

Final report for OPTA



Mobile BULRIC model
documentation

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0 Introduction

This document accompanies the release of the final bottom-up long-run incremental cost (BULRIC) model by OPTA as part of its draft national consultation in June 2006.

The final cost model specifies in detail the demand, network and service costing parts of the hypothetical new entrant model. A schematic of the model is shown in Exhibit 1.

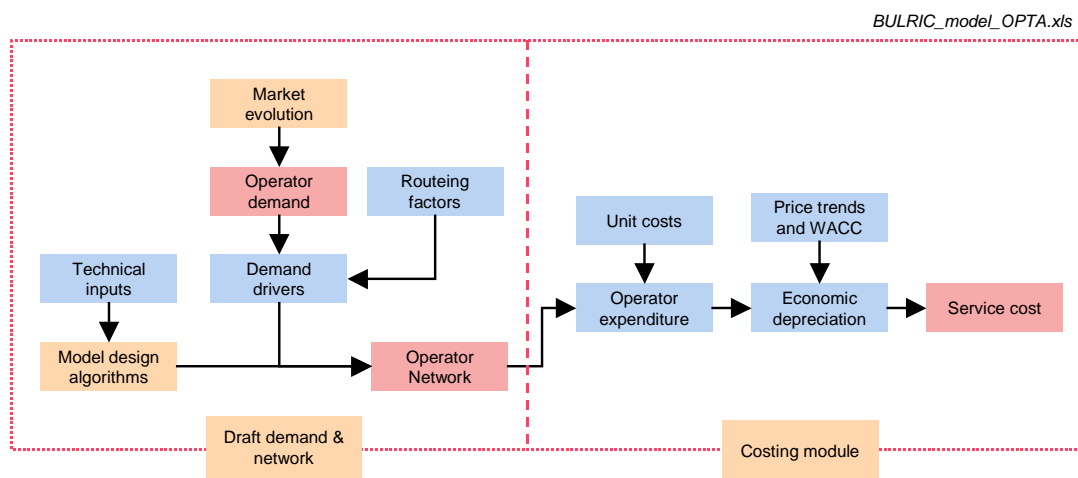


Exhibit 1: Model schematic [Source: Analysys]

In the final cost model, the demand, network and costing components are populated in detail with our final data, estimates and assumptions that are appropriate for the hypothetical network operator’s deployment. The costing calculations in the final cost model are fully populated with final data, estimates and assumptions on unit prices, price trends, WACC and common/incremental asset splits.

This documentation therefore covers the whole model:

- Section 1 explains how to install and run the model
- Section 2 provides a quick reference to the main inputs of the final model
- Section 3 describes the assumptions and structure of the demand module
- Section 4 details the network design algorithms of the network module
- Section 5 describes the expenditure calculations
- Section 6 explains the cost annualisation calculations
- Section 7 details the service costing calculations.

1 Installing and running the model

This section presents the basic operation of the model.

1.1 Model workbooks

The model is presented in a single Excel workbook, called *BULRIC_model_OPTA_final_v3.xls*. There are no external links or macros. The model has been developed using Microsoft Excel 2000. Although it should be compatible with newer versions of Excel, some of the features may differ slightly.

The structure of the Excel workbook is detailed in Exhibit 2:

<i>Sheet name</i>	<i>Description</i>	<i>Sheet name</i>	<i>Description</i>
<i>Con</i>	Description of contents	<i>Full_Nw</i>	Network requirements in each year
<i>V.H</i>	Version history	<i>Dem_In</i>	Transposition of service demand and definition of the GSM-specific recovery profiles
<i>Style</i>	Style guide	<i>RouFac</i>	Network elements routing factors
<i>Lists</i>	Definition of lists commonly used in the model	<i>NwEle_Out</i>	Element output – routed service demand
<i>Sensitivities</i>	Presentation of a number of sensitivity tests	<i>CostTrends</i>	Real term cost trends and output weighted by cost trends
<i>Area</i>	High-level geographic database of the Netherlands	<i>NwDeploy</i>	Purchasing algorithms – expenditure schedule in function of network requirements
<i>Market</i>	Market and demand scenario – subscribers and traffic	<i>DiscFacs</i>	WACC and discount factors for PV calculations
<i>Lifetime_In</i>	Assets economic lifetime and planning period	<i>UnitCapex</i>	Forward-looking unit capex
<i>Cov&Dem_In</i>	Coverage area and demand inputs per geotype	<i>TotCapex</i>	Total capital expenditures
<i>DemCalc</i>	Conversion of service demand into cost driver demand	<i>UnitOpex</i>	Forward-looking unit opex
<i>UtilisationIn</i>	Asset maximum utilisation, including scorched node allowance	<i>TotOpex</i>	Total operating expenditures
<i>QoS_In</i>	Quality of service inputs	<i>EconDep</i>	Cost annualisation – economic depreciation algorithm
<i>NwDes_Para</i>	Network design parameters, including spectrum allocation and asset capacity	<i>Com_incr</i>	Input of common assets by category and by incremental and common costing calculation
<i>NwDes</i>	Network design algorithms	<i>Results</i>	Cost per service demand unit

Exhibit 2: *Model worksheet description [Source: Source: OPTA final demand network and demand model, Analysys]*

1.2 Running the model

In order to run the model, simply press the **F9** (re-calculate) key. On some versions of Excel, a full recalculation (**CTRL + ALT + F9**) may be required. The model has finished the run and calculation when “calculate” is no longer displayed in the Excel status bar.

2 Main inputs: description and location

The model uses a number of input parameters that can be easily changed in the model.

<i>Market share of subscribers and traffic</i>	Location: <i>Market</i> worksheet This input controls the acquisition of market share from 1 January 2006.
<i>Spectrum allocation</i>	Location: <i>NwDes_Para</i> worksheet, lines 14–30 The spectrum allocation input into the model is controlled using a scenario template. Each spectrum scenario is characterised by a spectrum allocation in the GSM and DCS bands. A spectrum choice needs to be input for coverage (in each geotype) and capacity (in each geotype), as well as associated spectrum purchase parameters.
<i>Network roll out speed</i>	Location: <i>Cov&Dem_In</i> worksheet, cell B22 This input controls the proportion of area covered by the network in each year.
<i>Network design parameters</i>	Location: <i>NwDes_Para</i> worksheet These parameters control all the static aspects of the network design:

- cell area factor, based on assumed cell geometry
- minimum and maximum transceivers per sector
- frequency re-use pattern
- site sectorisation
- backhaul: split between microwave and leased lines
- proportion of BSCs that are remote
- capacity of core network elements
- relationship between numbers of MSC and switch sites
- relationship between numbers of MSC and transit switches.

Most parameters can be modified by the user as required.

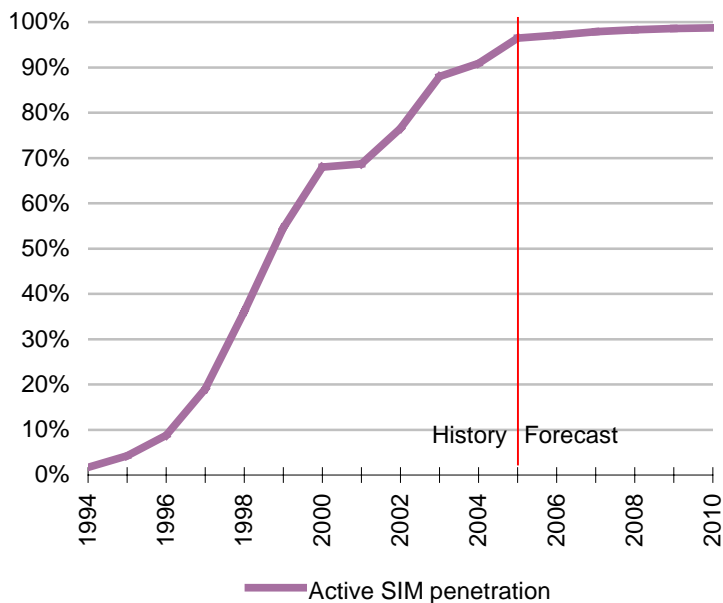
3 Demand and network assumptions in the final model

3.1 Market demand

Market demand is modelled at an aggregate level for historical years, based on data provided by Industry Group (IG) members. For future years, a forecast is presented in which the market experiences a steady growth in subscribers and traffic.

Subscribers

The number of active subscribers in the market is calculated using a projection of the future population and an assumed level of digital mobile penetration, as shown in Exhibit 3.

**Exhibit 3:**

Modelled mobile penetration, in active SIMs

[Source: Analysys]

Traffic

The traffic demand of the hypothetical new entrant is determined by the total demand in the market and the market share of subscribers.

Total market demand in historical years has been extrapolated assuming a steady growth in usage. As the modelled operator is assumed to be targeting a cross-section of the market, no distinction is made between subscriber and traffic market shares.

Voicemail message minutes have been included in the total demand. The model currently assumes that all voicemail messages deposited on the VMS are being picked up, and that the radio network usage of deposited messages is later allocated to the depositing service (e.g. incoming calls).

