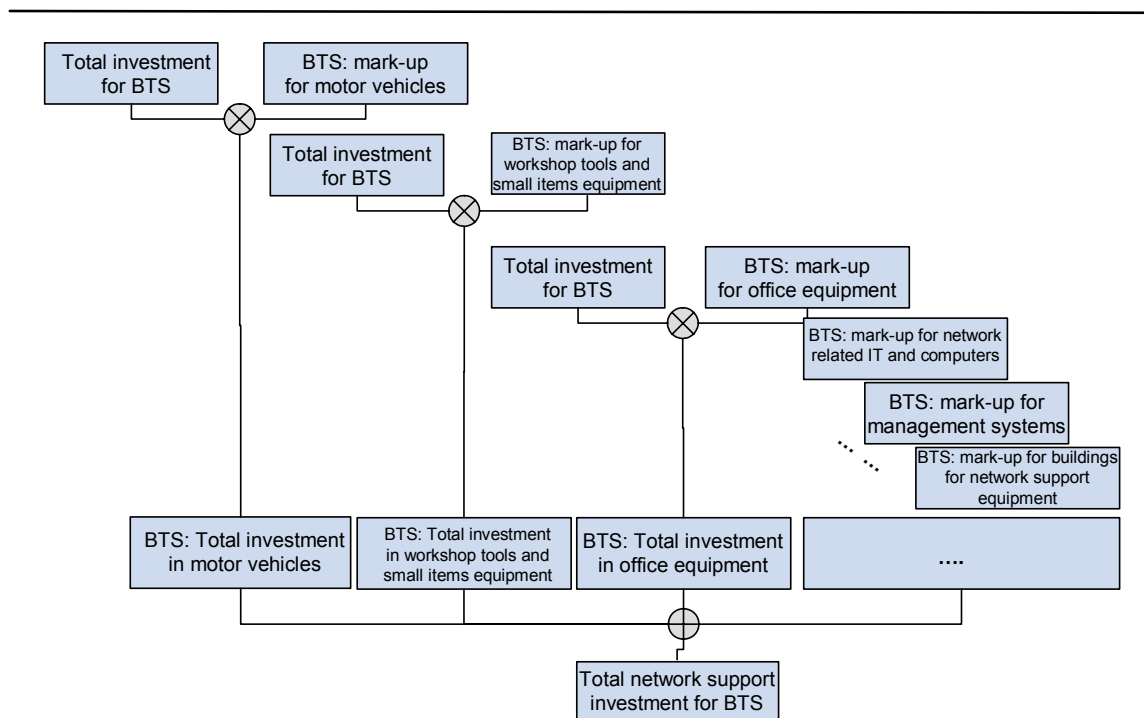
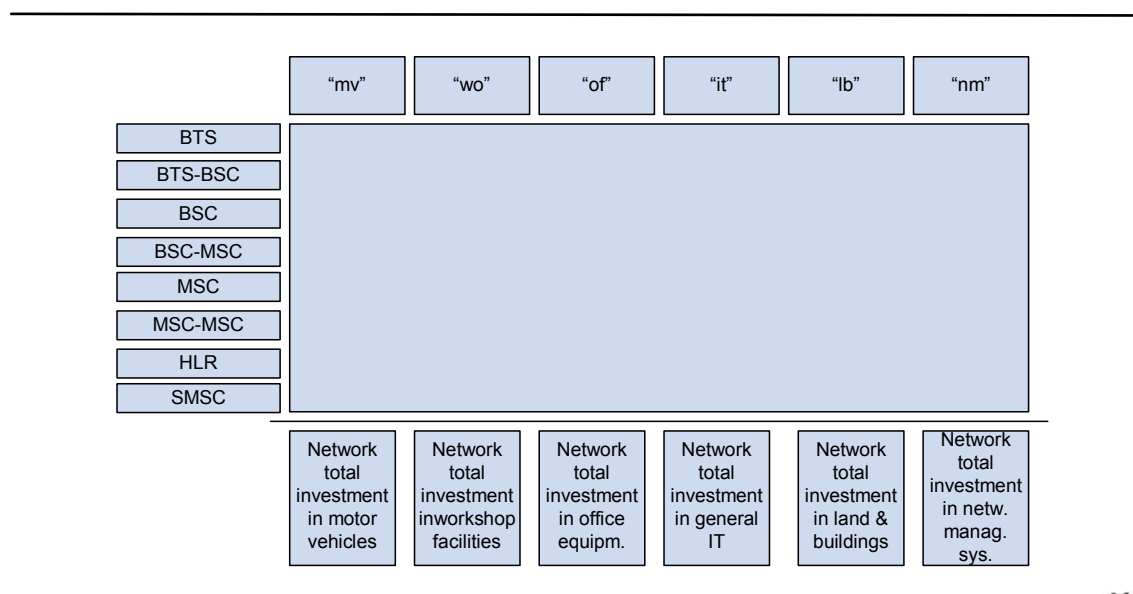


Figure 4-17 illustrates how network support asset investment is determined as a percentage of BTS investment. This procedure is repeated for all productive network elements. The reason for this is that different network elements may make use of network support assets more intensively than others. The WIK-MNCM accordingly

applies different mark-ups for different network support assets for each productive network element. The sum over all network support asset categories gives the total network support assets investment.

Figure 4-18: Total investment in network support assets



The calculation of network support assets investment is the final step in the investment calculation. Once all investment values which are relevant in deriving the MTAS costs have been determined, the next step is to convert these investment values into annualised costs.

4.3.2 Cost calculation

This section deals with the conversion of productive network assets and network support assets investment into annualised CAPEX. Furthermore, this section illustrates the calculation of OPEX as well as the mark-up for common organisational-level costs.

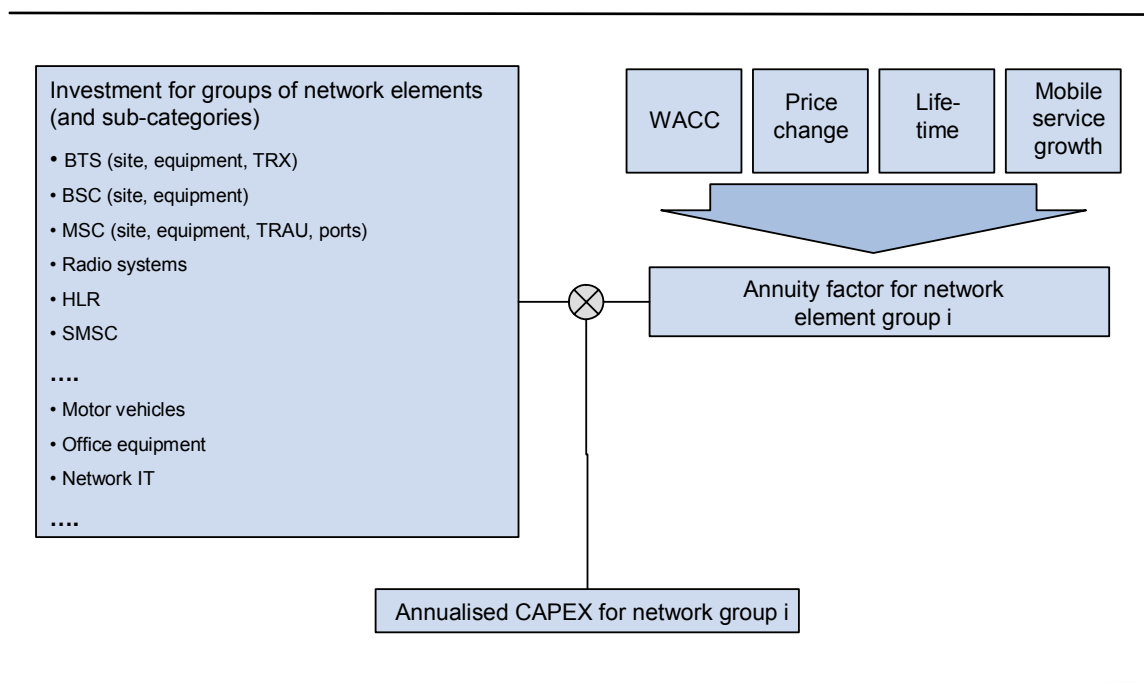
4.3.2.1 Direct and indirect costs

The calculation of the network element costs (for both productive network and network support assets) are based on the investment value of the network assets which has been previously derived. To convert this investment value for each relevant asset into an annual cost, the following factors are also required: the expected annual rate of the price change; the expected growth of mobile services; the economic lifetimes of the

relevant assets; and the cost of capital (WACC) which does not vary according to particular network elements.

The investment value relating to a particular network asset is transformed into annualised CAPEX using the annuity formula as discussed in section 3.4.2. If necessary, investment values of a network element are grouped into subcategories to account for differences in annual rates of price change or economic lifetimes (for example site and equipment).

Figure 4-19: Calculation of annualised CAPEX for productive network and network support assets



As illustrated in Figure 4-19, the annualised CAPEX is calculated for both, productive network assets investment and network support assets investment.

As outlined in section 3.5, the annualised costs of frequency spectrum for GSM 900 and GSM 1,800 are included in the costs for the BTS.

4.3.2.2 OPEX

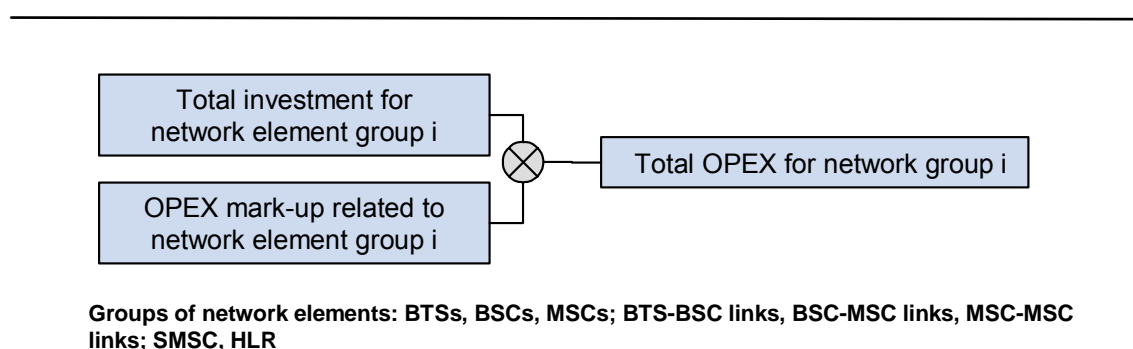
It is common practice in bottom-up modelling to express OPEX as a percentage mark-up on the investment value of all network assets where the value is expressed in

current prices. This is not only current best practice in bottom-up cost modelling but also the approach often used by operators in their own business case planning scenarios.

The OPEX covers the operation and maintenance costs of the whole network and its network elements. Costs which are related to operation and maintenance are typically labour costs, leased facilities and other recurring annual costs.

The mark-ups for OPEX used in the WIK-MNCM are applied to each category of productive network and network support assets. The mark-ups are applied to the investment values for productive network and network support assets to derive the relevant OPEX relating to those assets.

Figure 4-20: Calculation of OPEX as a mark-up on investment

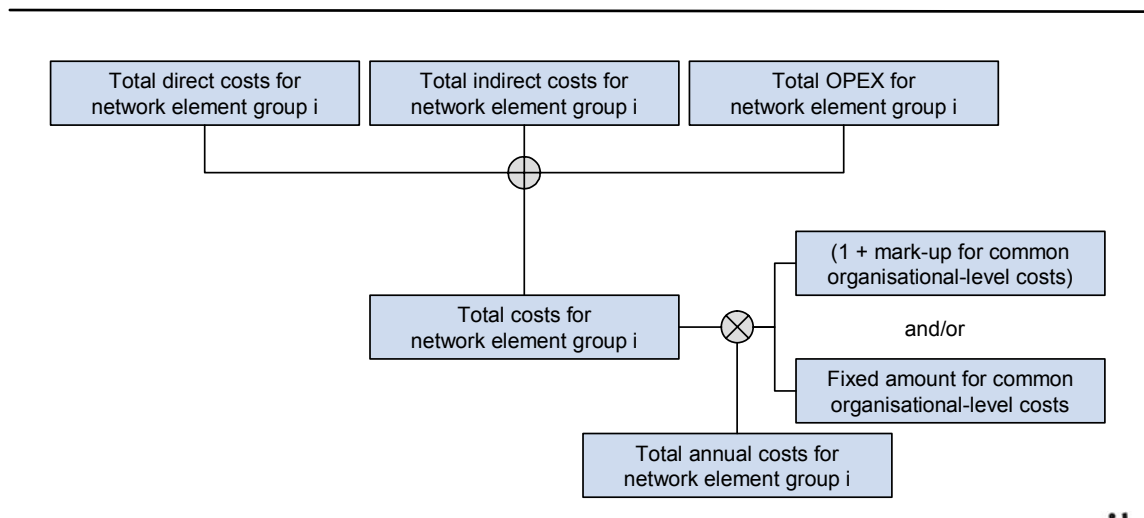


4.3.2.3 Common organisational-level costs

Common organisational-level costs include costs for management, administration, human resources etc.

Common organisational-level costs are calculated as a percentage mark-up on the total network cost (annualised CAPEX and OPEX). Furthermore, a pre-defined fixed amount of common organisational-level costs to capture licence and other regulatory fees (see section 3.9) is added. In the case of the latter, first the percentage relationships between the relevant amounts and the total network costs are established, then these percentages are applied to the network cost to account for common organisation-level costs as in an EPMU approach.

Figure 4-21: Consideration of common organisational-level costs



The aggregation of annualised CAPEX, OPEX and common organisational-level costs represents the total annual costs of delivering the services of the mobile network to customers. Once these are determined, the next step is to derive the cost per minute for each marketed service to be considered.

4.3.2.4 Costs per minute

The WIK-MNCM's overall objective is to derive the average cost per minute for the MTAS. In relation to the above described investment and cost calculations for the underlying mobile network this section considers the derivation of the cost per minute of the MTAS.

4.3.2.4.1 Relevant services

The traffic volume generated by mobile users typically represents a suite of services. The services considered in the WIK-MNCM include: Voice (Origination Off-Net, Termination Off-Net, On-Net), SMS, Basic Data with 9.6 Kbps, Multimedia Message Service (MMS), GPRS and High Speed Circuit Switched Data.

The volume of traffic associated with each of these services is essential for dimensioning each network element used. Some of those network elements and hence the corresponding costs are service-specific, for example GPRS Support Nodes for GPRS traffic. In some of these cases, these network elements may not be used in the production of MTAS. The derivation of the cost per minute for the MTAS should only

include the costs of the network elements producing the MTAS. Other network elements, for example the GPRS-specific or SMS equipment, are not included in the MTAS cost calculation.

The MTAS may use the same network elements as other services. Where this is the case, the cost of MTAS will be determined by the relative traffic volumes of the MTAS to all services using those common network elements.

For most network elements, the services mentioned in Table 4-3 are relevant cost drivers.

Table 4-3: Relevant services

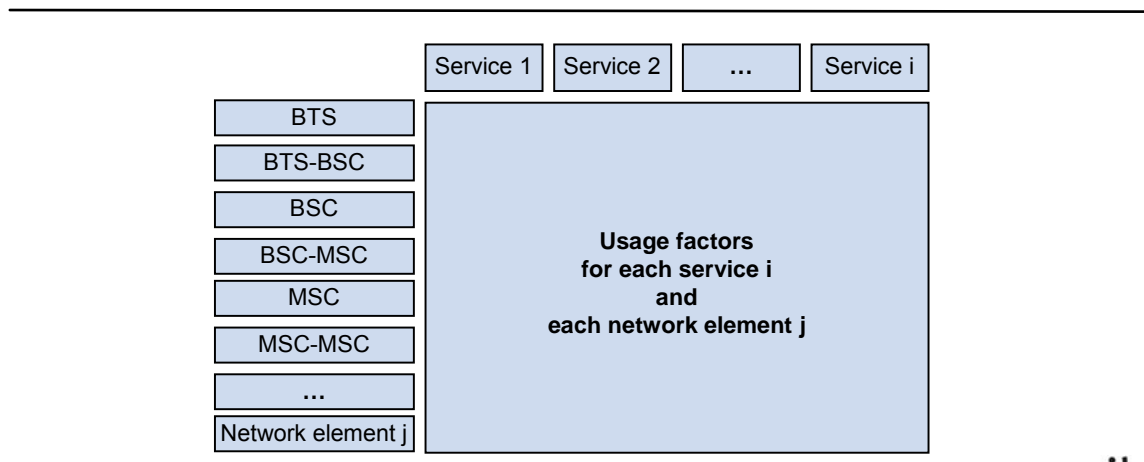
Voice Origination Off-Net
Voice Termination Off-Net
Voice On-Net
SMS
Basic Data Service with 9.6 Kbps
MMS
GPRS
High Speed Circuit Switched Data Service

An example of a common network element is a BTS, which would be used in the provision of all the services outlined above. As a different example, the SMSC is used by SMS traffic only. Hence, the corresponding costs for the SMSC have to be carried by SMS traffic rather than by other services.

4.3.2.4.2 Usage factors

The intensity of use is expressed by usage factors which are endogenously calculated by the WIK-MNCM. Usage factors determine how many units of a network element is used for each minute of a service, or, they determine the amount of each network element's output required to provide each service.

Figure 4-22: Routing matrix: Usage factors for network elements and services



For example, an Off-Net minute which is to be terminated on the network, uses the BTS once. Additionally, it may be the case that the call has to be terminated within another MSC area than the one where the call has entered the network. Hence, on average the terminated Off-Net voice minute will use more than one MSC which will be reflected as a usage factor for the MSC which will be larger than one for that type of service. Similar relationships can be found amongst the other network elements and the other services. The values for each usage factor are calculated endogenously by the WIK-MNCM ('routing matrix'). They are the result of the traffic matrix used by the SNPT for distributing traffic over the network.

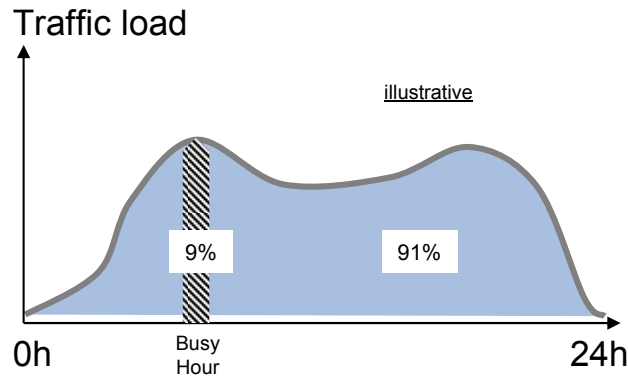
In order to calculate service costs, unit output costs of the network elements are therefore multiplied by the usage factors.

4.3.2.4.3 Annual traffic volumes

For calculating the cost per minute of a service, the unit costs of each relevant network element need to be derived. Costs have been calculated on a network element basis and refer to busy hour traffic volumes. Busy hour traffic volumes need to be transformed into annual traffic volumes for each network element to determine its average (network element) cost per minute.

Since network dimensioning is a function of traffic loads during the busy hour, those volumes have to be transferred into annual traffic volumes. The procedure to derive annual traffic figures is based on the assumption that the busy hour traffic is described as a typical share of the daily traffic. This results from traffic load figures which may be shaped for a telecommunication network as shown in Figure 4-23.