On-net demand has been linked to market share, through weights reflecting the propensity of subscribers to call subscribers on their own network, on other mobile networks or on the fixed network.

3.2 Market share of a hypothetical new entrant

As explained in Section 2, the market share assumptions in the model can be altered by the user. The final model presents one market share scenario:

- achievement of 25% market share by the end of 2014.

Exhibit 4 shows the evolution of market share. In the final model, this market share is applied to traffic and subscribers.

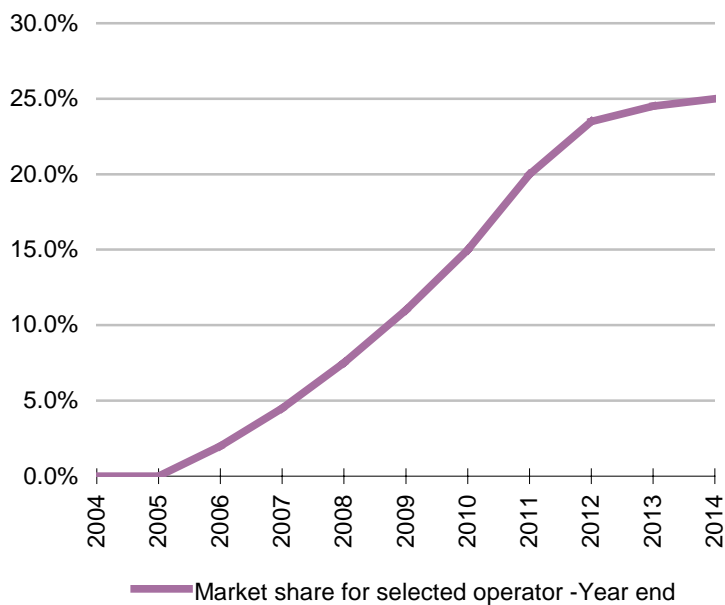


Exhibit 4:
Final market share
scenario [Source:
Analysys]

3.3 Main network assumptions

The main assumptions and choices about network design are documented in the following subsections.

Geotypes

The model considers three geotypes, characterised by different sizes, population densities and traffic intensities.¹

Geotype	Area (km ² , %)	Population	Traffic %
Urban	321 (1%)	9.66%	19.2%
Suburban	4165 (12.3%)	44.03%	50.9%
Rural	29 301 (86.7%)	46.31%	29.9%

Exhibit 5: Geotype definition [Source: Source: Analysys]

The population to area relationship used is shown in Exhibit 6 and is based on data from the Web site of the Dutch Centraal Bureau voor de Statistiek (CBS).² The population to area relationship is used to estimate the population coverage of the network as it is rolled out. However, it should be noted that the direct input to the model is the proportion of area covered; therefore the associated population coverage estimate should only be used as a guide.

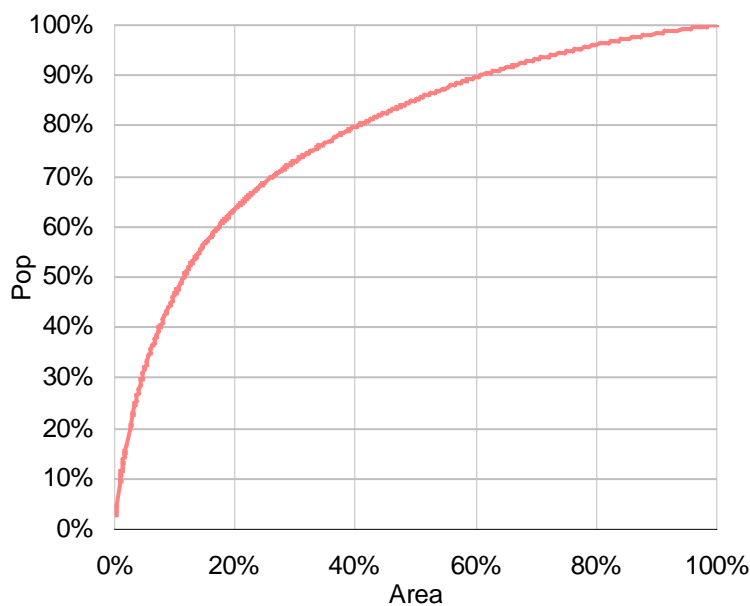


Exhibit 6: Population to area relationship in the Netherlands [Source: CBS]

¹ Traffic intensity is measured against the maximum extent of roll out.

² <http://statline.cbs.nl>.

The definition of the geotypes can be found in the *Area* worksheet (for geographical parameters) and *Cov&Dem_In* (for traffic parameters).

Coverage

The proportion of area covered by the network is entered as a maximum proportion of the area and roll-out profile by geotype.

These can be found in the *Cov&Dem_In* worksheet.

Macro, micro, pico and repeater sites

Macro and pico cells are dimensioned to support a certain proportion of urban traffic. This can be found in the *QoS_In* worksheet.

Repeater sites are deployed to serve special areas that cannot be covered by other types of sites. Based on a comparative analysis of the deployment actually undertaken by operators in the Netherlands, it has been assumed that 115 repeaters provide a sufficient coverage of these areas. This roll out is defined in the *Cov&Dem_In* worksheet.

Sectorisation

Macro sites deployed in the Netherlands are mainly tri-sectored, although some other types of sectorisation are deployed. For the purposes of modelling, it was considered appropriate to simplify the cost model so that all sites deployed are tri-sectored. Sectorisation inputs can be found in the *NwDes_Para* worksheet.

Backhaul configuration

The majority of the backhaul is provided by microwave links. The remaining leased lines are modelled as 2Mbit/s links.

The microwave backhaul networks deployed in the Netherlands typically rely on site chaining to maximise efficiency. To this effect, the model deploys a backhaul topology where sites are either individually linked to a BSC, or are part of a chain.

Inputs to the dimensioning calculation are the maximum length of a microwave chain and the average number of sites per chain. These assumptions can be found in the *NwDes_Para* worksheet.

BSC deployment

BSCs are driven by the number of transceivers in the network. Modern BSCs available in the Netherlands can control up to 1024 TRXs, and the majority are deployed in co-location with MSCs. The inputs associated with this deployment can be found in the *NwDes_Para* worksheet.

Remote BSCs and associated BSC-MSC links

Only 30% of the BSCs are assumed to be deployed outside main switching offices. The traffic transiting through these BSCs is backhauled to the MSC using leased lines.

MSC/VLR deployment

MSC deployment responds to two demand drivers. Processor load is assessed based on the number of calls, SMSs and location updates of each type that need to be switched. This determines the number of CPUs required. Transmission requirements determine the number of E1 port cards required to support transmission to and from the MSCs. Each MSC has a limited capacity in terms of ports.

Switching layer

In order to model the deployment of switches and switch locations in a way that is reflective of actual practices in the Netherlands, switching sites are assumed to be deployed using a simple functional relationship, as shown in Exhibit 7.

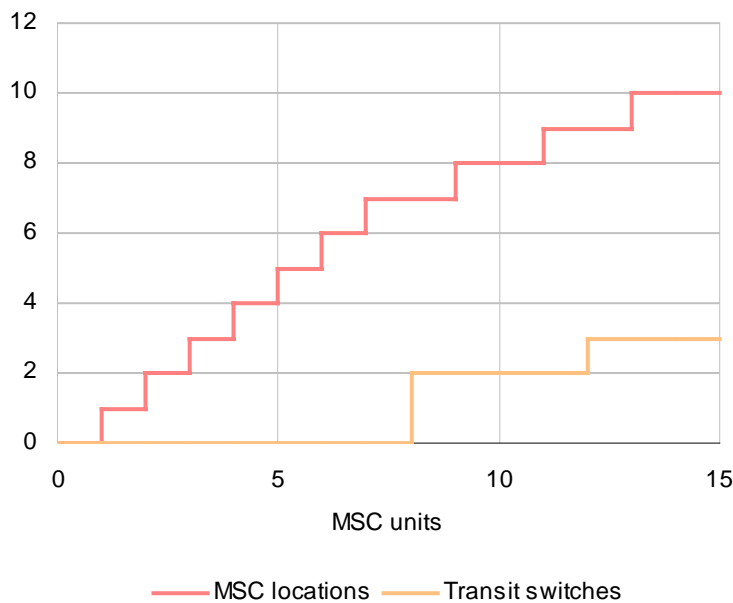


Exhibit 7:
Deployment rules
for MSC sites and
transit switches
[Source: Analysys]

A minimum of two MSCs in two switching locations are deployed. MSCs are then deployed singly in new sites until seven MSCs are present in seven locations around the country. After this point, MSCs begin to double up while further switching sites are deployed.

Transit layer

When the number of MSC units deployed reaches eight, a transit layer is deployed. This transit layer contains dedicated switches that are above standard MSCs in the logical hierarchy of the network. All the traffic between MSCs is handled by the transit layer first. Every MSC is linked to two different TSCs for redundancy purposes.

Backbone network

The backbone links are assumed to be deployed in STM-1 increments. This is applied for MSC to MSC links (if no transit layer), MSC to TSC links and transit links between TSCs.

Other network elements

We have included explicit calculations of what we believe to be the remaining significant network element deployments: HLR, network management systems, IN, billing systems, VMS, GPRS and SMS infrastructure. Licences and spectrum fees are also modelled according to the spectrum available.

4 Network design algorithms

This section details the algorithms used to build up a network based on the modelled demand described in Section 3.

4.1 Radio network: site coverage requirement

To satisfy the coverage requirements, the number of macro sites deployed has to be able to provide coverage for a certain area defined by geotype. The inputs to the calculation for coverage macro sites are the spectrum band used to provide coverage, the total area covered by the different geotypes and the site radius of each geotype. Exhibit 8 shows a flow diagram describing the calculation of macro sites deployed.

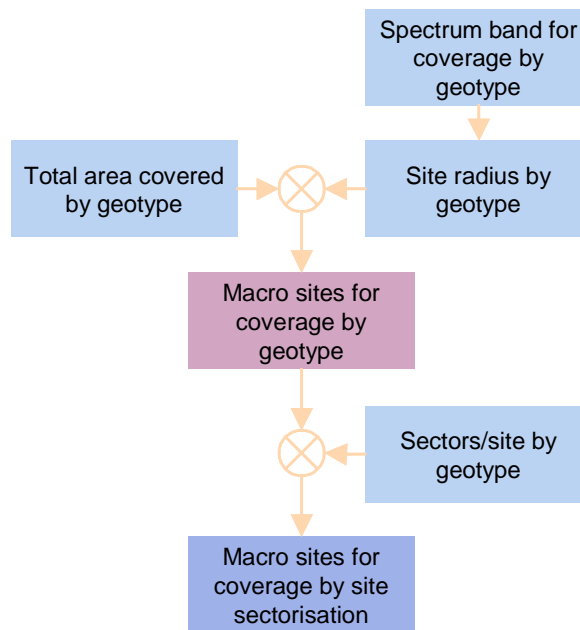


Exhibit 8:
Coverage network
design [Source:
Analysys]

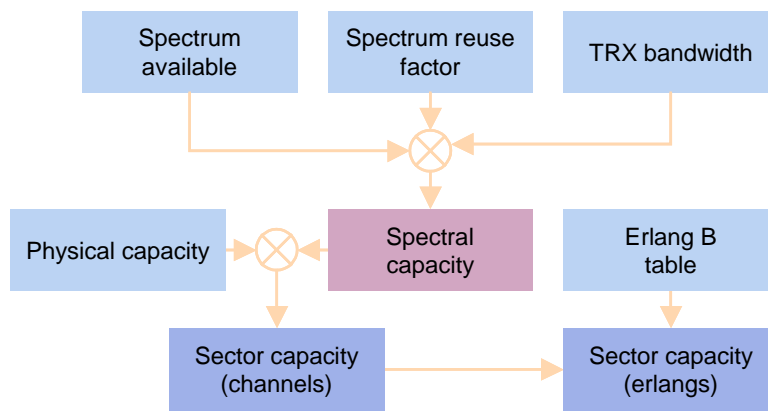
The spectrum band used to provide coverage for each geotype determines the site radius used for the calculation. From the site radius, the area covered for a site in a given geotype is calculated. The total area covered for the geotype divided by this site area determines the number of macro sites for coverage.

Given the number of sectors in a site, the number of macro sites deployed by site sectorisation is also calculated.

4.2 Radio network: site capacity requirement

Step 1: Erlang capacity per sector

Before the capacity requirements of a radio network are calculated, the Erlang capacity for a given sector is evaluated. The inputs to this calculation are the availability of spectrum, the spectrum re-use factor and transceiver bandwidth. Exhibit 9 shows a flow diagram describing the calculation of Erlang capacity for a sector.

**Exhibit 9:**

Sector capacity

calculation [Source:

Analysys]

The spectral capacity is the number of transceivers that can be deployed in a sector given a certain spectrum re-use factor. GSM transceivers have a bandwidth of 200kHz. Thus the spectral capacity in terms of number of transceivers is obtained by dividing the available spectrum with the product of the spectrum re-use factor and the transceiver bandwidth.

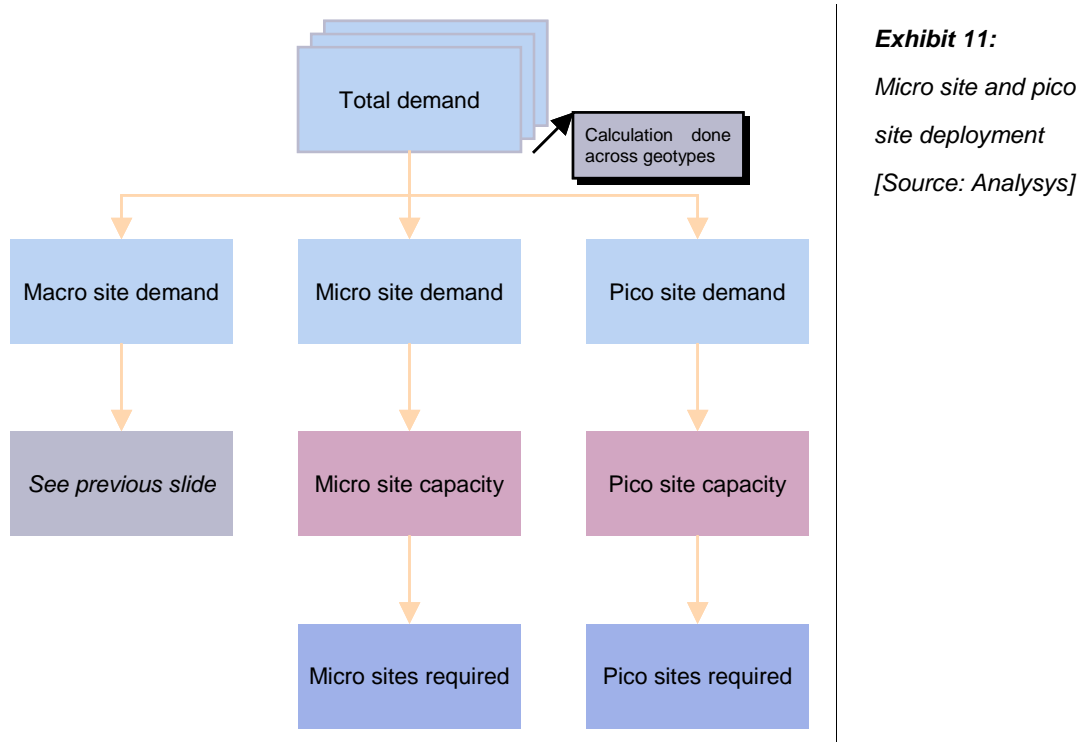
The lesser of the physical capacity and the spectral capacity of a sector is the sector capacity in transceiver numbers. The sector capacity in Erlangs is obtained using the Erlang B conversion table.

Step 2: Capacity-driven macro sites

The number of new macro sites required for capacity is calculated by taking into account the primary and secondary spectrum available and the capacity already provided by the coverage network. The inputs into the model are busy-hour traffic by geotype, coverage-driven macro sites, BTS and transceiver utilisation and the proportion of sites that can support an overlay. Exhibit 10 shows a flow diagram describing the calculation of new macro sites deployed for capacity.

Step 3: Micro/pico site design

Micro site and pico site design algorithms are similar and are obtained simply by considering the demand on the sites and capacity of a single site. Exhibit 11 shows a flow diagram describing the calculation of micro site and pico site deployment.



Micro sites and pico sites are designed for urban areas and are assumed to be omnisectioned. A proportion of the total demand of the network is carried by the micro and pico sites. Dividing this traffic by the capacity of a single micro/pico site gives the micro/pico sites deployed for traffic.

A number of repeaters are also deployed to provide special areas with coverage (e.g. tunnels, airports, tall buildings and shopping malls).

4.3 Radio network: TRX requirements

To calculate the total number of transceivers required, the inputs involved are the busy-hour traffic, number of sites required, number of sectors per BTS and transceiver utilisation. Exhibit 12 shows a flow diagram describing the calculation of transceivers required.