Figure 4-23: Traffic shape and busy hour



The share of busy hour traffic volume in the daily traffic volume is set as an input parameter of the WIK-MNCM. The daily traffic shape illustrated above is usually not valid for all 365 days of a year. Therefore, a further input parameter defines the number of days that are equivalent to typical business days.

The total annual traffic is calculated (for each group of network elements and for each type of service) using the following formula:

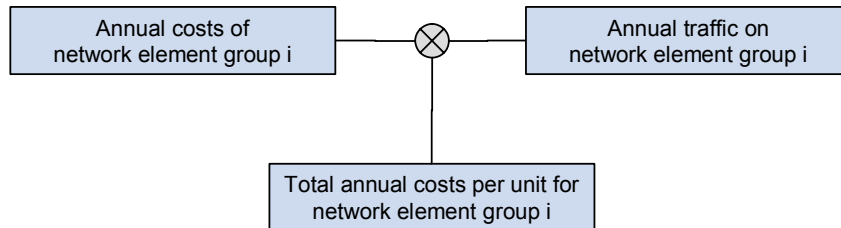
$$\text{Annual Traffic} = \left(\frac{\text{Busy Hour Traffic}}{\text{Percentage Busy Hour Day}} \right) * \text{Number of Days}$$

As long as reasonable empirical data exist, which should be available from an MNO's annual statistics, it is possible to calibrate those input parameters such that the WIK-MNCM's annual traffic volume is close to what is observed and to be expected in reality.

4.3.2.4.4 Unit costs of network elements

The unit costs of network elements are calculated by dividing the total annual costs for each group of network elements by the corresponding total annual traffic volume on that group of network elements (see above).

Figure 4-24: Annual network element costs per unit



4.3.2.4.5 Costs per minute of services

The cost per minute of a service is calculated by using the unit costs for each network element and the corresponding usage factors:

$$\text{Cost_per_Minute}_{\text{Service}_i} = \sum_{\text{NetworkElements}_j} \text{Unit_costs}_{\text{NetworkElement}_j} * \text{uf}_{\text{NetworkElement}_j}^{\text{Service}_i}$$

The cost per minute of a service, as calculated using the above equation, covers the total costs of delivering the relevant service (network element costs (annualised CAPEX and OPEX), pre-determined annual lump-sum costs of frequency spectrum and licence fees and common organisational-level costs).

5 Derivation of parameter values

5.1 Information on geography and population

The WIK-MNCM relies on a set of geographical data which are the basis for network dimensioning and cell deployment. This refers mainly to aspects of coverage and spatial distribution of mobile subscribers across Australia as well as the topography of the country.

The procedure for processing the base data consists of several steps and draws on different data sources which are described in the following sections. The base data comprises information about:

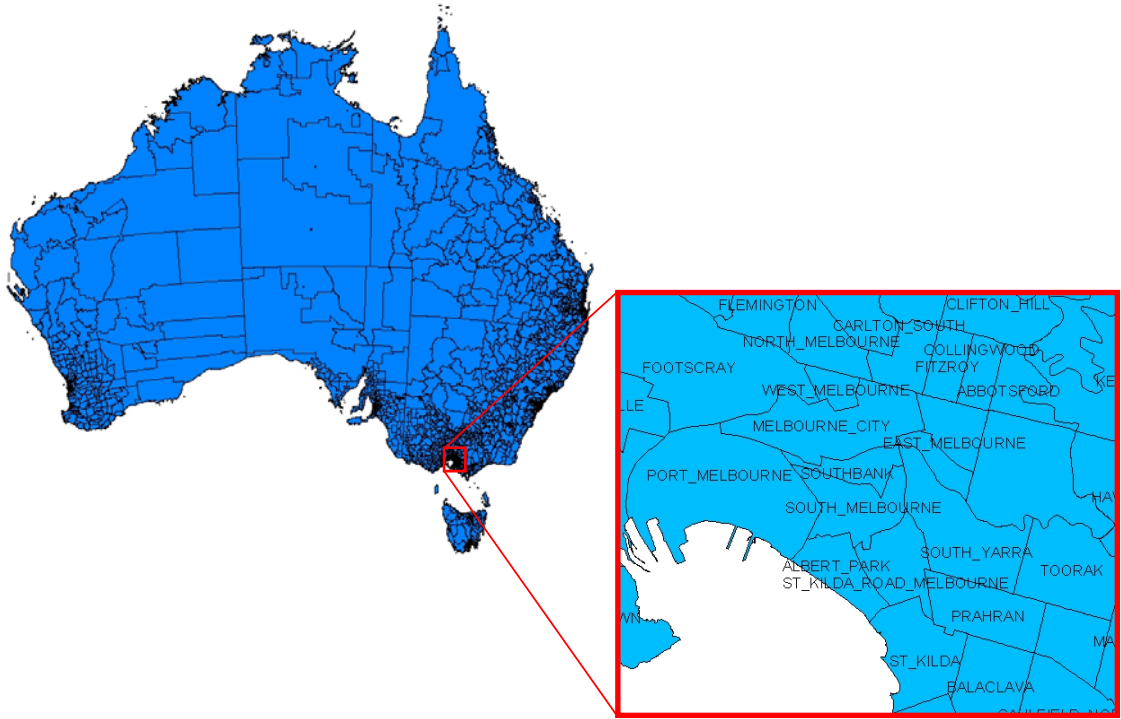
- 1) POAs which are used to form BTS districts,
- 2) Population at a POA level, which is used to derive information on traffic demand and its spatial distribution,
- 3) Workforce data, which is used on a POA-basis to identify business and administrative districts, and
- 4) Topology, which is used for network dimensioning.

5.1.1 Postal Areas

One of the basic data sets used in the WIK-MNCM comprises information about the POAs in Australia. This information has been sourced from the Australian Bureau of Statistics (ABS).⁸⁵ Australia has 2429 POAs. For each POA information is available concerning i) the area, ii) the boundaries and iii) the geographical centre.

⁸⁵ This product (WIK-MNCM) incorporates data which is Copyright Commonwealth of Australia. The data has been used in the WIK-MNCM with the permission of the Commonwealth. The Commonwealth has not evaluated the data as altered and incorporated within the WIK-MNCM, and therefore gives no warranty regarding its accuracy, completeness, currency or suitability for any particular purpose.

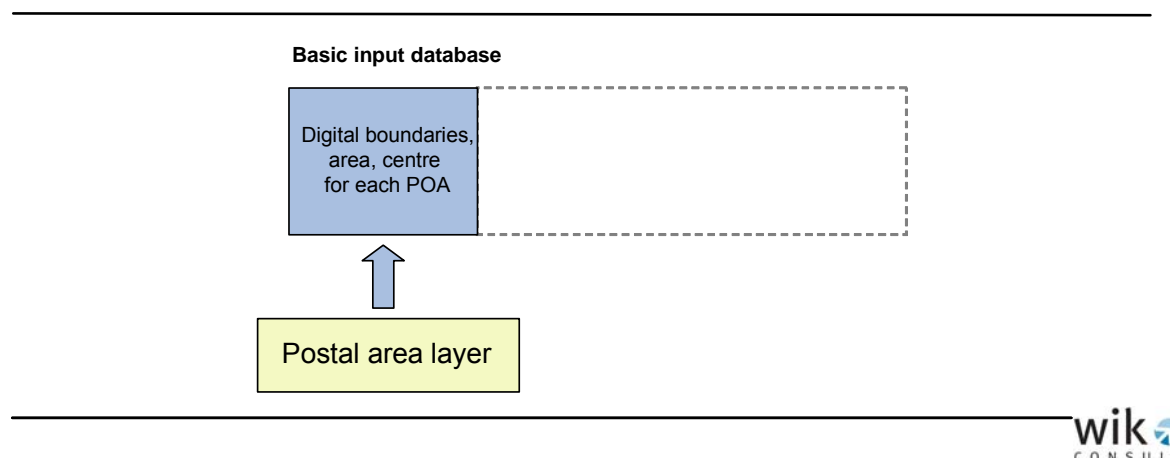
Figure 5-1: POAs in Australia



Source: WIK, Australian Bureau of Statistics

The complete database which comprises all the relevant information on the POAs in Australia has been taken as a starting point for building the model's basic input database.

Figure 5-2: Building Basic Input Database (1)



Source: WIK

5.1.2 Population

Using the basic POA data the next step consists of matching the residential population data to these POAs. The population data used for this purpose in the WIK-MNCM is 2006 extrapolated from the ABS Census data from 2001.

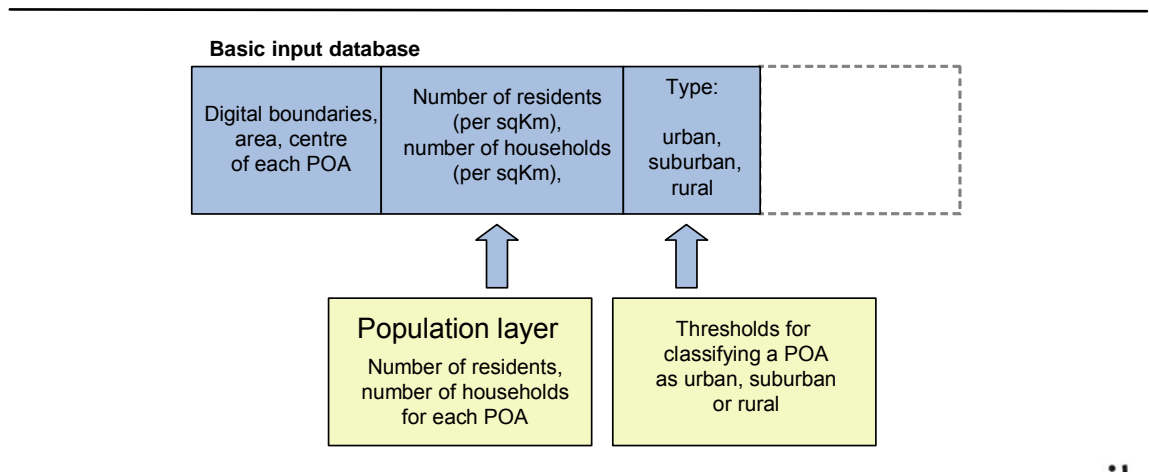
The database shows a total population of 20.4 million residents for all POAs. This figure corresponds to the one the ABS has projected for end of 2005, 20.4 million inhabitants.⁸⁶

Since population data are available on a POA basis, the number of residents and households is known for each POA. Both the population data as well as the POA data base have been amalgamated using a Geographical Information System (GIS) tool.

This amalgam of information yields population densities in each POA and allows each POA to be classified as urban, suburban or rural.

⁸⁶ See ABS, Australian Demographic Statistics (Catalogue 3101), December 2005, p. 1.

Figure 5-3: Building Basic Input Database (2)



Source: WIK

POAs are classified according to the following residential population thresholds:

- **rural** for density below 1,000 residents per square kilometre,
- **suburban** for density above 1,000 and below 5,000 residents per square kilometre,
- **urban** for density above 5,000 residents per square kilometre.

This data information complements the basic input database as shown in Figure 5-3.

5.1.3 Workforce data

The number and distribution of residents within a POA does not totally reflect the demand for mobile services in a POA, which is required for the network dimensioning and cell deployment. This is especially the case in business and financial districts, where the residential population can be quite different to the transient working population, which may require mobile services during the busy hour. These POAs typically have fewer residents compared to working population which may demand a very different network dimension than might be suggested by the residential population. If the network dimensioning was based purely on a residential population this would significantly underestimate the coverage requirements and traffic demand in certain areas.

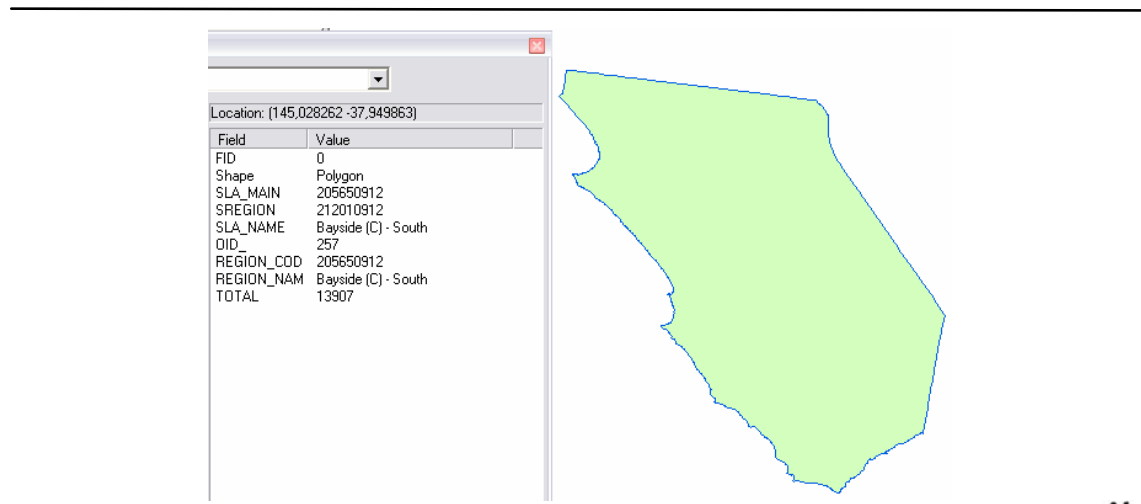
To account for this issue, the population data are overlaid with workforce distribution data for Australia.

ABS Workforce data are also based on the 2001 Census data. The data are based on Statistical Local Areas (SLAs). There are a total of 1,300 SLAs in Australia. The database reports 7,515,691 employed persons. The 2001 Census data deviates somewhat from current work force statistics available from ABS which report a labour force of nearly 9.1 million employed persons at the end of 2005.⁸⁷ For this purpose the number of employees has been proportionally increased for each SLA to be consistent with the current level of employees at the end of 2005.

Since the boundaries of the SLAs are not congruent with the POAs both layers of data were matched to each other to approximate the number of employees in each POA. This process is illustrated below.

The first step consists of identifying each relevant SLA, its geographical boundaries and the corresponding number of employed persons. The modelling approach is demonstrated for a particular SLA.⁸⁸

Figure 5-4: SLA data



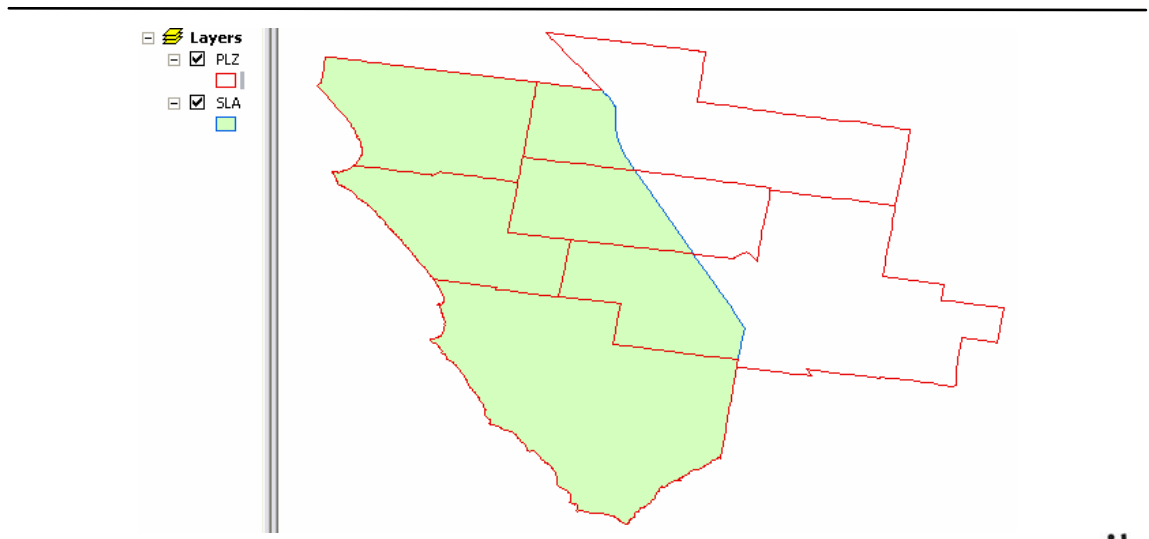
Source: WIK

⁸⁷ See ABS, Australian Economic Indicators (Catalogue 1350), Table 6-1, page 68. August 2006.

⁸⁸ Our example is Bayside (C)-South.

The next step is to identify all POAs which are covered by that SLA which in the example account for nearly 14,000 employees. As described above, the boundaries of these data sets are not normally congruent, as the following figure shows.

Figure 5-5: Joining SLA and POAs

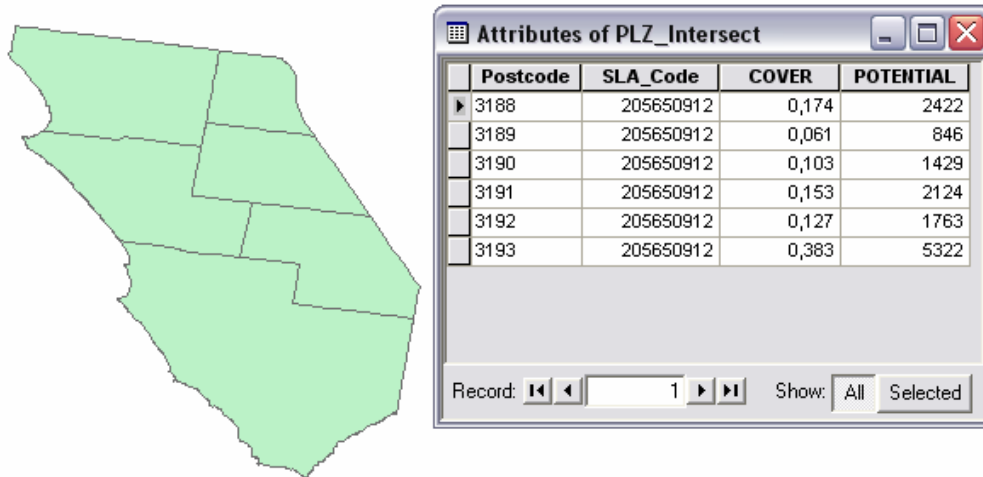


Source: WIK

Figure 5-5 shows that in total 6 POAs are (partly) covered by the relevant SLA. With the aid of a GIS tool, the extent to which each POA is covered by the SLA has been calculated. The number of employees has then been distributed to the POAs according to the degree of each POA's coverage.

The following figure illustrates both the intersection of the SLA and the corresponding POAs as well as the quantitative results regarding coverage and the number of employees allocated to each POA. The following example shows how the incongruence of the two data sources is addressed.

Figure 5-6: Allocation of SLA workforce to POAs

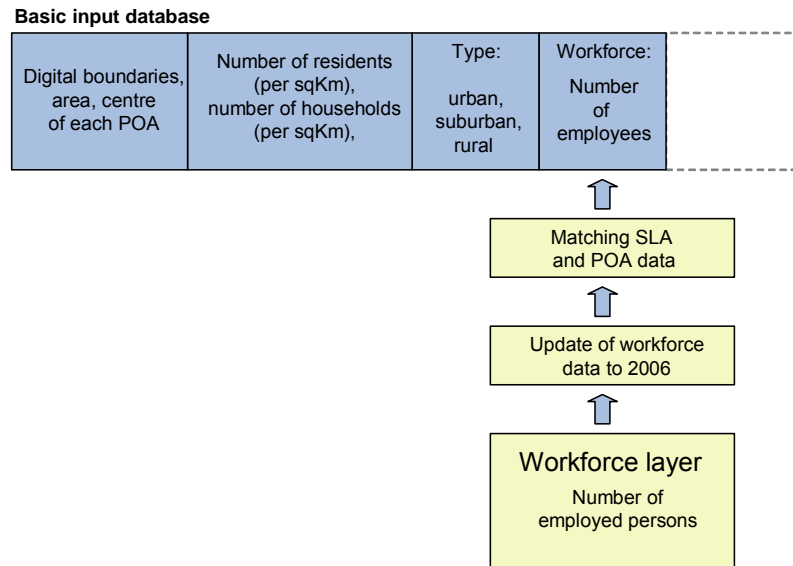


Source: WIK

For example, the POA with the postcode 3188 covers 17.42 per cent of the SLA’s area. Accordingly, 17.42 per cent of the 13,907 employees (i.e. 2,422 employees) in that SLA are assumed to be located in that POA. Note that in the case that an adjacent SLA exists (which is not shown in the example above) the procedure is repeated such that additional employees might be allocated to the POA. The number of employees for each POA is determined after joining all the SLAs and POAs.

To ensure that the workforce is distributed over all POAs, this procedure is conducted for all SLAs. The results are then transferred to the basic input data base of the WIK-MNCM.

Figure 5-7: Building Basic Input Database (3)



Source: WIK

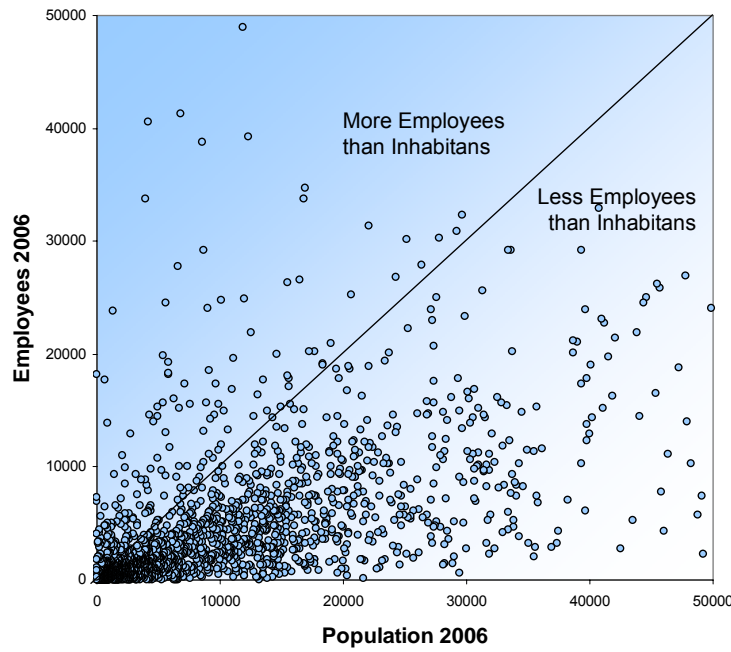
5.1.4 Determining the relevant number of mobile users

The population and the workforce data are the basis for determining the distribution of mobile subscribers. The market penetration rate is the relationship between the number of mobile users and the population base. In the WIK-MNCM the penetration rate is an input parameter which is defined by the WIK-MNCM user. This parameter is being applied to the population base.

As already outlined, the distribution of mobile users is mainly based on POA (residential) population data and augmented for the working population in key business districts. In addition, as also outlined, POAs in business districts are characterised by a relative low number of residents and a large transient working population. In these POAs, the number of relevant mobile users is given by the number of employees during normal business hours, so as to account for the number of mobile users in the business districts.

Figure 5-8 shows there are a significant number of POAs where the number of employees exceeds the number of residents.

Figure 5-8: Population and workforce in Australian POAs



Source: WIK

Figure 5-9: Population base for deriving the number of mobile users

Basic input database

Digital boundaries, area, centre of each POA	Number of residents (per sqKm), number of households (per sqKm),	Type: urban, suburban, rural	Workforce: Number of employees	Population base for deriving no. of mobile users	
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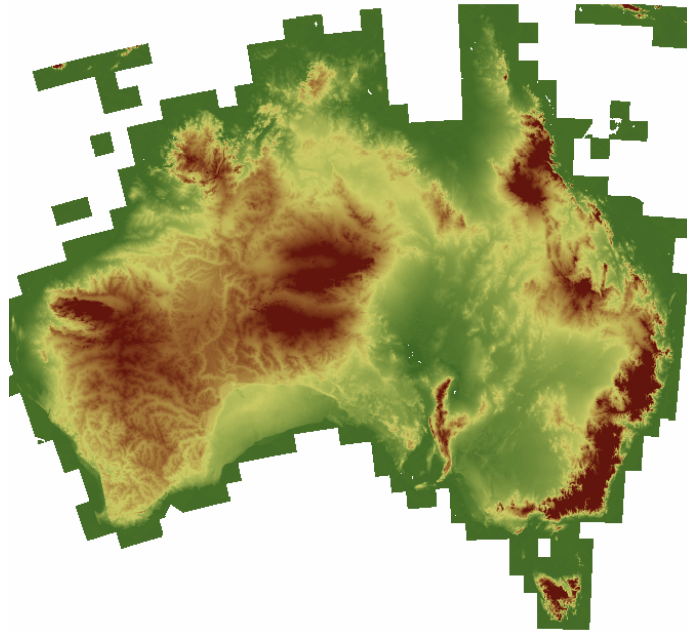
Source: WIK

5.1.5 Topological data

For the purpose of the network modelling, it is necessary to characterise the topology of each POA. The WIK-MNCM distinguishes three topological classes i) flat, ii) hilly and iii) mountainous.

Information on the topology of each POA has been derived from a Digital Elevation Model (DEM). Elevation data for Australia are available and used in the WIK-MNCM.

Figure 5-10: Digital Elevation Model of Australia



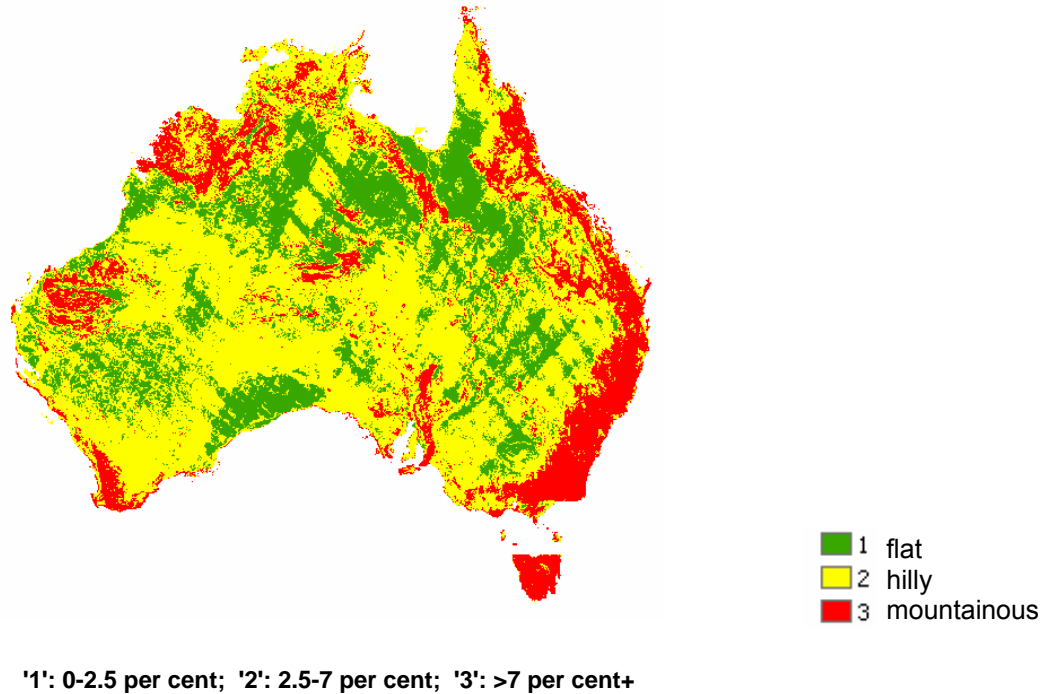
Source: WIK

POAs are classified as flat, hilly or mountainous according to the following thresholds:

- **flat**, if the average gradient is below 2.5 per cent,
- **hilly**, if the average gradient is above or equals 2.5 per cent and below 7 per cent, and
- **mountainous**, if the average gradient is above or equals 7 per cent.

Transforming the elevation data (Figure 5-10) to these three classes, leads to the topological distribution as shown in Figure 5-11.

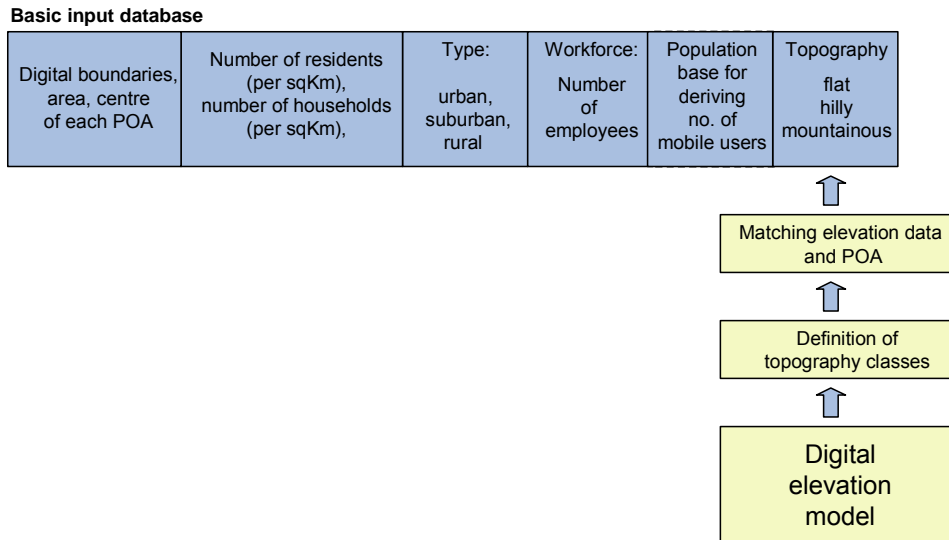
Figure 5-11: Topological classes in Australia



Source: WIK

Matching the topological information with the POA information has been done using a GIS tool. The resulting data information complements the general input database as shown in Figure 5-12.

Figure 5-12: Building Basic Input Database (4)



Source: WIK

5.2 Demand for the different services

In section 5.1 the derivation of one factor of demand, i.e. the number of mobile users, has already been described as a function of the total number of population, the mobile services penetration rate, and the transient working population moving from residential to business and financial districts during working hours. The other demand factor is the traffic per user, which (multiplied by the number of users) gives the total demand for traffic. This total demand for traffic is the most important cost driver in the WIK-MNCM.

The WIK-MNCM determines the capacity of the network such that it meets demand at the hour during which a user generates on average the heaviest demand on the network, this is the so-called busy hour demand. It is conventionally expressed in milli-Erlang per hour. This measure is the basic input for dimensioning the network. For deriving the relevant per-unit cost figures, however, one needs to know the total number of minutes of all the services that the average user is demanding. Note as outlined the other services are usually measured in units other than minutes, which for the purposes of dimensioning and cost derivation are expressed in minute equivalents. The figure in milli-Erlang thus needs to be transformed into the number of (equivalent) minutes for the busy hour, this number is converted into number of minutes for the average business day. Once the number of minutes for the average day is identified this is converted into the number of minutes for the year. This is because the total cost of the

network, as well as the costs of individual network elements, is calculated as an annual cost. The specific parameter values that have been used for the calculations presented in this report are discussed below.

Note that the figure derived for the demand per subscriber or user is 'normalised', i.e. as the total equivalent in voice minutes for all the services. The demand for the network that is modelled is, however, expressed as the average user's demand for each of the various services that the operator of that network is offering. The demand for each service is expressed as a percentage of the total demand during the busy hour. Thus, the total demand in the busy hour, expressed as milli-Erlang, as well as the percentages assigned to the services, are inputs into the model.

In order to be able to properly interpret the resulting (equivalent) minute figures for the data services, a transformation of these figures into the relevant dimensions need to be carried out. This has to be done for SMS, basic data service with 9.6 Kbps, MMS, High Speed Circuit Switched Data Service and GPRS. The relevant relationships are shown in Table 5-1.

Table 5-1: Relationships between equivalent voice minutes and units of data services

Data service	Conversion factor
SMS	432 messages per voice minute
MMS	187.5 messages per voice minute
GPRS	0.080357 MByte per voice minute
Basic Data	1 data minute per 1 voice minute
HSCSDS	0.5 data minute per 1 voice minute

Table 5-2 shows the parameter values defining demand that are used for the WIK-MNCM calculations. In some cases they depend on the particular operator that a user subscribes to, and in this case the values shown in the table are those for the reference case of a hypothetical operator with a 25 per cent market share. This applies in particular to the distribution of total demand for voices services between On-Net and Off-Net services.

Table 5-2: Demand parameters

Demand parameter	Value	Source
Busy-hour (BH) traffic per subscriber in Erlang in minutes (60 minutes / Erlang)	0.0083 0.50	WIK-Consult experience value
Total number of subscribers	19.6 million	Population of 20.4 million times a penetration rate of 96 per cent
Total minutes across all services in the busy hour (19.6 mill. * 0.50) in the representative day (9.8 mill. / 0.085) per annum (115.3 million * 250)	9.8 million 115.3 million 28.8 billion	See values above Both the 8.5 per cent of busy hour share in a day's volume and the number of 250 for full-day equivalent days in a year are values commonly used in comparable bottom-up cost models (see the discussion in the text)
Percentage of ... Voice calls, of which On-net calls Off-net calls outgoing Off-net incoming calls Data services, of which HSCSD data traffic GPRS data traffic SMS data traffic MMS data traffic Modem data traffic	94 22.6 35.7 35.7 6 0.8 3.0 0.1 0.1 2.0	On the basis of actual traffic observed in the Australian market, interpolated to represent 25 per cent market share case Shares of data services are according to WIK-Consult experience values

The most important parameters are the amount of 0.0083 Erlang of demand for traffic by the average user during the busy hour, on the one hand, and the 8.5 per cent share of the busy hour traffic in a day's total volume or traffic as well as the number of full-day equivalents of usage in a year, on the other hand. The first represents a WIK-Consult experience value for industrialised countries like Australia, particularly WIK-Consult's experience in European countries.⁸⁹ The other two values are regularly used in bottom-up cost modelling for telecommunications services, see in particular the cost modelling exercises carried out in the context of proceedings regarding mobile termination rates by regulators in Norway, Sweden, the UK and the Netherlands.⁹⁰ On the basis of these parameter values from different data sources, the total amount of traffic in voice minutes

⁸⁹ One publicly available very rough indicator for the busy hour Erlang value per subscriber is as follows. Traffic in the fixed network in terms of total minutes is about 6 times that of mobile networks. The two networks have quite similar daily load curves. The WIK model for the fixed switched network in Germany uses a BH Erlang value of 0.05. Dividing 0.05 Erlang by 6 leads to a value of 0.0083 Erlang.

⁹⁰ See Postal & Telestyrelsen (2003), Norwegian Post and Telecommunications Authority (2006), OPTA (2006), Ofcom (2006).

of 28.8 billion is representative (within a reasonable margin of error) of the total volume of voice services observed in the Australian market.⁹¹

The distribution of the minutes of voice calls between On-Net, Off-Net outgoing and Off-Net incoming reflects the relationships between traffic flows actually observed in the Australian market. Observations regarding the total of originated minutes and Off-Net incoming minutes result in a number for the total minutes in the network. Since across all networks Off-Net incoming and Off-Net outgoing minutes are equal, and on the assumption that this applies to the assumed hypothetical operator, it is possible, using the information on Off-Net incoming minutes, to determine the percentages of Off-Net incoming and Off-Net outgoing minutes in the total.

The distribution of the equivalent minutes of data services reflect observed market data in the case of SMSs and the distribution of traffic for the remaining data services reflect WIK-Consult's experience regarding the importance of such flows in current mobile networks.

5.3 Technical and economic input data

The WIK-MNCM relies on a broad set of input data, which are required for the procedure of network dimensioning and the cost calculation. This section provides an overview on these input data and values used for each input parameter in the WIK-MNCM. Values for the input parameters are mainly derived from three sources:

- 1) Public data, used in comparable international modelling exercises,
- 2) Publicly available Australian data, and
- 3) Values informed by WIK-Consult's knowledge and expertise in the field of bottom-up network modelling, cost studies and analyses.

The following sections deal with the input parameters contained in the WIK-MNCM and the relevant values for these parameters are set out in Annex A and Annex B.

5.3.1 Technical data for the cell deployment

The input for the cell deployment can be defined by the following categories.

- District related information,
- Operator service portfolio,

⁹¹ Based on Market Indicator Report 2004-05 data.

- BTS and mobile equipment configuration parameters, and
- General technical parameters.

5.3.1.1 District related information

The starting point for the cell deployment is the demographic and geographic information about the districts which underlie the network design. For each district a large set of parameters is required and can be classified as follows:

- Terrain parameters: Total area in Km², percentages of the different types of areas (urban, suburban and residential), percentages of flat, hilly and mountainous terrains,
- Population parameters: Total population and percentages per district type, and
- General parameters: Name of the district, X and Y coordinates in UTM units, the height of the buildings and BTSs and the losses by topography.

5.3.1.2 Operator service portfolio

In the current market situation each MNO may provide a different suite of services. The WIK-MNCM concentrates this range of services to the following:

- Voice services: Voice traffic is classified into On-Net, incoming Off-Net and outgoing Off-Net,
- Basic Data Modem Service: Circuit Switched Data service at a rate of 9.6 Kbps using a single slot,
- High Speed Circuit Switched Data (HSCSD): Circuit Switched data using several time slots,
- SMS: A very popular service with an increasing relevance for mobile networks in Australia,
- GPRS: Also known as 2.5G it is the most important way to transmit data in TDMA networks, and
- MMS: The natural extension of the SMS with pictures and sound. It uses GPRS as the transmission system.

The WIK-MNCM accounts for user demand in two different ways. The first option is to define the total traffic per user in 1/1000 of Erlang (mErl) in voice equivalent and identify

the individual demand as a percentage of the total traffic offered by the MNO. The second option is to define the traffic parameters for each service individually.

For the dimensioning of voice equivalent traffic the WIK-MNCM defines an equivalent blocking probability typically set to 2 per cent.

5.3.1.3 BTS and mobile equipment parameters

The BTS equipment determines the cell radius for both criteria, traffic and coverage, which are the key parameters in the network configuration. The parameters that define the BTS are:

- Transmission power per radio-channel and the type of district, antenna and amplifier gains and equipment losses,
- Minimum and maximum number of sectors, number of TRXs per sector and per radio-channel, number of traffic channels per TRX, and
- Utilisability of the BTS for urban / suburban / rural districts,⁹² utilisability for the urban increment,⁹³ utilisability for double band and the priority factor of the BTS.

There are fewer parameters for a mobile handset: the transmission power, the antenna gains and the set of losses due to the electronic equipment.

5.3.1.4 General technical parameters

The WIK-MNCM includes some technical parameters for the calculation of the link budget in the radio propagation studies such as the fast, slow and interference margins or the building penetration losses for the three types of districts considered.