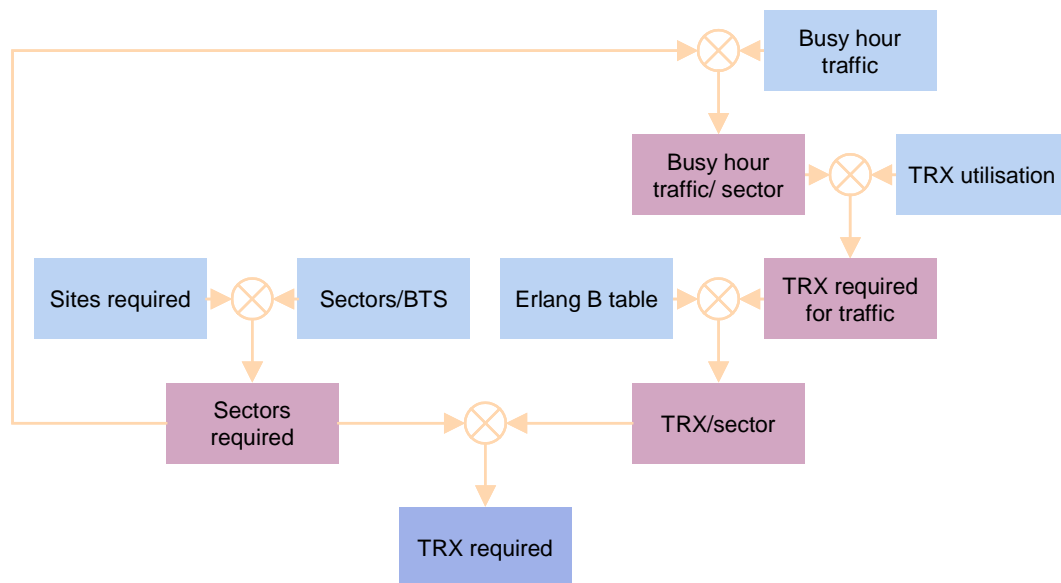


Exhibit 12: Transceiver design [Analysys]

A multiplication of the sites required and the number of sectors in a BTS provides the total number of sectors required.

The number of transceivers per sector required to meet the demand is calculated taking into consideration the transceiver utilisation and converting the Erlang demand per sector using the Erlang B table.

The number of transceivers required is obtained by multiplying the number of sectors and the number of transceivers per sector.

4.4 Backhaul transmission

Step 1: Capacity requirements

The number of E1 required per site is calculated to fulfil the capacity requirements for a backhaul link. Exhibit 13 shows a flow diagram describing the calculation of the number of E1 required per site.

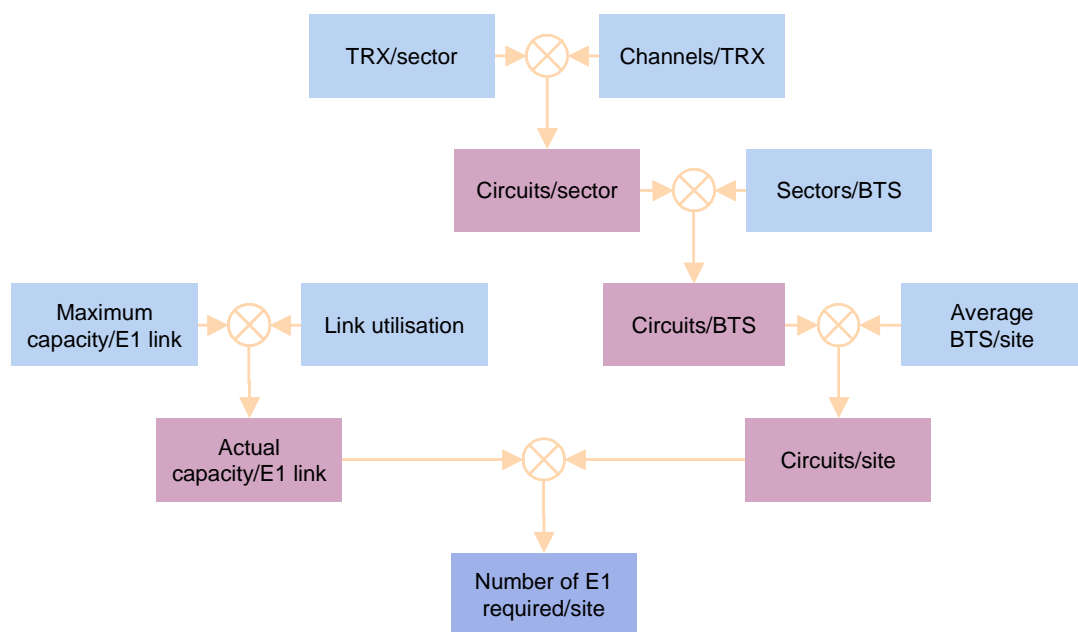


Exhibit 13: Capacity requirements for backhaul links [Source: Analysys]

There are eight channels per transceiver, which translate into eight circuits in the backhaul since the backhaul is dimensioned to support all the transceiver channels. Taking into consideration the co-location of primary and secondary BTS on the same site, the number of circuits per site is calculated by multiplying the circuits per BTS with the average number of BTS on a site.

The actual capacity per E1 link is calculated considering the maximum capacity of an E1 link and the link utilisation.

The number of E1 links required per site is obtained by simply dividing the number of circuits per site with the actual capacity per E1 link.

Step 2: Backhaul network design algorithms

There are three configurations that are used for backhaul network design

- leased line backhaul with a single site
- microwave backhaul with a single site
- microwave backhaul with chained sites.

Exhibit 14 shows a diagram of the possible backhaul configurations.

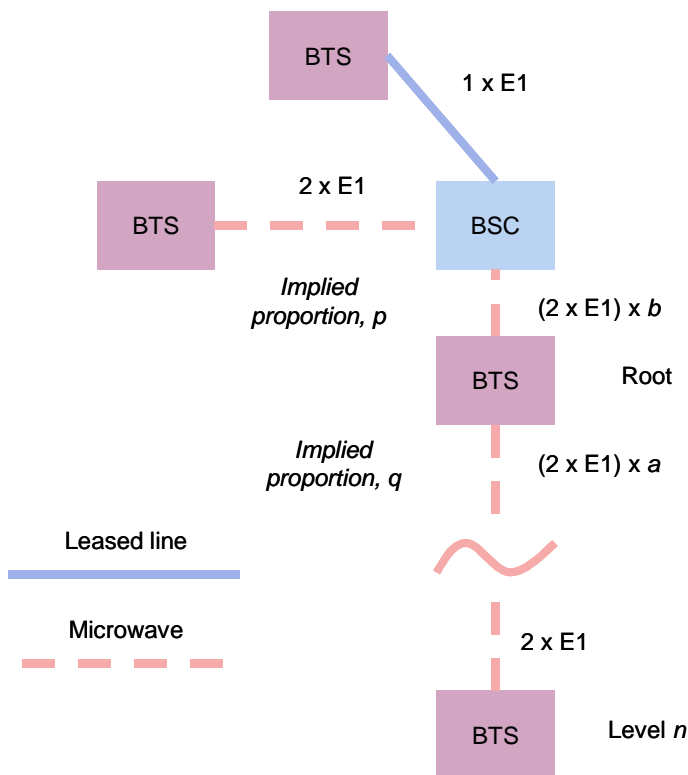


Exhibit 14:
Backhaul configurations
[Source: Analysys]

For simplification purposes, the only configurations allowed for the microwave backhaul are maximum and minimum chaining. Due to microwave link type modularity, the non-chained site links and the chained sites at the furthest level deploy $2 \times E1$.

The average number of sites per backhaul link is an input data into the model. The implied proportion of chains per number of sites is calculated by iteration so that the average number of sites per backhaul link converges to this input data.

Step 3: Microwave backhaul

The microwave backhaul calculations can be divided into two sections. Exhibit 15 shows the flow diagram of the first section, where the total sites at the root level and at any deeper level is calculated.

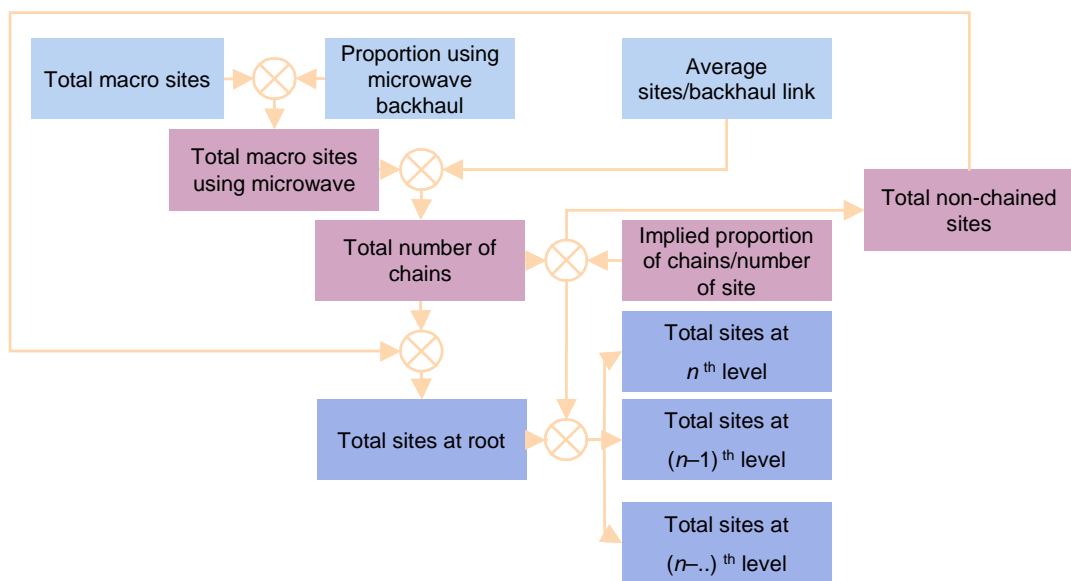


Exhibit 15: Total sites at root and any given level on the chain [Source: Analysys]

To calculate the number of sites at any level on a microwave chain, the total macro sites using microwaves is calculated. The total number of microwave chains is then calculated by multiplying this figure with the average number of sites per backhaul link.