However, the most important information is related to the deployment strategies of the mobile operator particularly whether the operator works in a unique band (900 or 1,800 MHz) or whether it uses a double band (900/1,800 MHz).

Furthermore, the terrain coverage target for each district and each district classification or type (i.e. rural, suburban or urban) in the scenario is defined by the corresponding set of parameters. More specifically, the WIK-MNCM requires the percentage of terrain coverage for urban/suburban/rural in each district. Typical values for each district classification are 100/100/85 respectively.

⁹² The model has to avoid outcomes which would for example install picocells in rural areas, which would be inappropriate because of the very small, unprotected nature of this equipment.

⁹³ In the dense urban areas, there may be shadow areas not explicitly modelled in the WIK-MNCM and hence the number of BTSs needs to be increased to account for this.

Australia has many POAs covering large areas with a very low population density. In such POAs it is not reasonable to provide coverage for the whole area. In these cases the WIK-MNCM determines a unique site in the central point of the POA.

5.3.2 Technical data for the aggregation network

The key inputs required for the aggregation network include:

- The number of BSC locations,
- A distance threshold which ensures that the BSCs are not located too closely together,
- The maximum number of BTSs which can be aggregated to a BSC location, the higher the threshold, the closer the BTS hub is located to the BSC,
- The penalty value for the number of hops in the BSCTREE, a value larger than or equal to zero, where a higher value (such as 100 in the case of the 25 per cent market share scenario) tends toward a star topology and a value of zero results in a tree topology which minimises the tree length, and
- The maximum value for the occupancy of the E1 groups, which determines the degree of network resilience.

Typical values for an efficient cost solution, taking into account network resilient factors, are shown in Table 5-3 below:

Table 5-3: Parameter values for the aggregation network

Nº of BSC locations	Minimal distance between BSCs Km	Max. Nº of BTSs/BSC location	Penalty factor for Nº of hops	No. of channels used in E1 groups
20	80	200	1	28

5.3.3 Technical data for the backhaul network

The three parameters which influence the backhaul network configuration are the number of MSC locations, the maximum number of users aggregated at a MSC location

and the minimum distance between the MSC locations. Note that the MSC locations are selected from the BSC locations.

The MSC locations are co-located with the BSC locations, which aggregate the maximum values of traffic. A higher number of MSC locations reduces the lengths of the backhaul links connecting BSC locations to their corresponding MSC locations.

As with the aggregation network, a maximum value for the occupancy of the E1 groups for a certain capacity overhead is also required for the backhaul network.

Typical values for an efficient cost solution for the backhaul network, which take into account network resilient factors are outlined in Table 5-4.

Table 5-4: Parameter values for the backhaul network

Nº of MSC locations	Minimal distance between MSCs Km	Max. Nº of user per MSC location	No. of channels used in E1 groups
5	300	2,000,000	28

5.3.4 Site sharing

Site sharing is common for Australian MNOs. MNOs share sites they own with other operators or lease towers from specialist tower (infrastructure) owners such as Crown Castle Australia and Broadcast Australia.

Crown Castle⁹⁴ is the leading provider of independent wireless communications infrastructure and services in Australia. In April 2000 Crown Castle acquired 758 towers from Optus; a year later Crown Castle acquired an additional 627 towers from Vodafone. Both companies agreed that Crown Castle could lease space on these towers to other MNOs. As at 28 February 2006 Crown Castle owned 1,385 towers which are located throughout Australia and covering 92 per cent of the population. Crown Castle leases mobile towers to all four MNOs but most of its business is generated by providing leasing services to Optus and Vodafone. The total revenues of Crown Castle in 2005 accounted for A\$76 million, 96 per cent of which was derived from providing leasing services to the four MNOs.

Broadcast Australia⁹⁵ owns over 400 sites located in regional Australia. All four MNOs lease towers from Broadcast Australia.

⁹⁴ See Crown Castle (2006).

⁹⁵ http://www.macquarie.com.au/au/mcg/acrobat/full_year_results_2006.pdf.

An example of an MNO which also provides leasing services is Telstra.⁹⁶ Telstra indicates in its latest Annual Report that it allows access to its towers and sites for the purpose of installing radio and mobile antenna equipment. Telstra's wholesale 'Facilities Access' services business generated revenues of A\$83 million in the 2005-06 financial year.⁹⁷

It is clear that Australian MNOs can realise cost savings from site sharing. These cost savings are represented in the WIK-MNCM by site sharing assumptions of 50 per cent for Macrocells and 30 per cent for Microcells, but no assumption of sharing is made in relation to Picocells. These site sharing assumptions are considered conservative. Site sharing is assumed to reduce the initial investment in sites by 40 per cent. Given these assumptions, the site sharing factor for Macrocells is 80 per cent and 88 per cent for Microcells.

5.3.5 Technical data for the core network

The core network design provides the traffic routing among the MSCs and each MSC with other networks or service centres. The input data set allows the user to determine the number of MSC locations and the SNPT selects the MSC location with the largest traffic values among these MSC locations. Additionally, blocking probabilities for the dimensioning of the core links and the interconnection facilities can be selected. Best practice generally designates a value of 1 per cent for all blocking probabilities for each MSC location with other voice and data networks. The WIK-MNCM considers for access to the SMS service centres a 75 per cent utilisation factor.⁹⁸

Finally, the WIK-MNCN accounts for the time differences in the business hours between Eastern and Western Australia through a traffic reduction factor of 10 per cent for the busy hour on the core links to and from MSC locations. The maximum value for the occupancy of the E1 groups on the core links is the same value used for the dimensioning of the backhaul links. Table 5-5 shows typical parameter values used for the core network.

⁹⁶ See Telstra (2006).

⁹⁷ Just recently Telstra has notified an access dispute with Optus to the ACCC relating to access to telecommunications towers owned and operated by Telstra and the sites of such towers (see ACCC News Release dated 5 September 2006).

⁹⁸ This value must be smaller than one and the selected value of 75 per cent is common practice in dimensioning of waiting systems, see Akimaru et al. (1999).

Table 5-5: Parameter values of the core network

Parameter	Value
MSC locations for voice interconnection	5
MSC locations for data interconnection	5
MSC locations for SMS server	1
Blocking probability (for all) (%)	1
Degree of capacity utilisation for SMS server connection (%)	70
Busy hour traffic reduction factor for Eastern and Western Australia core links (%)	10

Once the network design and dimensioning is complete and the capacities for the different network elements determined, the Cost Module identifies the value of investment for the equipment to satisfy these capacities. The quantity of each network element used in the WIK-MNCM is outlined in Table 5-6.

Table 5-6: Capacity limitations for network equipment

Network element	Value
TRX/BSC	800
TRX/TRAU	70
E1 Ports/MSC	4,032
BHCA/central processor	270,000
BHCA/signalling processor	270,000
User/HLR	1,200,000
BH-SMS/Server	2,000,000

Similarly, the number of transmission links used in the WIK-MNCM is listed in Table 5-7.

Table 5-7: Thresholds for transmission equipment

Transmission equipment	Threshold
Minimum number of 2 Mbps radio links for updating to a 8 Mbps link	2
Minimum number of 8 Mbps radio links for updating to a 34 Mbps link	2
Minimum number of 34 Mbps radio links for updating to a 140 Mbps link	2
Number of E1 per STM-1 leased line	63
Maximum length of a radio link system in Km	70

5.3.6 Equipment prices

In the WIK-MNCM, equipment prices reflect the current replacement values for the network elements. The equipment prices are derived from benchmarking analyses informed by bottom-up costing modelling undertaken in the UK⁹⁹, the Netherlands¹⁰⁰, Sweden¹⁰¹ and Germany.¹⁰²

Equipment prices used for the calculation of the investment value are set out in detail in Table A-1 of Annex A. Benchmark values originally expressed in foreign currencies have been translated to an Australian dollar equivalent by using foreign exchange data from the Reserve Bank of Australia (average exchange rates from February – November 2006).¹⁰³

5.3.7 Leased line prices

Leased line prices used in the WIK-MNCM reflect Telstra's wholesale leased line pricing.

The leased line prices consist of an upfront one-off payment for the provision of the leased line and an annual price component as follows:

⁹⁹ See Ofcom (2006).

¹⁰⁰ See Opta (2006).

¹⁰¹ See PTS (2004).

¹⁰² WIK-Consult (2006).

¹⁰³ See <http://www.rba.gov.au/Statistics/HistoricalExchangeRates/index.html>.

Table 5-8: Leased line prices in Australia

Types of leased lines	BTS hub - BSC 2 Mbps	BSC - MSC 155 Mbps	MSC - MSC 155 Mbps
	Price per Km in A\$		
<10 Km	1,891	47,278	
10 Km – 150 Km	641	16,023	
>150 Km	131	3,271	
Core			1,246
	Upfront Connection Fee in A\$		
	3,750	40,408	

Table 5-8 contains a simple average of leased line prices for the key distance bands only. Individual prices within the distance bands may vary significantly from these prices. The prices ignore any discounts which may also be available to MNOs.

5.3.8 Mark-ups for network support asset investments

As described above network support assets are modelled as a percentage mark-up on investment of the productive network assets. The values of the mark-ups used in the WIK-MNCM are set out in detail in Annex A, Table A-2. The values shown are based on information used in other bottom-up network modelling applications.

5.3.9 Mark-ups for OPEX

As described above OPEX is modelled as a percentage mark-up on the investment of productive network and network support assets. The values of the mark-ups used in the WIK-MNCM are set out in detail in Annex A, Table A-3. The values shown are based on information from other regulatory proceedings in bottom-up modelling of mobile and fixed networks.

5.3.10 Mark-ups for common organisational-level costs

The mark-up for common organisational-level costs used in the WIK-MNCM is 10 per cent of total network costs. In the experience of WIK-Consult this is a conservative value.

5.3.11 Rates of price change

Information on the annual rates of price change is based on information from other regulatory proceedings in bottom-up modelling of mobile and fixed networks. Price changes for sites as well as for IT and software equipment are based on the ABS cost index.¹⁰⁴ The annual rates of price change used in the WIK-MNCM are set out in Annex A, Table A-7.

5.3.12 Economic lifetimes

Information on the economic lifetimes is based on information from other regulatory proceedings in bottom-up modelling of mobile and fixed networks. The values of the asset lifetimes used in the WIK-MNCM are set out in Annex A, Table A-8.

5.3.13 Licence fees and universal service levy

With reference to the information in Table 3-8, the licence fee of A\$1.944 million is calculated as the average of the fees of Vodafone and Optus in 2006 which should approximate the relevant fee payable by an MNO with a 25 per cent market share. As a result, one third of the licence fee of the hypothetical operator is allocated to network services consistent with the relative proportion of network costs to total costs of an MNO in Table 3-1.

In the same way the USL of the hypothetical operator is calculated. Given the downward trend in the value of USO contributions, a conservative approach to a forward looking value is to consider the levy paid by Vodafone and Optus Mobile for the financial year 2005-2006.¹⁰⁵ The hypothetical operator is assumed based on this information to contribute A\$14.6 million annually for the USL. One third of this amount is allocated to the network services as an additional organisational-level cost.

The licence fee and USL contributions add an additional A\$5.5 million in common organisational-level costs.

¹⁰⁴ ABS (2005).

¹⁰⁵ See Table 3-10.

6 Scenarios

6.1 The reference case: The hypothetical efficient operator

6.1.1 The concept of the efficient operator

The ACCC's RFT refers to the provision of 'a tool for the assessment of the efficient costs of providing termination by hypothetical operators under differing circumstances'. These circumstances include market share, population coverage and extent of integration with a fixed-line network. The ACCC also requires consideration of the 'most efficient operator', including in relation to what is achievable by existing carriers.

In the experience of WIK-Consult, a typical reference point for regulatory policy decisions on the TSLRIC of a regulated service is a hypothetical operator which may be an operator newly entering the market. That operator makes decisions on the best-in-use technology which is commercially available. This technology is the cost-efficient forward-looking technology an operator would apply today, under the current level of demand. This carrier also operates efficiently with regard to operating expenses and common organisational-level costs. Its decisions on technology, network structure and all inputs are not distorted by decisions of the past and its investments and costs therefore are not path-dependent. The efficient production of services requires that the (modelled) network to provide those services is designed to meet the current level of subscribers and the level of traffic demand they are generating. Established quality of service standards and regulatory requirements need to be met.

The best-in-use technology requires use of technology and network equipment that is actually deployed in operating networks and has proven its operational feasibility and its cost-effectiveness. The network structure and design should as far as possible be based on an optimised scorched earth approach. The resulting optimised network structure must not necessarily fit to the structure of any operator actually operating in the market. Conceptually, this approach of efficiency may be in contrast to scorched node approaches where the modelled network is constructed on the basis of existing locations of the nodes of a particular operator.

The efficient operator competes in an effectively competitive market. If there are relevant economies of scale present in the production of network services the concept of a hypothetical efficient operator may generate trade-offs to the principle of competitive neutrality. The principle of competitive neutrality defines a reference point such that all operators in the market have the chance to reach a market position of equal market share. This means that in a four carrier scenario the efficient operator should represent a market share of 25 per cent. Exhausting all economies of scale and

therefore becoming the most efficient operator in the market may on the other hand imply a significantly higher market share.

If the possibility of roaming is taken into consideration a different conclusion follows on the market position of a hypothetical efficient operator. Telstra, Optus and Vodafone started more or less at the same time to roll-out their 2G networks, have access to the same frequency bands and have got similar frequency allocations. Hutchison, the fourth operator in the market, started as a late comer being licensed several years later than the other three operators, has access to different frequencies and follows a different business model. Hutchison has concentrated its own network to the major metropolitan areas and is relying on roaming arrangements to cover the rest of the country. Hutchison's business model and network mean that it has a different cost structure as compared to the other three operators. Under that perspective, WIK-Consult sees good reasons to assume that only three operators have the chance to reach an equal market share given the specific historic licensing approach and market development in Australia. Based on these considerations a hypothetical efficient operator might have a market share of 31 per cent.¹⁰⁶

The ACCC has put the competitive standard in the forefront of its identification of an efficient operator by arguing '[...] in an effectively competitive market, it could be expected that prices would reflect an efficient level of costs. In such circumstances, MNOs could not maintain inefficient practices and would have to replicate (or supersede) other MNOs cost advantages in order to survive in the market. Thus, the competitive level of prices could be taken to being equal to efficiently-incurred costs (including a normal rate of return on investment)'.¹⁰⁷ The ACCC expressed its expectation that economies of scale may be relevant to determine the optimal size and structure of an efficient operator, but was not able to further evaluate them at that time. In this context the ACCC considered that where efficiencies are achievable by all MNOs, it is appropriate to reflect these in the efficient costs of the MTAS price. We fully share this view.

Adapting these principles to Australian market conditions, WIK-Consult considers the following options regarding the reference-case hypothetical efficient mobile operator. The first option (known as the '25 per cent reference case') is defined by the following elements:

- (1) The efficient operator has a market share of 25 per cent.
- (2) The operator operates a 2G mobile network.
- (3) The operator's network is determined as a stand-alone mobile network.

¹⁰⁶ Under the assumption of 7 per cent market share for the fourth operator.

¹⁰⁷ ACCC (2006b), p. 33f.

For the reasons mentioned above a second option for a hypothetical efficient operator can also be defined, with a market share of 31 per cent. This is referred to as the '31 per cent reference case'.

6.1.2 Relevant input parameter values

The parameter set of the SNPT and the Cost Module of the WIK-MNCM is set out in Annex A and Annex B. The parameters which define the reference-case for a hypothetical efficient operator are discussed and compared with different scenarios below.

Where the efficient hypothetical operator is defined to have a market share of 25 per cent, this means that it serves 4.9 million out of a total of 19.6 mobile users in Australia, and this operator's network is assumed to be deployed to reach 96 per cent of the population. This degree of coverage is currently reached by the GSM networks of Telstra and Optus. To be sufficiently competitive it is assumed that this hypothetical operator has the capacity to reach the designated level of coverage.

The distribution of traffic between the different voice services is not fixed but systematically varies with market share. The share of On-Net traffic increases with the size of a network in terms of connected subscribers and therefore ceteris paribus with market share. The assumed distribution of traffic - based on actual market data where available or alternatively benchmarking assumptions – between the different services is outlined in Table 6-1.

Table 6-1: Traffic distribution between services

Service	Total traffic (%)
Voice On-Net	22.6
Voice Termination	35.7
Voice Origination	35.7
Basic Data	2.0
High Speed Circuit Switched Data	0.8
GPRS	3.0
SMS	0.1
MMS	0.1
Total	100.00

6.1.3 Model results

The efficient mobile operator with 25 per cent market share produces voice termination at a cost of 5.9 cpm. Table 6-2 shows the TSLRIC+ of providing the other mobile services. A minute of voice origination is produced at lower costs than voice termination because on average less network elements are being used by that service. The cost per minute of data services represents the cost of an equivalent minute of traffic as outlined in section 5.2. The costs for the Basic Data, High Speed Circuit Switched Data, GPRS and MMS services only include the cost of the service from the user terminal to the corresponding interface at the MSC location. The WIK-MNCM results shown below or in any of the scenarios for Basic Data, High Speed Circuit Switched Data, GPRS and MMS services do not include the costs for the interface or the corresponding service centre cost. The only data service for which the full cost of the service is provided in the WIK-MNCM is for the SMS service. In this case (SMS), the WIK-MNCM considers the total cost of the service including the service centre costs and the corresponding interface. The cost of conveying a SMS message therefore amounts to 0.03 cents (per message). Different to SMS the costs of the other data services shown do not include the use of service-specific network elements.

Table 6-2: Costs per minute (cpm) of services for an efficient operator (25 per cent market share)

Service	cpm
Voice On-Net	10.7
Voice Termination	5.9
Voice Origination	5.2
Basic Data	5.2
High Speed Circuit Switched Data	5.2
GPRS	5.0
SMS	12.9
MMS	5.6

The network of the efficient operator needs 4,266 BTSs to reach 96 per cent of population which are located at 2,504 BTS sites. The relationship between these two numbers represents the use of overlay cells in the 1,800 MHz bands, as the BTSs which operate in the 900 MHz band are co-located with the BTSs used in the 1,800 MHz network. The BTSs are aggregated and controlled by 20 BSCs. The traffic of the network is switched in five MSC centres which are located in the five major cities in Australia.

The network elements of the efficient operator represent a total investment value of A\$1,257 million, 7.2 per cent of which is investment in network support assets.

As Table 6-3 shows, the network services of the efficient operator are produced at annual costs of A\$506.3 million. A\$455.3 million of those costs are TSLRIC and A\$51.0 million represent the common organisational-level costs allocated to the network services.

Table 6-3: The annual costs of the efficient operator (25 per cent market share)

Network element	Annual costs (A\$ million)	Proportion of TSLRIC (%)
Base Stations	297.7	65.4
BSC	37.3	8.2
MSC (incl. SP, CP and TRAU)	15.9	3.5
HLR	5.9	1.3
SMSC	0.6	0.1
Radio links BTS-BTS hub	25.0	5.5
Radio links BTS hub-BSC	17.7	3.9
Leased lines BTS hub-BSC	-	0.0
Leased lines BSC-MSC	25.7	5.6
Leased lines MSC-MSC	29.5	6.5
Total annual network costs	455.3	100.0
Common organisational-level costs	51.0	
Total annual costs	506.3	

The costs of the efficient operator are dominated by the BTS costs representing 65.4 per cent of the TSLRIC of the network. The various transmission links connecting the other network elements (realised as microwave links or leased lines) amount to 21.5 per cent of the total cost.

6.1.4 Sensitivity analyses

To show the impacts of certain parameter changes on the cost of the MTAS WIK-Consult has calculated some parameter sensitivities under *ceteris paribus* assumptions, e.g. WIK-Consult only changed the value of a single parameter leaving all the others unchanged.

In section 3.4.3 WIK-Consult derived a value of 11.68 per cent for the WACC. The first sensitivity considered is increasing the WACC to 15 per cent. Given the assumption that coverage is a major cost driver of the network, WIK-Consult also considers the impact of reducing the level of coverage from 96 per cent to 92 per cent. As the mobile market still is growing, the cost of delivering the MTAS today will be higher than the cost of delivering the MTAS in the future if economies of scale can still be realised in the network. This effect is captured when WIK-Consult increases the traffic volume by 10 per cent.

Table 6-4: TSLRIC+ impact of parameter value changes

	Reference Scenario 25 % market share, 96 % coverage, WACC 11.68 %	Scenario 25 % market share, 96 % coverage, WACC 15 %	Scenario 25 % market share, 92 % coverage WACC 11.68 %	Scenario 25 % market share, 96 % coverage, Traffic +10 % WACC 11.68 %
	cpm	cpm	cpm	cpm
Voice On-Net	10.7	11.5	10.2	10.2
Voice Termination	5.9	6.2	5.6	5.6
Voice Origination	5.2	5.5	4.9	4.9
Basic Data	5.2	5.5	4.9	4.9
High Speed Circuit Switched Data	5.2	5.5	4.9	4.9
GPRS	5.0	5.3	4.7	4.7
SMS	12.9	13.8	12.5	18.9
MMS	5.6	5.9	5.3	5.3

Table 6-4 shows the result of the sensitivity analyses. Increasing the WACC from 11.68 per cent to 15 per cent (all other things remaining equal) increases the cost of the MTAS from 5.9 cpm to 6.2 cpm. A lower degree of coverage (all other things remaining equal) reduces MTAS costs by 0.3 cpm. The network of the efficient operator (25 per cent market share reference case) can achieve relevant cost reductions in the future from the market and industry growth. If traffic increases by 10 per cent, cost per minute for the MTAS can fall by 5 per cent. The economies of scale effects are mainly driven by a more efficient utilisation of BTSs reflecting to a large extent that BTS numbers are still coverage and not capacity driven.

6.2 An alternative reference case representing an efficient operator with a market share of 31 per cent

In section 6.1.1 WIK-Consult has argued that under the mobile market conditions in Australia a hypothetical efficient operator might not have a market share of 25 per cent but of 31 per cent. The results of the WIK-MNCM for this (alternative) reference case are presented in the following section.

6.2.1 Relevant input parameter values

As in the previous reference case the hypothetical efficient operator modelled in this scenario is a stand-alone mobile operator whose network provides a 96 per cent population coverage. Due to its higher market share this MNO serves 6.1 million customers out of the total of 19.6 million mobile users in Australia. Because the share of On-Net traffic depends on the own customer base of an MNO, the traffic distribution of this operator is different to the operator with a 25 per cent market share and outlined in Table 6-5.

Table 6-5: Traffic distribution between services

Service	Proportion of total traffic (%)
Voice On-Net	24.4
Voice Termination	34.8
Voice Origination	34.8
Basic Data	2.0
High Speed Circuit Switched Data	0.8
GPRS	3.0
SMS	0.1
MMS	0.1
Total	100.00

6.2.2 Model results

Under this scenario the cost of mobile termination decreases to 5.3 cpm, a decrease of nearly 10 per cent compared with the 25 per cent reference case. The per minute costs of all services are outlined in Table 6-6 and compared with those of the previous reference case.

Table 6-6: Costs per minute (cpm) of services for an operator with 31 per cent market share

Service	Scenario 31 % market share, 96 % coverage, WACC 11.68 %	Reference Scenario 25 % market share, 96 % coverage, WACC 11.68 %
	cpm	cpm
Voice On-Net	9.6	10.7
Voice Termination	5.3	5.9
Voice Origination	4.6	5.2
Basic Data	4.6	5.2
High Speed Circuit Switched Data	4.6	5.2
GPRS	4.4	5.0
SMS	17.3	12.9
MMS	5.0	5.6

The hypothetical operator modelled here operates the same number of BSCs and MSCs as the operator of the reference case. It operates, however, 4,654 BTSs at 2,606 BTS sites, representing just 9 per cent more BTSs and 4 per cent more BTS sites than the 25 per cent market share operator needs to service its demand. Altogether, the network of the operator with 31 per cent market share represents a total investment value of A\$1,374 million which is 8.5 per cent more compared to the reference case.

Table 6-7 shows the entire cost structure of the hypothetical efficient operator modelled in this scenario. The cost structures of the hypothetical efficient operators in both cases reveal only slight differences.

Table 6-7: Structure of the annual costs of an operator with a 31 per cent market share

Network element	Annual costs A\$ million	Proportion of TSLRIC (%)
Base Stations	321.5	63.4
BSC	42.6	8.4
MSC (incl. SP, CP and TRAU)	17.2	3.4
HLR	7.9	1.6
SMSC	1.3	0.3
Radio links BTS-BTS hub	26.3	5.2
Radio links BTS hub-BSC	19.5	3.8
Leased lines BTS hub-BSC	-	0.0
Leased lines BSC-MSC	32.4	6.4
Leased lines MSC-MSC	38.1	7.5
Total annual network costs	506.8	100.0
Common organisational-level costs	56.2	
Total annual costs	563.0	

6.3 A GSM operator covering 96 per cent of population with a market share of 44 per cent

WIK-Consult's analysis of the 25 per cent reference case revealed that economies of scale that can be derived with an increase in traffic volume are important. Economies of scale can be gauged from comparing the 25 per cent and 31 per cent reference cases. To further examine these effects WIK-Consult has determined the model results of an operator which has a market share of 44 per cent and – as before – a 2G network coverage of 96 per cent of the Australian population.

6.3.1 Relevant input parameter values

The parameter set for this scenario is basically the same as for the reference cases. Instead however, the MNO being modelled serves 8.6 million customers out of a total of 19.6 million mobile users in Australia. The share of On-Net traffic increases with the number of customers connected to a network so that the traffic distribution between the different services changes. WIK-Consult assumes the same share of non-voice services as in the reference case. The traffic distribution for all services is outlined in Table 6-8.

Table 6-8: Traffic distribution between services

Service	Proportion of total traffic (%)
Voice On-Net	32.0
Voice Termination	31.0
Voice Origination	31.0
Basic Data	2.0
High Speed Circuit Switched Data	0.8
GPRS	3.0
SMS	0.1
MMS	0.1
Total	100.00

6.3.2 Model results

This operator can deliver all of its services at a lower cost compared to the operator with a market share of 25 per cent, because of its larger market share, as shown in Table 6-9.

Table 6-9: Costs per minute (cpm) of services for a large operator

Service	Reference Scenario 25 % market share, 96 % coverage, WACC 11.68 %	Scenario 44 % market share, 96 % coverage, WACC 11.68 %
	cpm	cpm
Voice On-Net	10.7	8.9
Voice Termination	5.9	5.0
Voice Origination	5.2	4.2
Basic Data	5.2	4.2
High Speed Circuit Switched Data	5.2	4.2
GPRS	5.0	4.0
SMS	12.9	13.8
MMS	5.6	4.8

The TSLRIC+ of producing a minute of the MTAS falls from 5.9 cpm in the 25 per cent reference case to 5.0 cpm. The cost of conveying a SMS message increases slightly due to the installation of a second SMS centre caused by the larger SMS demand.

Even though the network of the large operator provides the same level of coverage as the network of the hypothetical operator, it has 5,767 BTSs or 35.2 per cent more BTSs than the network of the 25 per cent operator. This factor demonstrates that for this operator the number of BTSs is driven more by capacity than by coverage. The large operator has derived greater economic benefits from using overlay cells. Although its network operates an additional 1,501 BTSs, it only needs an extra 578 BTS locations to carry the additional traffic. Another impact of the additional number of BTSs for the large operator is that it needs to increase the number of BSCs from 20 to 30 and the number of MSC locations from five to six.

The entire network of the large operator represents a total investment value of A\$1,712 million, 7.2 per cent of which represents investments in network support assets. The network carries an annual traffic of 12.6 billion minutes.

Table 6-10 shows the cost structure of the large operator. The TSLRIC of its network amounts to an annual cost of A\$694.4 million. The increase in network efficiency of the large operator mostly manifests itself in the access network: the share of BTS costs decreases from 65.4 per cent to 57.0 per cent. Despite the increase in the number of BSCs and MSCs the cost share of these network elements remains more or less unchanged. However, there is a significant relative increase in transmission costs. The share of total transmission costs increases from 21.5 per cent to 29.0 per cent. This increase in transmission costs is because of the fully-meshed structure of the core network.

Table 6-10: Structure of the annual costs of the large operator

Network element	Annual costs A\$ million	Proportion of TSLRIC (%)
Base Stations	396.1	57.0
BSC	62.3	9.0
MSC (incl. SP, CP and TRAU)	22.7	3.3
HLR	10.9	1.6
SMSC	1.3	0.2
Radio links BTS-BTS hub	31.6	4.6
Radio links BTS hub-BSC	19.2	2.8
Leased lines BTS hub-BSC	-	0.0
Leased lines BSC-MSC	78.0	11.2
Leased lines MSC-MSC	72.3	10.3
Total annual network costs	694.4	100.0
Common organisational-level costs	75.0	
Total annual costs	769.4	

6.4 A GSM operator covering 92 per cent of population with a market share of 17 per cent

In this scenario the WIK-MNCM models a smaller operator with a market share of 17 per cent. Unlike the previous scenario the smaller operator does not offer the same network coverage as the larger operators. It offers a lower coverage or buys coverage through a roaming arrangement.

6.4.1 Relevant input parameter values

The market share assumption means that the smaller operator only serves 3.3 million customers. The smaller customer base results in a smaller share of On-Net traffic which is assumed to be 18.8 per cent of total traffic. Table 6-11 shows the traffic structure of all services.

Table 6-11: Traffic distribution of services

Service	Proportion of total traffic (%)
Voice On-Net	18.8
Voice Termination	37.6
Voice Origination	37.6
Basic Data	2.0
High Speed Circuit Switched Data	0.8
GPRS	3.0
SMS	0.1
MMS	0.1
Total	100.00

6.4.2 Model results

In this scenario two countervailing cost impacts emerge. The impact of network coverage decreases the cost per minute but the lower market share increases the cost per minute. Table 6-12 shows that these effects are not equal in impact on the TSLRIC+ cost of providing the MTAS. The smaller operator faces higher costs for all services compared to the 25 per cent operator. Its TSLRIC+ of providing voice termination increases from 5.9 cpm to 7.3 cpm or by 24 per cent. The costs of conveying a SMS message (per message) increases from 0.03 cent to 0.04 cent.

Table 6-12: Costs per minute (cpm) of services for a small operator

Service	Reference Scenario 25 % market share, 96 % coverage, WACC 11.68 %	Scenario 17 % market share, 92 % coverage, WACC 11.68 %
	cpm	cpm
Voice On-Net	10.7	13.4
Voice Termination	5.9	7.3
Voice Origination	5.2	6.4
Basic Data	5.2	6.4
High Speed Circuit Switched Data	5.2	6.4
GPRS	5.0	6.2
SMS	12.9	17.1
MMS	5.6	6.9

Due to the lower coverage and the reduced traffic volumes (4.9 billion of minutes per annum), the small operator can operate a smaller network. Compared with the 25 per cent reference case, the number of BTSs reduces to 3,401 and the number of BTS sites is lower at 2,115. The smaller operator still uses the same amount of network nodes as the 25 per cent operator (which also uses 20 BSCs and 5 MSCs).

The entire network (productive network assets and network support assets) represents an investment value of A\$1,032 million. Total annual costs of operating the network amount to A\$431.7 million per annum, A\$387.5 million of which represent the TSLRIC of the various network elements.

Table 6-13 represents the cost structure of the network. This cost structure is similar to that of the efficient operator.

Table 6-13: Structure of the annual costs of a small operator

Network element	Annual costs A\$ million	Proportion of TSLRIC (%)
Base Stations	250.1	64.5
BSC	34.0	8.8
MSC (incl. SP, CP and TRAU)	14.2	3.7
HLR	4.9	1.3
SMSC	0.6	0.2
Radio links BTS-BTS hub	20.7	5.3
Radio links BTS hub-BSC	12.5	3.2
Leased lines BTS hub-BSC	-	0.0
Leased lines BSC-MSC	24.8	6.4
Leased lines MSC-MSC	25.7	6.6
Total annual network costs	387.5	100.0
Common organisational-level costs	44.2	
Total annual costs	431.7	

6.5 An integrated mobile fixed-line operator covering 96 per cent of population with a market share of 25 per cent

6.5.1 Relevant input parameter values

Section 3.7.3 discussed the benefits of lower transmission costs, site sharing and overhead savings that an integrated fixed-line/mobile operator can realise. To identify these economies of integration within the modelling framework the following parameters are changed compared with the 25 per cent reference case:

- (1) The leased line prices as defined in Table 5-8 may be higher than the cost of production that a fixed-line operator is facing. To reflect this potential saving all leased line prices (in Table 5-8) are reduced by 30 per cent,
- (2) An integrated operator can realise a higher degree of site sharing for BSCs, MSCs and BTSs due to sharing with fixed-line network elements. In this scenario the following assumptions are made: BTS Macrocells share 60 per cent instead of 40 per cent of sites; Microcells share 50 per cent instead of 30 per cent of sites; Picocells share 50 per cent instead of 0 per cent of sites; repeater sites share 50 per cent instead of 30 per cent of sites; BSC sites share 50 per

cent instead of 0 per cent of sites; and MSCs share 100 per cent instead of 0 per cent of sites, and

- (3) The larger business organisation of the integrated operator results in cost savings from the sharing of certain overhead functions. Potential savings in costs are modelled through a reduction in the mark-up for organisational-level costs from 10 per cent to 9 per cent.

6.5.2 Model results

Table 6-14 shows the impact of integration on the costs of service of the 25 per cent operator. The combined effects of integration show that the total costs of the mobile operator are reduced from A\$506.3 million to A\$478.0 million or by 5.5 per cent. The cost of the termination service falls from 5.9 cpm to 5.5 cpm or by 6.8 per cent.

Table 6-14: Costs per minute (cpm) for service for an integrated operator

Service	Reference Scenario 25 % market share, 96 % coverage, WACC 11.68 %	Integrated operator 25 % market share, 96 % coverage, WACC 11.68 %
	cpm	cpm
Voice On-Net	10.7	10.2
Voice Termination	5.9	5.5
Voice Origination	5.2	5.0
Basic Data	5.2	5.0
High Speed Circuit Switched Data	5.2	5.0
GPRS	5.0	4.8
SMS	12.9	12.5
MMS	5.6	5.2

Table 6-15 outlines the entire cost structure of the integrated operator.

Table 6-15: Structure of the annual costs of the integrated operator

Network element	Annual costs A\$ million	Proportion of TSLRIC (%)
Base Stations	294.0	67.8
BSC	37.1	8.6
MSC (incl. SP, CP and TRAU)	14.9	3.4
HLR	5.9	1.4
SMSC	0.6	0.1
Radio links BTS-BTS hub	25.0	5.8
Radio links BTS hub-BSC	16.0	3.7
Leased lines BTS hub-BSC	1.4	0.3
Leased lines BSC-MSC	18.0	4.1
Leased lines MSC-MSC	20.7	4.8
Total annual network costs	433.6	100.0
Common organisational-level costs	44.4	
Total annual costs	478.0	

6.6 Implications of 3G and other emerging technologies on 2G

To examine the implications of 3G costs and the relative cost savings compared to 2G technology there are two impacts that are considered: the cost savings of sharing infrastructure; and the effects of an increase of the data traffic on 2G. Both (sub-) scenarios are calculated for the reference case of 25 per cent market share and 96 per cent coverage.

6.6.1 Relevant input parameter values

An MNO operating a 2G and a 3G network can realise cost savings due to site sharing capabilities for equipment such as BTSs, MSCs and BSCs. The parameters for these savings are defined in the same way as in the scenario of an integrated fixed-line/mobile operator in section 6.5.1.

For the second (sub-) scenario the traffic volumes for data traffic are increased. For that purpose the busy hour traffic of a mobile user is increased from 8.3 to 9.3 milli Erlang. This is due to the three-fold increase in data traffic. The share of data traffic increases from 6 per cent to 16 per cent as shown in Table 6-16.

Table 6-16: Traffic distribution with increased share of data traffic

Service	Proportion of total traffic (%)
Voice On-Net	20.2
Voice Termination	31.9
Voice Origination	31.9
Basic Data	5.4
High Speed Circuit Switched Data	2.2
GPRS	8.0
SMS	0.3
MMS	0.2
Total	100.00

6.6.2 Model results

The costs savings of site sharing (BTS, BSC, MSC) reduce total annual costs from A\$506.3 million to A\$500.9 million or by 1 per cent, mainly at the BTS level. Table 6-17 shows that the costs of voice termination go down from 5.9 cpm to 5.8 cpm due to site sharing between the 2G and 3G infrastructures.

Table 6-17: Costs per minute (cpm) of services in case of 2G/3G site sharing

Service	Reference Scenario 25 % market share, 96 % coverage, WACC 11.68 %	Site Sharing (2G/3G)
	cpm	cpm
Voice On-Net	10.7	10.6
Voice Termination	5.9	5.8
Voice Origination	5.2	5.1
Basic Data	5.2	5.1
High Speed Circuit Switched Data	5.2	5.1
GPRS	5.0	4.9
SMS	12.9	12.9
MMS	5.6	5.5

The effect of increasing the level of data traffic, all things being equal, is similar but more significant as shown in Table 6-18. In this case the costs for the MTAS decrease to 5.4 cpm. The cost decrease of a SMS equivalent traffic minute is more significant (as expected) falling from 12.9 cpm to 9.3 cpm. The network carries 8.0 billion of minutes instead of 7.2 billion of minutes as in the 25 per cent reference case.

Table 6-18: Costs per minute (cpm) of services in case of larger data traffic

Service	Reference Scenario 25 % market share, 96 % coverage, WACC 11.68 %	Data traffic increases (2G/3G)
	cpm	cpm
Voice On-Net	10.7	9.9
Voice Termination	5.9	5.4
Voice Origination	5.2	4.8
Basic Data	5.2	4.8
High Speed Circuit Switched Data	5.2	4.8
GPRS	5.0	4.6
SMS	12.9	9.3
MMS	5.6	5.2

6.7 The costs of 3G compared to the costs of 2G

In this scenario it is assumed that 3G W-CDMA technology is used in the radio access part of the network instead of 2G GSM technology and that the same outputs are being produced. The calculations are carried out for the radio access part of the network because these embody the main differences between the two technologies. The focus is on the number of Node Bs used by 3G technology instead of the number of BTSs used for 2G, and on the likely cost differences that arise as a result. The assumptions regarding demand, coverage and market share are the same as in the 25 per cent reference scenario. 3G services can be delivered using either the 2.1 GHz band or the 850 MHz band in Australia.