Since only maximum and minimum chaining is allowed, there are only two figures for the implied proportion of chains per number of site, which are the proportion of non-chained sites and the proportion of chained sites at the maximum level n . Given the implied proportion of chains, the total non-chained sites can be obtained.

For chained sites, the total sites at root level can be calculated from the implied proportion of chains. To obtain the total sites at any level, the total sites is the smaller of either the number of sites at root or the number of sites at the n^{th} level, since only maximum or minimum chaining is allowed.

Exhibit 16 shows how the total number of microwave backhaul links required by type is determined.

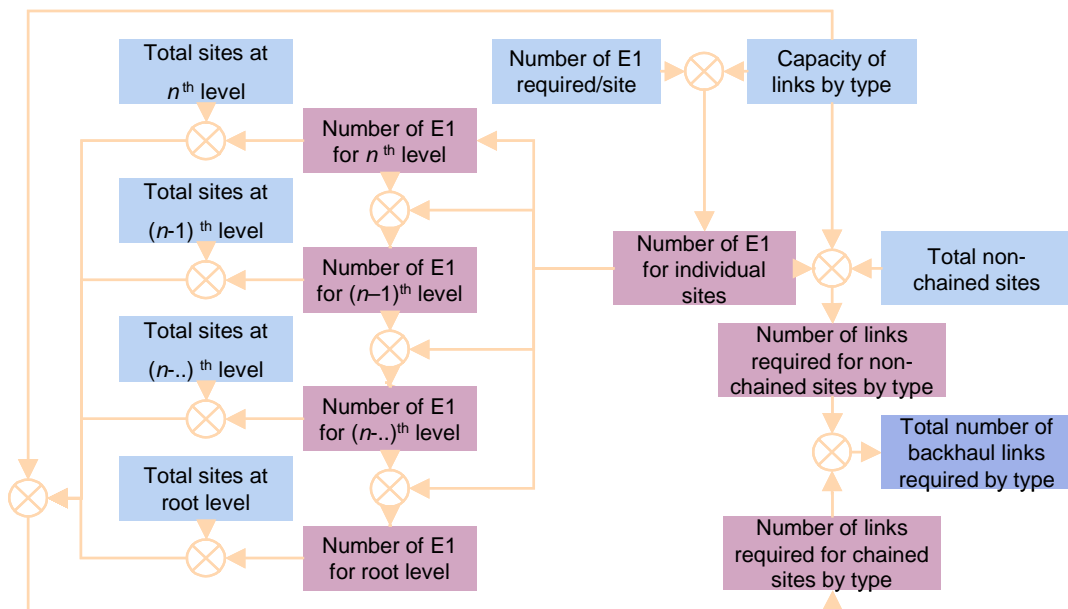


Exhibit 16: Calculation of microwave backhaul links by type [Source: Analysys]

There are four types of microwave links, which are 2 E1, 2x2 E1, 4x2 E1 and 8x2 E1.

From Step 1, the number of E1 needed due to demand requirements is obtained. By comparing this calculated value to the type of microwave links available, the number of E1 for individual sites is obtained by choosing the smallest capacity link above the required number of E1 per site.

To calculate chained sites, let the number of E1 required by demand at the n^{th} level be y E1. The microwave backhaul is designed so that at any level, the number of E1 required by demand is $(n-k+1) y$ E1. The number of E1 at this level is chosen to the next smallest microwave link capacity above $(n-k+1) y$ E1.

As an example, if the maximum level $n = 4$ and if the number of E1 required at that level is 1 E1, the number of E1 required by demand at level 2 is 3 E1. The smallest available link capacity is chosen, which is 2x2 E1, since no 3 E1 links are modelled.

Non-chained sites require an individual microwave backhaul. Hence, the number of links required for non-chained sites by type of link is the sum of non-chained sites according to link type.

The number of links required for chained sites by link capacity type is obtained by summing the total sites at all levels after comparing the number of E1 for each level with the capacity of links by type. The total number of backhaul links is the sum of the chained and the non-chained sites.

Step 4: Leased line backhaul

The leased line backhaul links modelled are more granular than microwave backhaul links, thus 1 E1 are used. Exhibit 17 shows a flow diagram of the calculation for leased line links.

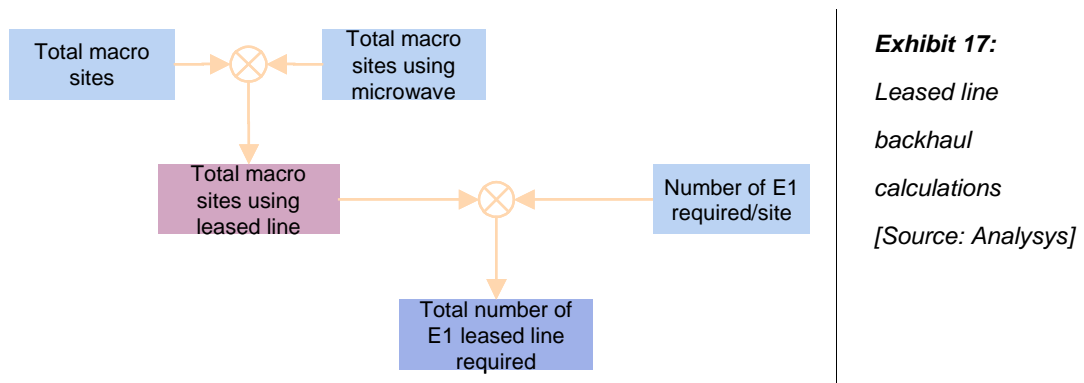


Exhibit 17:
Leased line backhaul calculations
 [Source: Analysys]

The number of macro sites using leased lines is the difference between the total macro sites and the total macro sites using microwaves. The total number of E1 leased lines required is calculated by multiplying the total macro sites using leased line and the number of E1 required per site (from Step 1).

Micro, pico and repeater sites are assumed to use only leased line backhaul and hence are added to the leased line requirements of the macro layer.

4.5 BSC deployment

BSC units calculation

The number of BSC units deployed is dependent on the capacity of a BSC, its utilisation and the total number of transceivers required. Exhibit 18 shows the calculation of remote BSC units and average traffic per remote BSC.

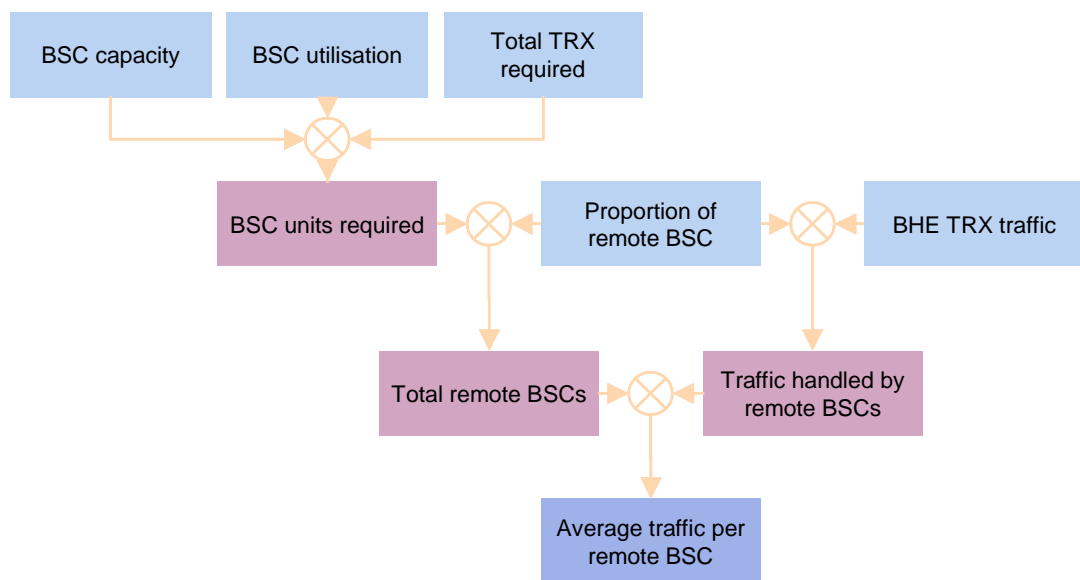


Exhibit 18: Average traffic per remote BSC calculation [Source: Analysys]

The number of BSC units deployed must be able to accommodate the number of transceivers deployed (see Section 4.3). A proportion of BSCs are remote, and therefore require physical links to the MSC and are located in a separate building at some position in the radio network. The total traffic handled per remote BSC can be calculated using the total busy-hour Erlang transceiver traffic.

The average traffic per remote BSC is used to dimension the BSC-MSC links and is calculated by dividing the traffic handled by remote BSCs by the total number of remote BSCs deployed.

BSC-MSC links calculation

Remote BSCs require physical BSC-MSC links and the total is calculated from the total number of remote BSCs and the link capacity required. The flow of BSC-MSC link calculations is shown in Exhibit 19.

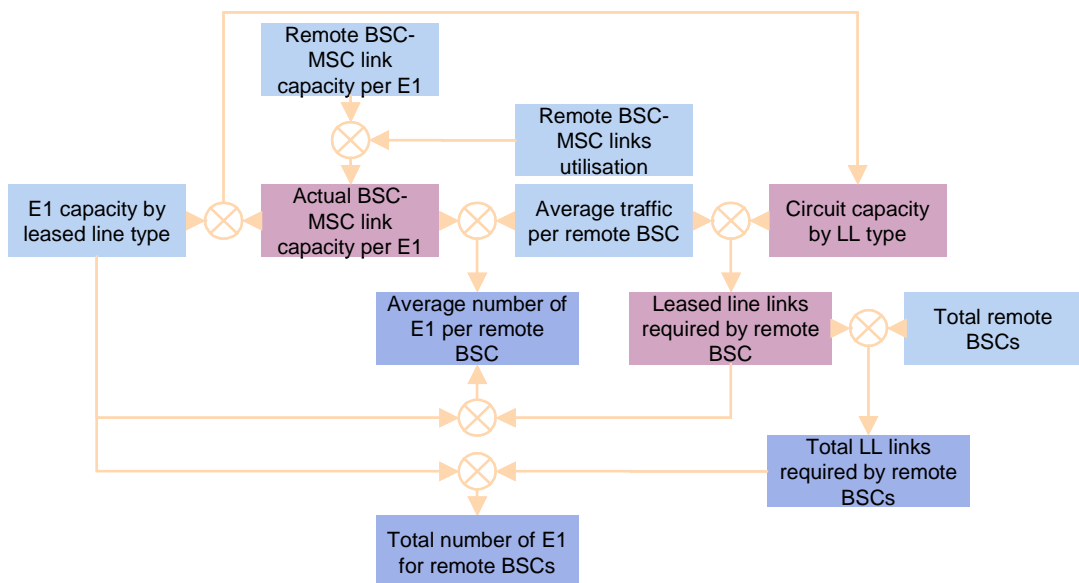


Exhibit 19: BSC-MSC link calculation [Source: Analysys]

The average number of E1 per remote BSC is calculated by dividing the average traffic on a remote BSC with the actual BSC-MSC link capacity per E1.

Dividing the average traffic per remote BSC by the circuit capacity by leased line type results in the number of leased lines required for an average BSC-MSC link. Multiplying this total by the E1 capacity produces the same average number of E1 per remote BSC as an output of the model.

The total leased line MSC-BSC links required is calculated by multiplying the average MSC-BSC leased lines required by the total number of remote BSCs deployed.

Total outgoing ports for co-located BSCs

Given the total number of co-located BSCs and busy-hour Erlang transceiver traffic, the total number of outgoing ports for co-located BSCs is calculated. Exhibit 20 shows the flow of calculation for co-located BSC ports.

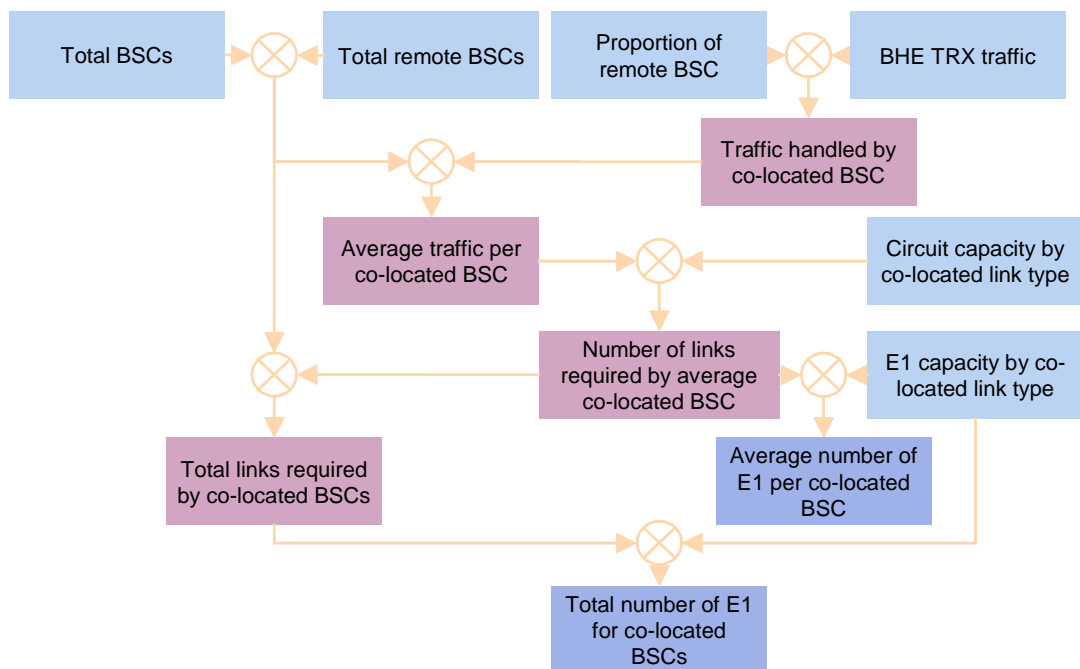


Exhibit 20: *Total outgoing ports for co-located BSCs calculation [Source: Analysys]*

The total number of co-located BSCs is calculated as the difference between the total number of BSCs and the number of remote BSCs. The amount of traffic handled by co-located BSCs is obtained from the remote proportion of BSCs and the busy-hour Erlang transceiver traffic. The average traffic per co-located BSC can then be calculated by dividing the total traffic with the total number of co-located BSCs. Using circuit capacity by link type, the links required per co-located BSC is obtained simply by dividing the average traffic per BSC by this capacity.

The total outgoing links for co-located BSCs is the product of the total co-located BSCs and the average number of links per co-located BSC. Multiplying this number of links by the E1 capacity according to link type gives the total outgoing ports for co-located BSCs in terms of E1.

Incoming and outgoing ports

The incoming ports to the BSC are the ports facing the BTS, while the outgoing ports are the ports facing the MSC. Exhibit 21 shows the constituents of the incoming and outgoing ports.

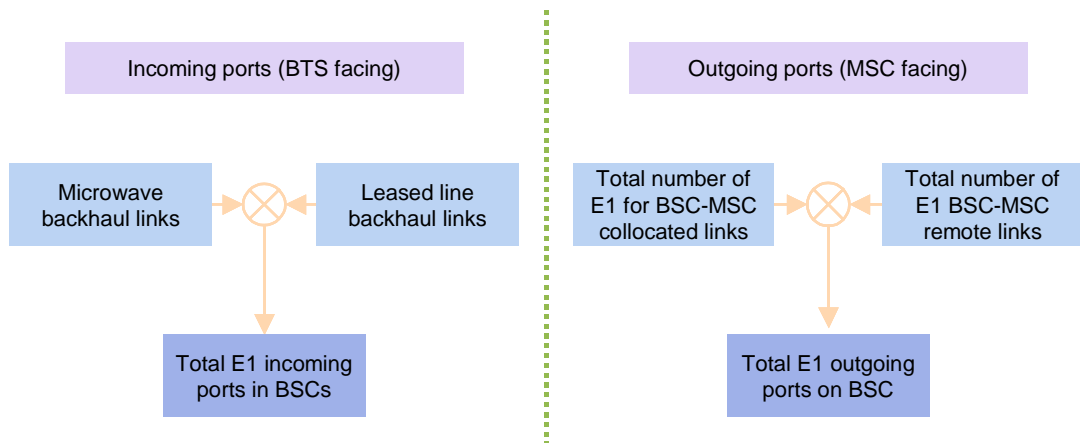


Exhibit 21: Total incoming and outgoing ports for BSC [Source: Analysys]

The total number of E1 incoming ports into the BSC is the sum of the microwave and leased line backhaul links, while the total outgoing ports is the sum of the total number of E1 for both remote and co-located BSCs.

4.6 MSC deployment

Calculation for MSC units to support processing demand

To support processing demand, the number of MSC units required is calculated from the CPU capacity, processor utilisation and the demand for the MSC. Exhibit 22 shows the sequence of this calculation.