This comparison is carried out primarily to determine the impact of the use of 3G compared with 2G GSM technology on the costs of services at the current level and composition of demand. The presumption is that once the volume of genuine 3G services has grown sufficiently, advantages of 3G technology together with economies of scale will drive cost levels substantially down also for 2G services which, at that point in time, will be provided with the same technology. The presumption is also that

currently the demand for 3G services has not yet reached that level and as a result 3G technology is assumed to be used in this scenario for a demand for which it would not in reality be employed. If this is the case, then this should show up in the results as an upward rather than downward impact on costs.

3G technology¹⁰⁸ is a set of systems and technologies under the common name of International Mobile Telephony 2000 (IMT-2000).¹⁰⁹ It is the natural evolution of mobile telecommunications from voice and narrowband services to broadband data services. Most 2G technologies, such as GSM, use Time Division Multiple Access (TDMA) in the radio air interface (between the user and the mobile station). They can be defined as hard blocking systems which means that a BTS has a fixed number of channels (depending on the equipment used) to provide services. Coverage (associated with radio propagation) and capacity for traffic are independent.¹¹⁰ 3G systems are commonly based in Wideband Code Division Multiple Access (W-CDMA). They are soft blocking systems which means that the Node B does not have a defined number of channels and its capacity depends on the interference produced by the users. The interference depends on the service type (voice, low speed data, High Speed Circuit Switched Data) and the distance of the user from the Node B. Capacity and radio coverage become interdependent under 3G technology due to the capacity related to interference factor.¹¹¹ This means that it is not possible to perform capacity and coverage assessments separately in W-CDMA systems.

Above it was pointed out that the focus will be on the radio access network. Concerning the 3G core network, most of the current implementations follow the Release 99¹¹² of the Third Generation Partnership Project (3GPP). The core network maintains the structure of GSM/GPRS technology with the new interfaces of the 3G access network equipment located in the MSCs and in the Serving GPRS Support Nodes (SGSNs).¹¹³ There are some 3G specific SGSN functions, for example carrying up to 300 kbps of traffic per subscriber, packet tunnelling towards the Radio Network Controller (RNC) and carrying out mobility management to the level of an RNC for the connected mode. The RNC is an intelligent piece of network equipment which deals with more complex functions than the BSC (its equivalent in GSM networks). Its capacity in terms of

108 For a thorough discussion see Portilla-Figueras et al (2003), Portilla-Figueras et al (2003a), Portilla-Figueras et al (2003b), Hackbarth et al (2003) and Hackbarth et al (2004).

109 ITU document, 'What's IMT-2000?', Geneva 2001-2002, <http://www.itu.int/osg/imt-project>.

110 Boucher (2004).

111 There is actually not one single factor which relates capacity and coverage but there is a whole set of factors that have influence in the dimensioning; see Holma et al (2004).

112 The Release 99 provides both circuit and packet switching units in the highest (MSC) level and therefore allows a seamless transition from 2G to 3G services and networks. Later on, more recent releases, in particular release 6, will be implemented to allow the full advantages of the packet switching technology also for narrowband circuit switched services like voice and circuit switched data services. Currently operators generally implement Release 6 only in the radio link part but not in the core network due to the fact that the corresponding technology is still not mature, see IMSVISON (no date), Corner (2006) and Nortel Networks (2005).

113 Rábanos et al (2000).

megabits per second, processor capacity, numbers of Node Bs and users served is greater than in a typical BSC.¹¹⁴ The number and locations of the RNCs depend on factors like the number and locations of the Node Bs, the amount of traffic and of course the structure of the other parts of the network. There will be fewer RNCs in a 3G core network than BSCs in a GSM core network, but this reduction is likely to be offset by the higher per unit cost of an RNC relative to a BSC.

6.7.1 Definition of the modelling approach

The basic assumptions of the reference scenario for a hypothetical operator with a 25 per cent market share and a coverage of 96 per cent of the population and there is a 94 per cent population penetration of mobile services in operation.

The assumed demand in the reference scenario - defined in traffic units, i.e. busy hour Erlang equivalents - is composed of 94 per cent voice services and 6 per cent data services where the latter are distributed as follows:

- GPRS: 3.0 per cent
- Basic Data Service: 2.0 per cent
- High Speed Circuit Switched Data Service: 0.8 per cent
- SMS: 0.1 per cent
- MMS: 0.1 per cent

The calculations are carried out for a sample of 18 districts from a total number of 638 districts that correspond to a 96 per cent population coverage. These 18 districts account for 339 BTSs or about 8 per cent of the total number of BTSs in the 2G technology 25 per cent market share reference scenario. The sample districts are selected in a way to obtain about the same number of districts for the following district types:

- A small district size and high population density,
- A small district size and low population density,
- A large district size and relatively high population density, and
- A large district size and low population density.

114 Gestner et al (2002).

Table 6-19 lists the 18 districts selected providing details regarding their sizes, population and population densities.

Table 6-19: List and details of 18 districts used in 3G / 2G comparison

	Area Km ²	Population	Population per Km ²
Prahran	38	180,036	4,680
Lakemba	56	709,284	3,261
Broadway	57	140,900	12,531
Bondi Junction	28	176,863	5,090
Neutral Bay	33	176,863	5,411
Carlton	61	203,757	3,334
Breadalbane	63	4,248	67
Toolamba	76	5,496	72
Postville Beach	75	5,082	68
Conpugna	76	5,693	74
Holsworthy Milpo	842	263,744	313
Hopper Crossing	795	190,646	240
Albion Park	672	107,772	160
Two Heads South	643	89,032	139
Maitland	1,020	59,474	58
Hazelbrook	1,182	46,680	39
Whyalla Norrie	1,116	28,105	25
Bucasia	1,149	73,959	64

For each of the selected districts, the calculations are performed to determine the number of Node Bs that would be necessary to implement the W-CDMA technology and deliver services. The resulting number of Node Bs for the 3G technology case are compared to the corresponding numbers of BTSs for the 2G technology case, which enables a cost comparison of delivering voice services using 3G rather than 2G technology.

6.7.2 WIK-MNCM results

Table 6-20 illustrates that in urban and suburban districts 3G technology is able to deliver services with a lower number of Node Bs than the number of BTSs required by

2G technology. In addition to the differences between 2G and 3G technologies, Table 6-20 illustrates that 3G services delivered using the 850 MHz frequency band require fewer Node Bs than when using the 2.1 GHz frequency band. The results differ for rural areas. In these areas, 3G technology (using either frequency, 850 MHz or 2.1 GHz) requires more Node Bs than the number of BTSs used by 2G technology for the same level of coverage. Note that these results assume that for a given level of coverage the same range of services (including all voice and data services in all covered areas) is available.

The figures in Table 6-20 indicate that the maximum reduction in the number of Node Bs is obtained in the dense urban areas. This follows from the fact that in these areas most Node Bs are capacity driven and 3G systems based on W-CDMA perform better in terms of capacity than 2G systems. Furthermore, in the present scenario, 94 per cent of the total network capacity is dedicated to voice services (On-Net and Off-Net) and W-CDMA systems have been demonstrated to be much more efficient than TDMA systems. The number of voice users per cell in a W-CDMA system can vary, depending on the cell loading, from 60 up to 168.¹¹⁵ In contrast, a GSM system will require about eight TRXs in a single sector to reach the same capacity for as few as 60 users.¹¹⁶

There is a significant difference between the number of Node Bs in the case of the use of the 2.1 GHz band for 3G compared to the number in the case of the 850 MHz band. In the 2.1 GHz band the propagation conditions are worse than in 850 MHz. Therefore, to obtain the same quality, a user in the 2.1 GHz band has to introduce much more interference in the system than in 850 MHz. Therefore, as the capacity in W-CDMA is limited by the amount of interference, the number of users that can be served by a single cell in the 850 MHz band is larger than in the 2.1 GHz band. As the Node Bs in the dense urban areas are capacity driven and there are more 'available resources' in the 850 MHz band than in the 2.1 GHz band, less cells or Node Bs are needed.

¹¹⁵ Holma et al (2004), Griparis et al (2005), Holma et al (2002), The CDMA Development Group (2000).

¹¹⁶ Considering that each TRX has between 7 to 8 traffic channels, each TRX can serve from 7 to 8 voice users. Therefore 8 TRXs can serve between 56-64 voice users.

Table 6-20: 3G / 2G comparison for 18 selected districts

	Number of BTSs / Node Bs		
	Dense urban	Urban/suburban	Rural
2G GSM technology	126	80	133
3G W-CDMA technology			
2.1 GHz spectrum used	55	66	925
850 MHz spectrum used	17	25	189

The sample districts results are extrapolated to show the deployment of Node Bs for the covered population in comparison to the deployment of BTSs. For this purpose the ratio of the number of BTSs for the covered population (known from the WIK-MNCM) to the number of BTSs in the sample districts - differentiated according to the three district types of urban, suburban and rural - are used to scale up the number of Node Bs to the level that would be required to deliver services on the basis of 3G technology to the covered population. Table 6-21 illustrates the results of this extrapolation and allows the comparison of the numbers of Node Bs with those of BTSs deployed Australia-wide under this scenario.

Table 6-21: 3G / 2G comparison with sample results extrapolated to the covered population

	Number of BTSs / Node Bs			
	Dense urban	Urban/suburban	Rural	Total
2G GSM technology	147	1,149	2,808	4,104
3G W-CDMA technology				
2.1 GHz spectrum used	64	948	19,529	20,541
850 MHz spectrum used	20	359	3,990	4,369

The last column highlights that the delivery of services using 3G technology for the covered population requires a larger number of Node Bs than BTSs. The total number of Node Bs required to deliver 3G services using the 850 MHz frequency band is similar albeit slightly larger than the number of BTSs required to deliver 2G services. The

difference is more pronounced if the number of BTSs is compared to the number of Node Bs required to deliver 3G services using the 2.1 GHz frequency.

Given that the equipment for Node Bs is about 30 per cent more expensive than the corresponding 2G equipment, delivery of the current set of services (share of voice services: 94 per cent) with 3G technology is a more expensive option.

A more realistic scenario may differentiate the range of 3G services available in urban and suburban areas compared to rural areas. One plausible scenario is a restricted deployment of the range of data services in rural areas to enable users to access voice services across the covered area but 3G data services only in the immediate vicinity of the Node B sites. In this scenario, users in urban and suburban areas have access to a substantially larger range of services compared with users in rural districts.¹¹⁷

In Table 6-22, considering the voice and limited data assumption in rural areas ('Rural voice and limited data' column), the number of Node Bs required under both 3G options for the sample districts is now substantially lower compared with the entire suite of data services available for rural users in the previous scenario outlined in Table 6-20.

Table 6-22: 3G / 2G comparison for sample districts - rural districts with voice and limited data services

	Number of BTSs/ Node Bs		
	Dense urban	Urban/suburban	Rural - voice and limited data
2G GSM technology	126	80	133
3G W-CDMA technology			
2.1 GHz spectrum used	55	66	250
850 MHz spectrum used	17	25	63

The results of Table 6-22 are again extrapolated to derive the number of Node Bs to deliver services to the covered population using both 2.1 GHz and 850 MHz (relative to the numbers of 2G BTSs). The results are shown in Table 6-23.

¹¹⁷ On this see <http://maps.vodafone.co.uk/coverageviewer/web/default.aspx> for the Vodafone 3G coverage map in the UK.

Table 6-23: 3G / 2G comparison for covered population - rural districts with voice and limited data services

	Number of BTSs / Node Bs			
	Dense urban	Urban/suburban	Rural - voice and limited data	Total
2G GSM technology	147	1,149	2,808	4,104
3G W-CDMA technology				
2.1 GHz spectrum used	64	948	5,278	6,290
850 MHz spectrum used	20	359	1330	1,709

In comparison to the situation where 3G services are assumed to be available for the total of the covered population, there is a significant shift in the number of Node Bs under the 'voice and limited data' for rural users scenario. Delivery of 3G services using 2.1 GHz spectrum still requires a large number of Node Bs compared with BTSs used by the 2G technology. However, the number of Node Bs required on the basis of the 850 MHz band is less than 50 per cent of the number of BTSs used by 2G technology.

This large reduction (more than 50 per cent) in the number of Node Bs using the 850 MHz frequency relative to the number of BTSs, even with a 30 per cent higher cost for Node-B equipment, will result in a reduction in the cost of the access network of around 30 per cent to 40 per cent when comparing the costs of 2G and 3G technologies.

It is well known that for GSM technology the cost of the radio access network accounts for about 60 percent of total network costs. The above reported 30 per cent to 40 per cent reduction in the cost of the radio access network, under 3G W-CDMA technology using the 850 MHz frequency band, implies there is a substantial reduction in overall network cost. Given the weight of the cost of the radio access network in the total cost, this cost reduction would amount to about 20 per cent to 25 per cent of that total. Since all services necessarily rely on the radio access network for the delivery of services to users, the cost reduction in the radio access network should be reflected in a cost reduction for all services delivered by that network. On-Net services that use the radio access network twice would experience the largest decrease in cost. In addition, the cost of services such as the termination of incoming calls should also fall.

Overall, the conclusions of this 2G and 3G technology comparison are twofold. When 3G technology is used at 2.1 GHz frequencies to provide the current suite of services, including 94 per cent of voice services, the number of Node Bs needed to ensure

delivery will exceed the number of BTSs that are required under the 2G technology. As initially expected, there would thus be no cost advantage from employing 3G technology for providing 2G services. The use of 2G technology would still represent the best available option for providing 2G services.

The conclusion is reversed, however, if 3G technology is used at the 850 MHz frequency and the suite of services offered to users in rural areas is limited, so that voice services are available to all of the covered population but 3G data services are only available in the vicinity of Node Bs. In this case a substantial reduction in the number of Node Bs relative to the required BTSs could be realised which, even considering that 3G technology is still 30 per cent more expensive than 2G technology, could result in significant cost savings.

Annex A: Input parameters of the Cost Module

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Table A-1: Equipment prices

Parameter Name	Description	Type	Range	Value	Comment
	Base Stations (BTS)				
	Macrocell				
p_bts_site_ma	Macrocell (Site): Average investment for site acquisition, preparation, land and building	Float	>=0	134,000	A\$
sf_bts_site_ma	Sharing factor reflecting the average impact on investment due to sharing of a BTS Macrocell site with other operators	Float	[0,1]	0.8	1 = No sharing 1-value = x %*100 reduction 50 % shared; 40 % sharing impact
p_bts_ma_1	Macrocell (1 sector): Average investment for equipment	Float	>=0	98,000	A\$
p_bts_ma_2	Macrocell (2 sectors): Average investment for equipment	Float	>=0	110,000	A\$
p_bts_ma_3	Macrocell (3 sectors): Average investment for equipment	Float	>=0	121,000	A\$
	Microcell				
p_bts_site_mi	Microcell (Site): Average investment for site acquisition, preparation, land and building	Float	>=0	86,000	A\$
sf_bts_site_mi	Sharing factor reflecting the average impact on investment due to sharing of a BTS Microcell site with other operators	Float	[0,1]	0.88	1 = No sharing 1-value = x %*100 reduction 30 % shared; 40 % sharing impact
p_bts_mi_3	Microcell (3 sectors): Average investment for equipment (3 sectors)	Float	>=0	61,000	A\$
	Picocell				
p_bts_site_pi	Picocell (Site): Average investment for site acquisition, preparation, land and building	Float	>=0	69,000	A\$
sf_bts_site_pi	Sharing factor reflecting the average impact on investment due to sharing of a BTS Picocell site with other operators	Float	[0,1]	1	1 = No sharing 1-value = x %*100 reduction
p_bts_pi_3	Picocell (3 sectors): Average investment for equipment (3 sectors)	Float	>=0	46,000	A\$
p_trx	TRX: Average investment for one TRX	Float	>=0	8,000	A\$
	Other				
lic_gsm900	Frequency fee for GSM 900 p.a.	Float	>=0	20,432,602	A\$
lic_gsm1800	Frequency fee for GSM 1,800 p.a.	Float	>=0	0	A\$
di_gsm1800freq	Investment for GSM 1,800 frequencies	Float	>=0	96,542,023	A\$

Parameter Name	Description	Type	Range	Value	Comment
Base Station Controller (BSC)					
p_bsc_site	Average investment for site acquisition, preparation, land and building	Float	>=0	150,000	A\$
sf_bsc_site	Sharing factor reflecting the average impact on investment due to sharing of a BSC site with other operators	Float	[0,1]	1	1 = No sharing 1-value = x %*100 reduction
p_bsc_unit_hw	Average investment for hardware equipment (Base unit)	Float	>=0	2,177,000	A\$
p_bsc_unit_sw	Average investment for software equipment (Base unit)	Float	>=0	726,000	A\$, assumed to be 25 % of total equipment invest
cap_bsc_unit	Maximum number of TRXs which can be controlled by one BSC unit	Float	>=0	800	
Mobile Switching Centre (MSC)					
p_msc_site	Average investment for site acquisition, preparation, land and building	Float	>=0	2,052,000	A\$
sf_msc_site	Sharing factor reflecting the average impact on investment due to sharing of a MSC site with other operators	Float	[0,1]	1	1 = No sharing 1-value = x %*100 reduction
p_msc_hw	Average investment for hardware equipment (Base unit)	Float	>=0	2,766,000	A\$
p_msc_sw	Average investment for software equipment (Base unit)	Float	>=0	922,000	Assumed to be 25 % of total equipment invest
p_trau	Average investment per TRAU	Float	>=0	0	Included in hardware equipment of MSC
p_port	Average investment per 2 Mbps port	Float	>=0	3,000	A\$
p_sp	Average investment in signalling processor	Float	>=0	200,000	A\$
p_cp	Average investment per CPU	Float	>=0	200,000	A\$
max_ports	Maximum number of ports of one MSC base unit	Float	>=0	4,032	Number of ports
cp_bhca	Maximum number of BHCA per CPU	Float	>=0	270,000	Number of BHCA
sp_bhca	Maximum number of BHCA per signalling processor	Float	>=0	270,000	Number of BHCA
ur_sp	Average utilisation ratio of signalling processor	Float	[0,1]	0.80	%*100
ur_cp	Average utilisation ratio of central processor	Float	[0,1]	0.80	%*100
HLR					
p_hlr	HLR equipment unit	Float	>=0	2,721,000	A\$
max_hlr	Maximum number of registered subscribers per HLR unit	Float	>=0	1,200,000	Subscribers
ur_hlr	Average utilisation ratio of a HLR component	Float	[0,1]	0.80	%*100

Parameter Name	Description	Type	Range	Value	Comment
	Short Message Service Centre (SMSC)				
p_smsc	Investment in equipment and installation per SMSC unit	Float	>=0	1,821,000	A\$
max_smsc	Maximum capacity in terms of number of SMS per SMSC unit	Float	>=0	2,000,000	Number of SMS in busy hour
ur_smsc	Average utilisation ratio of a SMSC unit	Float	[0,1]	0.8	%*100
	Leased Lines				
p_ll2_loc	2 Mbps leased line (< 10 Km): annual cost per Km	Float	>=0	1,891	A\$
p_ll2f_loc	2 Mbps leased line (< 10 Km): Upfront payment for the provision per leased line	Float	>=0	3,750	A\$
p_ll2_reg	2 Mbps leased line (10 Km-150 Km): annual cost per Km	Float	>=0	641	A\$
p_ll2f_reg	2 Mbps leased line (10 Km-150 Km): Upfront payment for the provision per leased line	Float	>=0	3,750	A\$
p_ll2_id	2 Mbps leased line (> 150 Km): annual cost per Km	Float	>=0	131	A\$
p_ll2f_id	2 Mbps leased line (> 150 Km): Upfront payment for the provision per leased line	Float	>=0	3,750	A\$
p_ll155_loc	155 Mbps leased line (< 10 Km): annual cost per Km	Float	>=0	47,278	A\$
p_ll155f_loc	155 Mbps leased line (< 10 Km): Upfront payment for the provision per leased line	Float	>=0	40,408	A\$
p_ll155_reg	155 Mbps leased line (10 Km-150 Km): annual cost per Km	Float	>=0	16,023	A\$
p_ll155f_reg	155 Mbps leased line (10 Km-150 Km): Upfront payment for the provision per leased line	Float	>=0	40,408	A\$
p_ll155_id	155 Mbps leased line (> 150 Km): annual cost per Km	Float	>=0	3,271	A\$
p_ll155f_id	155 Mbps leased line (> 150 Km): Upfront payment for the provision per leased line	Float	>=0	40,408	A\$
p_ll155_core	155 Mbps leased line (Core): annual cost per Km	Float	>=0	1,246	A\$
p_ll155f_core	155 Mbps leased line (Core): Upfront payment for the provision per leased line	Float	>=0	40,408	A\$
	Radio Link Systems				
p_rl2	Investment per 2 Mbps radio link system	Float	>=0	28,000	A\$
p_rl8	Investment per 8 Mbps radio link system	Float	>=0	43,000	A\$
p_rl34	Investment per 34 Mbps radio link system	Float	>=0	65,000	A\$
p_rl140	Investment per 140 Mbps radio link system	Float	>=0	80,000	A\$

Parameter Name	Description	Type	Range	Value	Comment
p_rl_fee	One-off licence charge for PTP RL systems, per PTP	Float	>=0	474	A\$
p_khz_bts_btsh	Annual charge for frequency per kHz for PTP systems between BTS and BTS hub	Float	>=0	0.8943	A\$
p_khz_btsh-bsc	Annual charge for frequency per kHz for PTP systems between BTS hub and BSC	Float	>=0	0.8943	A\$
Repeater					
p_rl2_rep	Investment per repeater for a 2 Mbps radio link system	Float	>=0	28,000	A\$
p_rl8_rep	Investment per repeater for a 8 Mbps radio link system	Float	>=0	38,700	A\$
p_rl34_rep	Investment per repeater for a 34 Mbps radio link system	Float	>=0	58,500	A\$
p_rl140_rep	Investment per repeater for a 140 Mbps radio link system	Float	>=0	72,000	A\$
p_rep_site	Investment for a repeater site	Float	[0,1]	43,000	A\$
sf_rep	Sharing factor reflecting the average impact on investment due to sharing of a repeater site	Float	[0,1]	0.88	30 % of sites, 40 % sharing impact
Dist_rl	Maximum distance for radio transmission in Km for which a repeater is not required	Float	>=0	70	Km

Table A-2: Mark-ups for network support assets

Parameter Name	Description	Type	Range	Value %	Comment
iif_mv_bts	for BTS	Float	>=0	1	Motor vehicles
iif_mv_bsc	for BSC	Float	>=0	1	Motor vehicles
iif_mv_trau	for TRAU	Float	>=0	1	Motor vehicles
iif_mv_msc	for MSC	Float	>=0	1	Motor vehicles
iif_mv_hlr	for HLR	Float	>=0	1	Motor vehicles
iif_mv_smsc	for SMSC	Float	>=0	1	Motor vehicles
iif_mv_r12_bts_btsh	for BTS – BTS hub	Float	>=0	3	Motor vehicles
iif_mv_rlx_btsh_bsc	for BTS hub - BSC radio links	Float	>=0	3	Motor vehicles
iif_mv_ll2f_btsh_bsc	for BTS hub - BSC leased lines	Float	>=0	3	Motor vehicles
iif_mv_ll155f_bsc_msc	for BSC - MSC links	Float	>=0	3	Motor vehicles
iif_mv_ll155f_core	for MSC - MSC links	Float	>=0	3	Motor vehicles
iif_wo_bts	for BTS	Float	>=0	1	Workshop facilities, tools
iif_wo_bsc	for BSC	Float	>=0	1	Workshop facilities, tools
iif_wo_trau	for TRAU	Float	>=0	1	Workshop facilities, tools
iif_wo_msc	for MSC	Float	>=0	1	Workshop facilities, tools
iif_wo_hlr	for HLR	Float	>=0	1	Workshop facilities, tools
iif_wo_smsc	for SMSC	Float	>=0	1	Workshop facilities, tools
iif_wo_r12_bts_btsh	for BTS – BTS hub	Float	>=0	1	Workshop facilities, tools
iif_wo_rlx_btsh_bsc	for BTS hub - BSC radio links	Float	>=0	1	Workshop facilities, tools
iif_wo_ll2f_btsh_bsc	for BTS hub - BSC leased lines	Float	>=0	1	Workshop facilities, tools
iif_wo_ll155f_bsc_msc	for BSC - MSC links	Float	>=0	1	Workshop facilities, tools
iif_wo_ll155f_core	for MSC - MSC links	Float	>=0	1	Workshop facilities, tools
iif_of_bts	for BTS	Float	>=0	0.50	Office equipment
iif_of_bsc	for BSC	Float	>=0	0.50	Office equipment
iif_of_trau	for TRAU	Float	>=0	0.50	Office equipment
iif_of_msc	for MSC	Float	>=0	0.50	Office equipment
iif_of_hlr	for HLR	Float	>=0	0.50	Office equipment
iif_of_smsc	for SMSC	Float	>=0	0.50	Office equipment

Parameter Name	Description	Type	Range	Value %	Comment
iif_of_rl2_bts_btsh	for BTS – BTS hub	Float	>=0	0.50	Office equipment
iif_of_rlx_btsh_bsc	for BTS hub - BSC radio links	Float	>=0	0.50	Office equipment
iif_of_ll2f_btsh_bsc	for BTS hub - BSC leased lines	Float	>=0	0.50	Office equipment
iif_of_ll155f_bsc_msc	for BSC - MSC links	Float	>=0	0.50	Office equipment
iif_of_ll155f_core	for MSC - MSC links	Float	>=0	0.50	Office equipment
iif_lb_bts	for BTS	Float	>=0	1	Land and buildings
iif_lb_bsc	for BSC	Float	>=0	1	Land and buildings
iif_lb_trau	for TRAU	Float	>=0	1	Land and buildings
iif_lb_msc	for MSC	Float	>=0	1	Land and buildings
iif_lb_hlr	for HLR	Float	>=0	1	Land and buildings
iif_lb_smsc	for SMSC	Float	>=0	1	Land and buildings
iif_lb_rl2_bts_btsh	for BTS – BTS hub	Float	>=0	1	Land and buildings
iif_lb_rlx_btsh_bsc	for BTS hub - BSC radio links	Float	>=0	1	Land and buildings
iif_lb_ll2f_btsh_bsc	for BTS hub - BSC leased lines	Float	>=0	1	Land and buildings
iif_lb_ll155f_bsc_msc	for BSC - MSC links	Float	>=0	1	Land and buildings
iif_lb_ll155f_core	for MSC - MSC links	Float	>=0	1	Land and buildings
iif_it_bts	for BTS	Float	>=0	2	General IT
iif_it_bsc	for BSC	Float	>=0	2	General IT
iif_it_trau	for TRAU	Float	>=0	2	General IT
iif_it_msc	for MSC	Float	>=0	2	General IT
iif_it_hlr	for HLR	Float	>=0	2	General IT
iif_it_smsc	for SMSC	Float	>=0	2	General IT
iif_it_rl2_bts_btsh	for BTS – BTS hub	Float	>=0	2	General IT
iif_it_rlx_btsh_bsc	for BTS hub - BSC radio links	Float	>=0	2	General IT
iif_it_ll2f_btsh_bsc	for BTS hub - BSC leased lines	Float	>=0	2	General IT
iif_it_ll155f_bsc_msc	for BSC - MSC links	Float	>=0	2	General IT
iif_it_ll155f_core	for MSC - MSC links	Float	>=0	2	General IT
iif_nm_bts	for BTS	Float	>=0	2	Network management

Parameter Name	Description	Type	Range	Value %	Comment
iif_nm_bsc	for BSC	Float	>=0	2	Network management
iif_nm_trau	for TRAU	Float	>=0	2	Network management
iif_nm_msc	for MSC	Float	>=0	2	Network management
iif_nm_hlr	for HLR	Float	>=0	2	Network management
iif_nm_smsc	for SMSC	Float	>=0	2	Network management
iif_nm_rl2_bts_btsh	for BTS – BTS hub	Float	>=0	2	Network management
iif_nm_rlx_btsh_bsc	for BTS hub - BSC radio links	Float	>=0	2	Network management
iif_nm_ll2f_btsh_bsc	for BTS hub - BSC leased lines	Float	>=0	2	Network management
iif_nm_ll155f_bsc_msc	for BSC - MSC links	Float	>=0	2	Network management
iif_nm_ll155f_core	for MSC - MSC links	Float	>=0	2	Network management

Table A-3: OPEX mark-ups

Parameter Name	Description	Type	Range	Value %	Comment
ocf_bts	OPEX: BTS	Float	>=0	11	
ocf_bsc	OPEX: BSC	Float	>=0	11	
ocf_trau	OPEX: TRAU	Float	>=0	11	
ocf_msc	OPEX: MSC	Float	>=0	11	
ocf_hlr	OPEX: HLR	Float	>=0	11	
ocf_smsc	OPEX: SMSC	Float	>=0	11	
ocf_bts_btsh	OPEX: BTS-BTS hub links	Float	>=0	11	
ocf_rl_btsh_bsc	OPEX: BTS hub-BSC ladio links	Float	>=0	11	
ocf_ll2f_btsh_bsc	OPEX: BTS hub-BSC leased lines	Float	>=0	11	
ocf_ll155f_bsc_msc	OPEX: BSC-MSC link	Float	>=0	11	
ocf_ll155f_core	OPEX: MSC-MSC link	Float	>=0	11	
ocf_mv	OPEX: Motor vehicles	Float	>=0	10	
ocf_wo	OPEX: Workshop facilities	Float	>=0	10	
ocf_of	OPEX: Office equipment	Float	>=0	10	
ocf_lb	OPEX: Land and buildings	Float	>=0	5	
ocf_it	OPEX: IT /General purpose computers	Float	>=0	10	
ocf_nm	OPEX: Network management	Float	>=0	30	

Table A-4: WACC and parameters for traffic annualisation

Parameter Name	Description	Type	Range	Value	Comment
	WACC				
WACC	WACC	Float	>=0	11.68 %	
sf_BH_day	Percentage of Busy Hour traffic per day	Float	>=0	8.5 %	
n_days	Number of relevant days per year	Float	>=0	250	

Table A-5: Mark-ups for common organisational-level cost

Parameter Name	Mark-up for common organisational-level cost	Type	Range	Value	Comment
coco_fix	Annual common organisational-level cost	Float	>=0	5,500,000	A\$
coco	Mark-up for common organisational-level cost	Float	>=0	10 %	

Table A-6: Growth rate for mobile service network elements

Parameter Name	Growth rate for mobile service network elements	Type	Range	Value %	Comment
g_bts_site	Growth rate: BTS site	Float	>=0	5	
g_bts_eq	Growth rate: BTS equipment	Float	>=0	0	
g_trx	Growth rate: TRX	Float	>=0	0	
g_gsm1800freq	Growth rate: GSM 1,800 frequency	Float	>=0	5	
g_bsc_site	Growth rate: BSC site	Float	>=0	5	
g_bsc_unit_hw	Growth rate: BSC Unit Hardware	Float	>=0	0	
g_bsc_unit_sw	Growth rate: BSC Unit Software	Float	>=0	0	
g_trau	Growth rate: TRAU	Float	>=0	0	
g_msc_site	Growth rate: MSC site	Float	>=0	5	
g_msc_hw	Growth rate: MSC Hardware	Float	>=0	0	
g_msc_sw	Growth rate: MSC software	Float	>=0	0	
g_ports	Growth rate: Ports	Float	>=0	0	
g_hlr	Growth rate: HLR	Float	>=0	5	
g_smsc	Growth rate: SMSC	Float	>=0	0	
g_rl2	Growth rate: BTS-BTS hub Radio Links	Float	>=0	5	
g_rlx_btsh_bsc	Growth rate: BTS hub-BSC Radio Links	Float	>=0	5	
g_rep_btsh_bsc	Growth rate: BTS hub-BSC repeater	Float	>=0	5	
g_rep_site	Growth rate: Repeater site	Float	>=0	5	
g_LL2f_btsh_bsc	Growth rate: BTS hub-BSC	Float	>=0	0	
g_LL155f_bsc_msc	Growth rate: BSC-MSC	Float	>=0	0	
g_LL155f_core	Growth rate: MSC-MSC	Float	>=0	0	
g_mv	Growth rate: Motor vehicles	Float	>=0	2	
g_of	Growth rate: Office equipment	Float	>=0	2	
g_wo	Growth rate: Workshop facilities	Float	>=0	2	
g_it	Growth rate: IT / General purpose computers	Float	>=0	2	
g_nm	Growth rate: Network management	Float	>=0	2	
g_lb	Growth rate: Buildings	Float	>=0	2	

Table A-7: Annual rates of price change

Parameter Name	Description	Type	Range	Value %	Comment
dp_bts_site	BTS site	Float	>=0	1.10	Based on data from ABS cost index
dp_bts_eq	BTS equipment	Float	>=0	-3.20	
dp_trx	TRX	Float	>=0	-3.20	
dp_gsm1800freq	GSM 1,800 Frequency	Float	>=0	0	
dp_bsc_site	BSC site	Float	>=0	1.10	Based on data from ABS cost index
dp_bsc_unit_hw	BSC_unit_hw	Float	>=0	-1.50	
dp_bsc_unit_sw	BSC_unit_sw	Float	>=0	-4.75	Based on data from ABS cost index
dp_trau	TRAU	Float	>=0	-1.50	
dp_msc_site	MSC site	Float	>=0	1.10	Based on data from ABS cost index
dp_bsc_unit_hw	MSC_unit_hw	Float	>=0	-3.20	
dp_bsc_unit_sw	MSC_unit_sw	Float	>=0	-4.75	Based on data from ABS cost index
dp_ports	MSC ports	Float	>=0	-1.50	
dp_hlr	HLR	Float	>=0	-1.50	
dp_smsc	SMSC	Float	>=0	-1.50	
dp_rl2	BTS-BTS hub radio link	Float	>=0	-3.20	
dp_rlx_btsh_bsc	BTS hub-BSC radio link	Float	>=0	-3.20	
dp_rep_btsh_bsc	BTS hub-BSC repeater	Float	>=0	-3.20	
dp_rep_site	Repeater site	Float	>=0	1.10	
dp_ll2f_btsh_bsc	BTS hub-BSC leased line	Float	>=0	1.50	
dp_ll155f_bsc_msc	BSC-MSC leased line	Float	>=0	1.50	
dp_ll155f_core	MSC-MSC leased line	Float	>=0	1.50	
dp_mv	Motor vehicles	Float	>=0	2.00	
dp_wo	Workshop facilities	Float	>=0	2.00	
dp_of	Office equipment	Float	>=0	2.00	
dp_lb	Buildings	Float	>=0	1.10	
dp_it	IT /General purpose computers	Float	>=0	-4.75	Based on data from ABS cost index
dp_nm	Network management	Float	>=0	2.00	

Table A-8: Economic lifetimes

Parameter Name	Description	Type	Range	Value (years)	Comment
el_bts_site	BTS site	Int	>=0	15	
el_bts_eq	BTS equipment	Int	>=0	8	
el_trx	BTS TRX	Int	>=0	8	
el_gsm1800freq	GSM 1,800 frequency	Int	>=0	15	
el_bsc_site	BSC site	Int	>=0	15	
el_bsc_unit_hw	BSC unit hardware	Int	>=0	8	
el_bsc_unit_sw	BSC unit software	Int	>=0	5	
el_trau	TRAU	Int	>=0	8	
el_msc_site	MSC site	Int	>=0	15	
el_msc_hw	MSC unit hardware	Int	>=0	8	
el_msc_sw	MSC unit software	Int	>=0	5	
el_ports	MSC Ports	Int	>=0	8	
el_hlr	HLR	Int	>=0	6	
el_smsc	SMSC	Int	>=0	8	
el_rl2	BTS-BTS hub radio link	Int	>=0	8	
el_rlx_btsh_bsc	BTS hub-BSC radio link	Int	>=0	8	
el_rep_site	Repeater site	Int	>=0	15	
el_rep_btsh_bsc	BTS hub-BSC repeater	Int	>=0	10	
el_ll2f_btsh_bsc	BTS hub-BSC leased line	Int	>=0	8	
el_ll155f_bsc_msc	BSC-MSC leased line	Int	>=0	8	
el_ll155f_core	MSC-MSC leased line	Int	>=0	8	
el_mv	Motor vehicles	Int	>=0	5	
el_wo	Workshop facilities	Int	>=0	5	
el_of	Office equipment	Int	>=0	6	
el_lb	Buildings	Int	>=0	15	
el_it	IT /General purpose computers	Int	>=0	5	
el_nm	Network management	Int	>=0	5	

Annex B: Input parameter of the network planning module

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Table B-1: Construction of Basic Input Data (ScenCreator)

Parameter Name	Description	Type	Range	Value	Comment
do_exclusion	Boolean variable that defines if some POA are excluded	Bool	{0,1}	1	
threshold_exclusion	Inhabitants threshold for the exclusion	Int	≥ 0	3,500	Value depends on the scenario
do_aggregation	Boolean variable that defines if some POA are aggregated to define districts	Bool		1	
n_aggdenstth_mi	Daily inhabitants density threshold (minimum)	Int	≥ 0	100	inhab/Km2
n_aggdistth_mi	Distance threshold (minimum)	Int	≥ 0	20	in Km
n_aggdenstth_me	Daily inhabitants density threshold (medium)	Int	≥ 0	500	inhab/Km2
n_aggdistth_me	Distance threshold (medium)	Int	≥ 0	10	in Km
n_aggdenstth_ma	Daily inhabitants density threshold (maximum)	Int	≥ 0	1,000	inhab/Km2
n_aggdistth_ma	Distance threshold (maximum)	Int	≥ 0	5	in Km

Table B-2: Cell deployment (General Inputs)