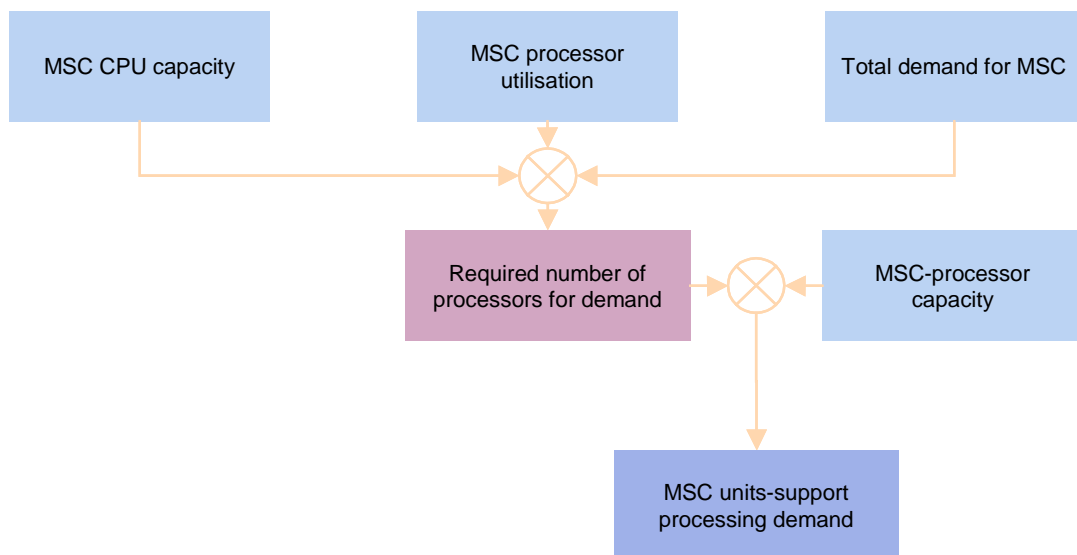


Exhibit 22: *Calculation of MSC units to support processing demand [Source: Analysys]*

Taking into account the MSC processor utilisation, the total processors required to meet the demand can be calculated as the total MSC demand divided by the actual MSC capacity. Thus, the total number of MSC units required to support processing demand is obtained by dividing the required number of processors for demand by an MSC processor's capacity.

Ports calculation (BSC-facing, interconnect and MSC-facing)

Exhibit 23 shows how the number of incoming and outgoing ports is obtained.

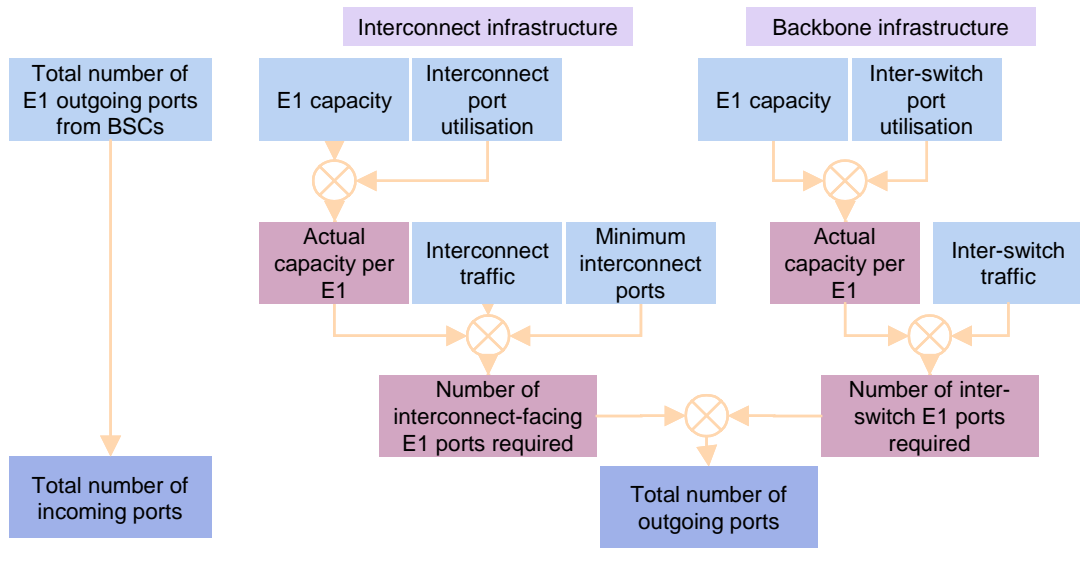


Exhibit 23: MSC ports calculation [Source: Analysys]

The total number of incoming ports into the MSC is the total number of E1 outgoing ports from the BSC.

The total outgoing ports comprises the number of interconnect-facing ports required and the number of inter-switch ports required. For the interconnect infrastructure, the total number of interconnect-facing ports required to meet demand is obtained by dividing the traffic with the actual E1 capacity of the port. The number of interconnect-facing E1 ports required can be calculated as the higher of either the minimum ports threshold or the calculated interconnect ports required. The same calculations as the interconnect-facing ports are carried out to obtain the number of inter-switch ports. The total outgoing ports are the sum of these two constituents.

Calculation for MSC units to support port demands

To support port demands, calculations are based on the total incoming and outgoing ports from the MSC. Exhibit 24 shows the calculation flow to obtain the number of MSC units required.

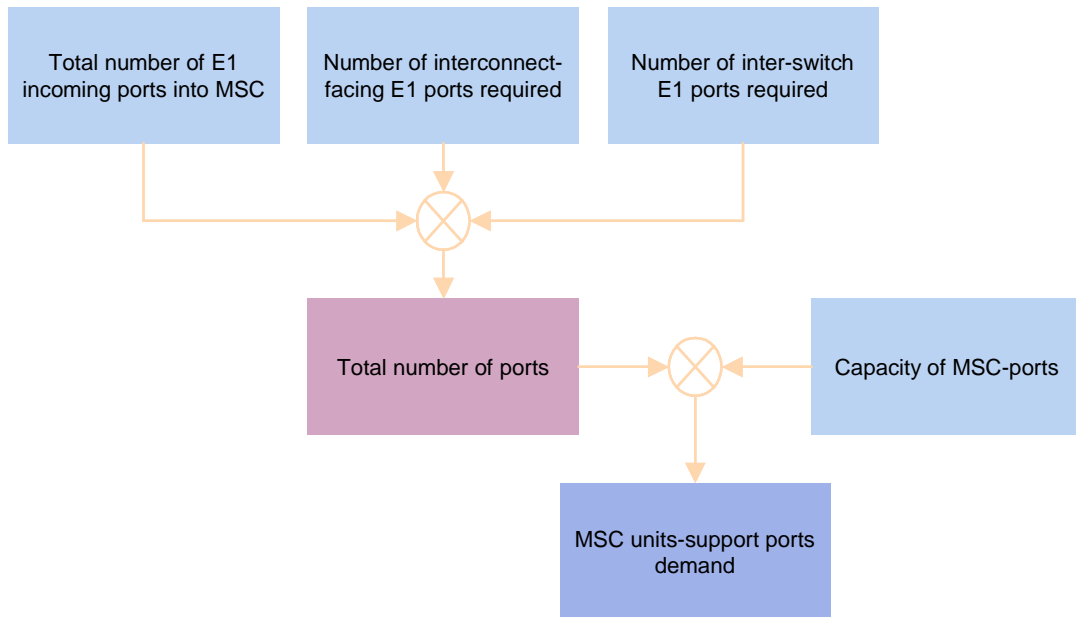


Exhibit 24: Calculation of MSC units to support port demands [Source: Analysys]

The total number of ports is the sum of all incoming and outgoing ports from the MSC. Dividing this total number with the port capacity of an MSC gives the number of MSC units to meet the port demand.

Overall MSC units, switching sites and transit switches required

Exhibit 25 shows how the MSC units, number of switching sites and number of transit switches are obtained from the previous calculations.

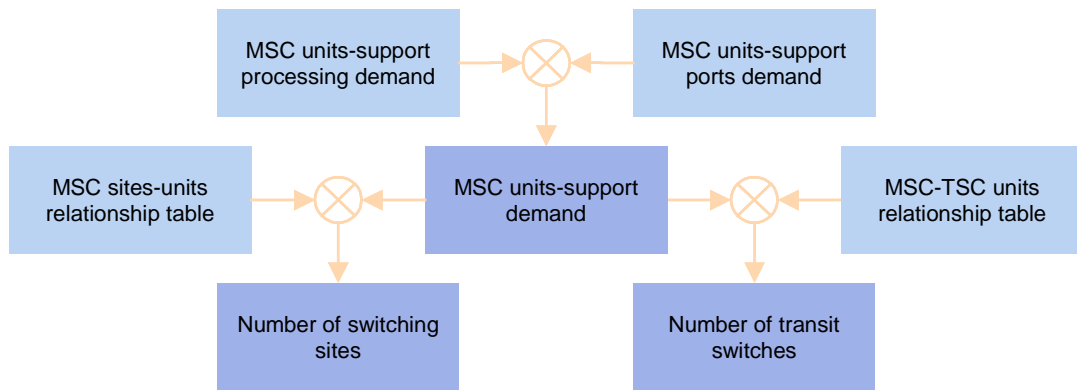


Exhibit 25: Overall MSC units, sites and transit switches calculation [Source: Analysys]

The number of MSC units that support demand is the higher of the number of units required to support either the processing demand or ports demand. To obtain the number of switching sites, the number of MSC units is compared against a table showing the relationship between the number of MSC sites and MSC units. The same procedure is carried out to obtain the number of transit switches required given a certain number of MSC units.

See *NwDes_Para* worksheet in the *BULRIC_model_OPTA.xls* for the table.

4.7 Backbone transmission

There are two backbone network design options:

- fully meshed network without a transit layer
- network with a transit layer.