Parameter Name	Description	Type	Range	Value	Comment
fl_1bulf	1st band uplink frequency. (>0) [MHz]	Double	[900...1,800]	900	
fl_1bdlf	1st band downlink frequency. (>0). [MHz]. fl_1bulf & fl_1bdlf must be in the same band	Double	[900...1,800]	900	
b_2b	0: One band ; 1: Dual band	Bool	{0,1}	1	
fl_2bulf *	2nd band uplink frequency. (>0). [MHz]	Double	[900...1,800]	1,800	
fl_2bdlf *	2nd band downlink frequency. (>0). [MHz]. fl_2bulf & fl_2bdlf must be in the same band	Double	[900...1,800]	1,800	
fl_ffm	Fast fading margin. Range = (-1000, +1000) [dB]	Double	[0...7]	0	Unchangeable parameter
fl_lnm	Log. Normal fading margin. Range = (-1000, +1000) [dB]	Double	[0...15]	10	Unchangeable parameter
fl_lm	Interference margin. Range = (-1000, +1000) [dB]	Double	[0...6]	0	Unchangeable parameter
Fl_build_loss	Average building penetration loss. Range = (-1000, +1000) [dB]	Double	[5...25]	20	Unchangeable parameter
Fl_sub_reduction	Building loss suburban reduction factor. (0-1)	Double	{0,1}	0.75	Unchangeable parameter
Fl_rural_reduction	Building loss rural reduction factor. (0-1)	Double	{0,1}	0.75	Unchangeable parameter
fl_perc_urban	Percentage of urban area coverage	Double	[0...1]	1	
fl_perc_suburban	Percentage of suburban area coverage	Double	[0...1]	1	
fl_perc_rural	Percentage of rural area coverage	Double	[0...1]	0.85	
fl_minimum_density	Minimum population density evaluative	Double	≥ 0	10	Threshold for one BTS per district
fl_picocell_incr_f	Picocell increment factor	Double	≥ 0	0.2	
N_zone_type	0: block zones; 1: anular zones	Bool	[0...1]	1	Currently fixed to 1 for block zones

Table B-3: Cell Deployment (BTS information)

Parameter Name	Description	Type	Range	Value	Comment
n_models	Number of BTS models	int	≥ 0	12	Unchangeable parameter
n_radioch	Number of radio channels. (n_radioch- n_handover- n_signalling > 0)	Int	8	8	The number of channels of the GSM frame Unchangeable parameter
n_handover	Number of handover channels	Int	[0-2]	1	Unchangeable parameter
n_signalling	Number of signalling channels	Int	[0-2]	1	Unchangeable parameter
fl_btsubpower_tx	Transmission power in urban area (>0) [W]	Double	≥ 0	0.25/1/10	The values represent: Pico cell / Micro cell / Macro cell Unchangeable parameter
fl_btssubpower_tx	Transmission power in suburban area (>0) [W]	Double	≥ 0	0.25/1/10	Unchangeable parameter
fl_btsrpower_tx	Transmission power in rural area (>0) [W]	Double	≥ 0	0.25/1/10	Unchangeable parameter
fl_btsFnoise_rx	Receiver total noise figure. Range = (-1000, +1000) [dB]	Double	≥ 0	2	Unchangeable parameter
fl_Lossables	Cable losses. Range = (-1000, +1000) [dB]	Double	≥ 0	3	Unchangeable parameter
fl_Losscomb	Losses in the combiners. Range = (-1000, +1000) [dB]	Double	≥ 0	0	Unchangeable parameter
fl_acoupler	Losses in couplers. Range = (-1000, +1000) [dB]	Double	≥ 0	0	Unchangeable parameter
fl_bts_gain_pre	Pre-amplifier gain. Range = (-1000, +1000) [dB]	Double	≥ 0	3	Unchangeable parameter
fl_bts_gain_rx	Transmitter antenna gain. Range = (-1000, +1000) [dB]	Double	≥ 0	18	Unchangeable parameter
fl_bts_gain_tx	Receiver antenna gain. Range = (-1000, +1000) [dB]	Double	≥ 0	18	Unchangeable parameter
fl_bts_prio	Priority factor of the BTS	Double	≥ 0	[70...160]	Depending on BTS type Unchangeable parameter
n_max_sect	Maximum number of sectors. (>0)	Int	≥ 0	[min-3]	Depending on BTS type Unchangeable parameter
n_min_sect	Minimum number of sectors. (>0). (n_max_sect - n_min_sect ≥ 0)	Int	≥ 0	[1-3]	Depending on BTS type Unchangeable parameter
n_trxurb	Number of TRXs per sector in urban area. (>0)	int	≥ 0	[1-3]	Depending on BTS type Unchangeable parameter
n_trxsurb	Number of TRXs per sector in suburban area. (>0)	int	≥ 0	[1-3]	Depending on BTS type Unchangeable

Parameter Name	Description	Type	Range	Value	Comment
n_trxres	Number of TRXs per sector in rural area. (>0)	int	≥0	[1-3]	Depending on BTS type Unchangeable parameter
b_av_urb	BTS type available in urban area. (0:No, 1:Yes)	Bool	{0,1}	1/0/0	Picocell/Microcell/Macrocell
b_av_surb	BTS type available in suburban area. (0:No, 1:Yes)	Bool	{0,1}	0/1/0	Picocell/Microcell/Macrocell
b_av_res	BTS type available in rural area. (0:No, 1:Yes)	Bool	{0,1}	0/1/1	Picocell/Microcell/Macrocell
b_av_dualb	BTS type available for dual band. (0:No, 1:Yes)	Bool	{0,1}	1/1/1	For all
b_av_ur_inr	BTS type available for urban increment	Bool	{0,1}	1/0/0	Picocell/Microcell/Macrocell

Table B-4: Cell Deployment (District parameters)

Parameter Name	Description	Type	Range	Value	Comment
n_district	Number of districts	int	≥ 0		Unchangeable parameter
n_excpoa	Number of excluded Postal Area Codes	int	≥ 0		Unchangeable parameter
n_aggpoa	Number of aggregated Postal Area Codes.	int	≥ 0		Unchangeable parameter
n_pop	Total population in the scenario	int	≥ 0		Unchangeable parameter
fl_popcov	Population coverage	Double	{0..100}	92-98	Unchangeable parameter
fl_ormodpopratio	Increment ratio of population	Double	≥ 1	1.15	Unchangeable parameter
For each District					Unchangeable parameter
First Line					Unchangeable parameter
District_name	Name of the city or postal district	string			Unchangeable parameter
Second Line					Unchangeable parameter
n_cityid	City identifier	int	{800-7470}		POA of the Centre of the District Unchangeable parameter
n_hab	Number of inhabitants of the city or District (≥ 0)	int	≥ 0		Unchangeable parameter
n_ext_type	0: Radial; 1: Extensión	bool	[0,1]	1	Unchangeable parameter
fl_ext	Radius in Km / extension in Km2 of the city (≥ 0)	Double	≥ 0		In Km2 Unchangeable parameter
fl_dutper	Percentage of dense urban terrain	Double	{0-100}		Unchangeable parameter
fl_sutper	Percentage of suburban terrain	Double	{0-100}		Unchangeable parameter
fl_restper	Percentage of rural terrain	Double	{0-100}		Unchangeable parameter
fl_dupper	Percentage of urban population	Double	{0-100}		Unchangeable parameter
fl_supper	Percentage of suburban population	Double	{0-100}		Unchangeable parameter
fl_respper	Percentage of rural population	Double	{0-100}		Unchangeable parameter
fl_flatper	Percentage of the area in a flat terrain	Double	{0-100}		Unchangeable parameter
fl_hilltper	Percentage of the area in a hilly terrain	Double	{0-100}		Unchangeable parameter
fl_montper	Percentage of the area in a mountainous terrain	Double	{0-100}		Unchangeable parameter

Parameter Name	Description	Type	Range	Value	Comment
n_bheight	Average building height in a high building concentration area (m)	int	≥ 0	45/25/10	Urban/suburban/rural Unchangeable parameter
n_bheightl	Average building height in a low building concentration area (m)	int	≥ 0	45/25/10	Urban/suburban/rural Unchangeable parameter
n_btsheight	BTS height in a high building concentration area (m) (n_bheight + n_btsheight > 0)	int	≥ 0	15/15/30	Urban/suburban/rural Unchangeable parameter
n_btsheightl	BTS height in a low building concentration area (m) (n_bheightl + n_btsheightl > 0)	int	≥ 0	15/15/30	Urban/suburban/rural Unchangeable parameter
n_cityproptype	Type of city for radio propagation studies	int	[0...6]		Used for propagation issues Unchangeable parameter
fl_tLoss	Terrain loss by orography. Range = (-1000, +1000) [dB]	Double	[0...10]	1.79	Unchangeable parameter
n_intcelltech	Type of cellular technology: 0 TDMA, 1 CDMA 2 W-CDMA	int	0	0	For future use (not implemented) Unchangeable parameter
fl_x	X Coordinate in UTM or degrees	Double			Depends on the city Unchangeable parameter
fl_y	Y Coordinate in UTM or degrees	Double			Depends on the city Unchangeable parameter

Table B-5: Cell Deployment (Voice & Data Services)

Parameter Name	Description	Type	Range	Value	Comment
fl_ratevoice_on	Percentage per user of On-Net voice traffic	Double	[0,100]	22.6	This value and the ones of the following 7 rows must sum up 100
fl_ratevoice_off_in	Percentage per user of Incoming Off-Net voice traffic	Double	[0,100]	35.7	
fl_ratevoice_off_out	Percentage per user of Outgoing Off-Net voice traffic	Double	[0,100]	35.7	
fl_ratgprs	Percentage per user of GPRS traffic	Double	[0,100]	3	Given in equivalent voice traffic
fl_ratehscsd	Percentage per user of HSCSD traffic	Double	[0,100]	0.835	Given in equivalent voice traffic
fl_ratemodem	Percentage per user of Modem traffic	Double	[0,100]	2	Given in equivalent voice traffic
fl_ratesms	Percentage per user of SMS traffic	Double	[0,100]	0.11	Given in equivalent voice traffic
fl_ratemms	Percentage per user of MMS traffic	Double	[0,100]	0.055	Given in equivalent voice traffic
fl_voice_lambda_on	Call origination and termination rate in the BH for On-Net voice service [calls in BH]	Double	≥ 0	0.07761	Unchangeable parameter
fl_voice_ts_on	Service time for On-Net voice service [sec]	Double	≥ 0	87	Unchangeable parameter
fl_voice_lambda_off_inc	Call origination and termination rate in the BH for Off-Net Incoming voice service [calls in BH]	Double	≥ 0	0.12261	Unchangeable parameter
fl_voice_ts_off_inc	Service time for Off-Net Incoming voice service [sec]	Double	≥ 0	87	Unchangeable parameter
fl_voice_lambda_off_out	Call origination and termination rate in the BH for Off-Net Outgoing voice service [calls in BH]	Double	≥ 0	0.12261	Unchangeable parameter
fl_voice_ts_off_out	Service time for Off-Net outgoing voice service [sec]	Double	≥ 0	87	Unchangeable parameter
n_gprs_ns	Average number of slots used in GPRS connection	Integer	≥ 0	2	Unchangeable parameter
fl_gprs_lp	GPRS data packet length [bytes]	Double	≥ 0	50	Unchangeable parameter
fl_gprs_np	Average number of packets transmitted in GPRS connection	Double	≥ 0	4000	Unchangeable parameter
fl_gprs_lambda	GPRS connection rate in the BH [connections / hour]	Double	≥ 0	0.01120	Unchangeable parameter
fl_gprs_ts	Service time for GPRS connection in the BH [s]	Double	≥ 0	0.02777	Unchangeable parameter
n_hscsd_ns	Average number of slots used in HSCSD connection	Integer	≥ 0	2	Unchangeable parameter
fl_hscsd_lambda	HSCSD connection rate in the BH [connections / hour]	Double	≥ 0	0.00069	Unchangeable parameter

Parameter Name	Description	Type	Range	Value	Comment
fl_hscsd_ts	Service time for HSCSD [s]	Double	≥ 0	180	Unchangeable parameter
fl_data_lambda	Basic data connection rate (MODEM) [connections/hour]	Double	≥ 0	0.00332	Unchangeable parameter
fl_data_ts	Basic data service time (MODEM) [s]	Double	≥ 0	180	Unchangeable parameter
n_sms_length	SMS message length. [bytes]	Integer	≥ 0	125	Unchangeable parameter
fl_sms_lambda	SMS sending rate [sms/hour]	Double	≥ 0	0.31553	Unchangeable parameter
n_mms_ns	Average number of slots used in GPRS/MMS connection	Integer	≥ 0	2	Unchangeable parameter
n_mms_length	MMS message length [bytes]	integer	≥ 0	600	Unchangeable parameter
fl_mms_lambda	MMS sending rate [MMS/hour]	Double	≥ 0	0.06847	Unchangeable parameter
fl_avumov	Average user movement speed [Km/h]	Double	≥ 0	3	
fl_ms	Operator's market share	Double	[0,1]	0.18; 0.25; 0.31; 0.46	Depends on the scenario
fl_mp	Mobile market penetration in the country	Double	[0,1]	0.96	
fl_blockprob	Service blocking probability	Double	[0,1]	0.02	

Table B-6: Cell Deployment (Mobile Station Parameters)

Parameter Name	Description	Type	Range	Value	Comment
Fl_tx_power	Mobile transmission power. [W]	Double	≥ 0	1	
Fl_mobile_height	Mobile average height [metres]	Double	≥ 0	1.5	
Fl_rx_noise	Mobile receiving noise figure. [dB]	Double	[-1000, 1000]	2	
Fl_gain	Mobile antenna gain [dB]	Double	[-1000, 1000]	0	
Fl_skin_loss	Mobile skin loss [dB]	Double	[-1000, 1000]	4	
Fl_mismatch	Mobile mismatch [dB]	Double	[-1000, 1000]	2	

Table B-7: Aggregation Network

Parameter Name	Description	Type	Range	Value	Comment
n_bsc	Number of BSC locations	integer	>1	20	
btsmax	Maximum number of BTS assignable to a BSC location	integer	>btsmin	200	Note that at a BSC location if required more than one BSC equipment might be assigned in case of a high value of this parameter
btsmin	Minimum number of BTS assignable to a BSC location	integer	≥0		Currently calculated endogenously without external limitation
epsilon	Distance increment factor for re-assignment	real	≥0	1	Internal parameter. Should be kept unchanged
dmin	Minimum distance between BSC location [Km]	real	>0	80	If this value is too high no solution is found and a warning message appears
nlbscmax	Maximum number of links connected to a BSC	integer	≥1	10000	Currently calculated endogenously without external limitation Unchangeable parameter
nlbtsmax	Maximum number of links connected to a BTS district (excluding internal radiolinks)	integer	≥0	10000	Currently calculated endogenously without external limitation Unchangeable parameter
alpha	Penalty factor for number of hops	real	≥0	1	Determines the relationship between leased line DSG and radio links
maxcdsgbts	Maximum number of circuits assigned to a DSG group on a BTS- BTS hub link	real	[1, 30]	28	Two free circuits considered for network resilience
maxcdsglink	Maximum number of circuits assigned to a DSG group on a BTS hub – BSC link	real	[1, 30]	28	Two free circuits considered for network resilience

Table B-8: Backhaul Network

Parameter Name	Description	Type	Range	Value	Comment
n_msc	Number of MSC locations	integer	[1, 10]	5	
usermax	Maximum number of users assignable to a MSC location	integer	\geq usermin	2,000,000	This value must be larger than the maximum number of users assigned to a BSC location to be found in the numerical analysis of the aggregation network. If this not the case the tool shows a warning message
usermin	Minimum number of users assignable to a MSC	integer	≥ 0	0	Currently calculated endogenously without external limitation Unchangeable parameter
epsilon	Distance increment factor for re-assignment	real	>0	1	Internal parameter. Shall be kept unchanged.
dmin	Minimum distance between MSC locations [Km]	real	>0	300	If this value is too large no solution is found; then the minimum value is always equal to the minimum distance between BSC locations
maxcdsg	Maximum number of circuits per DSG	integer	[1, 30]	28	Two free circuits considered for network resilience

Table B-9: Core Network

Parameter Name	Description	Type	Range	Value	Comment
n_vintc	Number of MSC locations with voice interconnection	integer	[1, n_msc]	5	This value must be at least one and not larger than the number of MSC locations.
n_dintc	Number of MSC locations with data service interconnection	integer	[1, n_msc]	5	This value must be at least one and not larger than the number of MSC locations.
n_mintc	Number of MSC locations with message service centre	integer	[1, n_msc]	1	This value must be at least one and not larger than the number of MSC locations.
block_vintc	Blocking probability for voice on voice interconnection facility	Real	[0, 1)	0.01	
block_dintc	Blocking probability for data on data interconnection facility	Real	[0, 1)	0.01	
block_core	Blocking probability on core links	Real	[0, 1)	0.01	
rho_mint	Use degree of the capacity for access to the SMS&MMS server	Real	[0, 1)	0.7	Must always be lower than one, the used value provides network resilience
maxcdsg	Maximum number of circuits per DSG	integer	[1, 30]	28	Two free circuits considered for network resilience
wtrafred	Traffic reduction for links between East and West locations	Real	[0, 1)	0.1	Considers the local time difference between the East and the West coast

Annex C: Interest rates on Government bonds with 10 years maturity

	USA	Euro-Zone	Singapore	Australia
4 Q. 1998	4.67	4.15	4.49	4.99
1 Q. 1999	4.98	3.99	4.34	5.35
2 Q. 1999	5.50	4.26	4.34	5.93
3 Q. 1999	5.89	5.05	4.72	6.30
4 Q. 1999	6.14	5.32	4.58	6.74
1 Q. 2000	6.48	5.62	4.32	6.72
2 Q. 2000	6.17	5.43	4.44	6.27
3 Q. 2000	5.89	5.44	4.52	6.24
4 Q. 2000	5.56	5.28	4.20	5.80
1 Q. 2001	5.05	4.99	3.63	5.28
2 Q. 2001	5.28	5.19	3.61	5.95
3 Q. 2001	4.99	5.12	3.53	5.71
4 Q. 2001	4.77	4.82	3.48	5.61
1 Q. 2002	5.08	5.14	3.90	6.09
2 Q. 2002	5.10	5.25	3.85	6.09
3 Q. 2002	4.27	4.76	3.51	5.63
4 Q. 2002	4.01	4.54	2.85	5.48
1 Q. 2003	3.92	4.15	2.24	5.19
2 Q. 2003	3.62	3.96	2.09	5.05
3 Q. 2003	4.23	4.16	3.44	5.43
4 Q. 2003	4.29	4.37	3.91	5.77
1 Q. 2004	4.02	4.15	3.27	5.62
2 Q. 2004	4.56	4.32	3.42	5.89
3 Q. 2004	4.30	4.19	3.39	5.62
4 Q. 2004	4.18	3.83	2.86	5.32
1 Q. 2005	4.30	3.65	3.04	5.55
2 Q. 2005	4.16	3.38	2.71	5.20
3 Q. 2005	4.21	3.24	2.76	5.18
4 Q. 2005	4.48	3.40	3.15	5.35
1 Q. 2006	4.57	3.55	3.48	5.35
2 Q. 2006	5.07	4.03	3.50	5.73
3 Q. 2006	4.90	3.96	3.37	5.67
Average	4.83	4.46	3.59	5.69

Sources:

USA: <http://research.stlouisfed.org/fred2/series/GS10/downloaddata?&cid=115>

EURO-Zone: http://epp.eurostat.ec.europa.eu/portal/page?_pageid=1996,45323734&_dad=portal&_schema=PORTAL&screen=welcomeref&open=/economy/exint/intr/Longterm/mat_y10&language=en&product=EU_MAIN_TREE&root=EU_MAIN_TREE&scrollto=228

Singapore: http://www.sgs.gov.sg/sgs_data/data_hprices.html

Australia: http://www.rba.gov.au/Statistics/AlphaListing/alpha_listing_g.html

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