Network without transit layer

The inter-switch transmission links for a network design without a transit layer are calculated based on the number of switching sites deployed. Exhibit 26 shows a flow diagram of how the calculations are carried out.

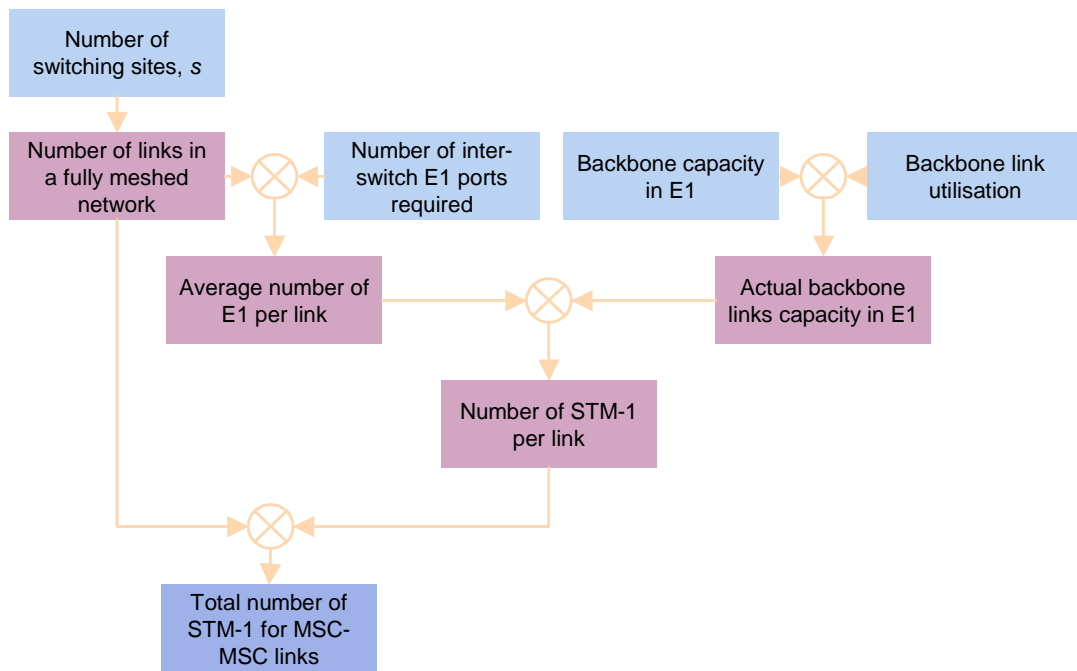


Exhibit 26: Total MSC-MSC links for a network without transit layers [Source: Analysys]

Backbone links are modelled as STM-1 (155Mbit/s). These can accommodate 63 E1 links.

For a fully meshed network, given the number of switching sites (s) the number of links (l) is calculated using the formula below:

$$l = s(s-1) / 2$$

The average number of E1 per link is obtained by dividing the number of inter-switch E1 ports with the number of links, while the actual backbone link capacity is obtained taking into account the link utilisation. Dividing the average number of E1 per link by the actual backbone link capacity gives the number of STM-1 required for a backbone link.

The total number of STM-1 for MSC-MSC links is calculated by simply multiplying the number of STM-1 per link by the total number of links in a fully meshed network.

Network with transit layer

For a transit layer network, the total number of links is calculated as the sum of the MSC-TSC links and the TSC-TSC links. The transit switches are assumed to be co-located with the other MSCs and each MSC is linked to two TSCs. Exhibit 27 shows the calculation for the MSC-TSC links.

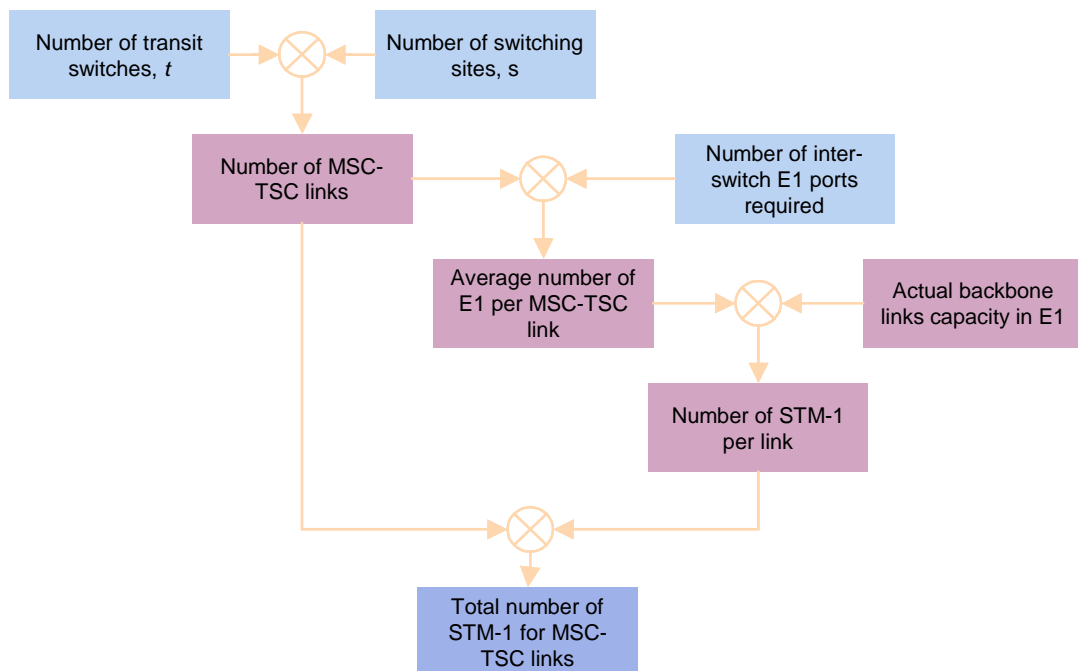


Exhibit 27: Total MSC-TSC links for a network with transit layers [Source: Analysys]

The number of MSC-TSC links is calculated from the number of transit switches (t) and the number of switching sites (s) using the formula below:

$$l = 2s - t$$

The subsequent calculations to obtain the total number of STM-1 for MSC-TSC links are similar to those carried out for the inter-switch transmission without a transit layer.

Exhibit 28 shows the calculation for the TSC-TSC links.

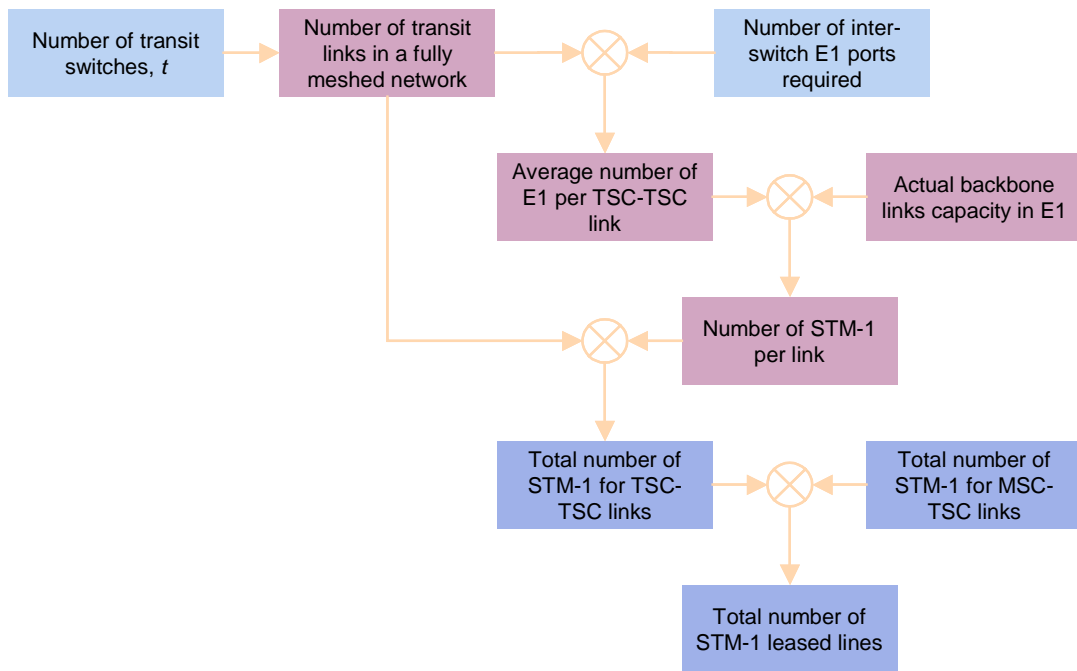


Exhibit 28: Total TSC-TSC links for a network with transit layers [Source: Analysys]

The number of TSC-TSC links is calculated directly using the number of transit switches (t) with the formula below:

$$l = t(t-1)/2$$

The subsequent algorithms for the total number of STM-1 for the TSC-TSC backbone link are similar to that carried out for the MSC-TSC links.

The total number of STM-1 leased lines is the sum of the total number of STM-1 for both.

4.8 Other

HLR

HLR units are deployed based on the number of registered subscribers at the end of the year. Exhibit 29 shows the calculations to obtain the number of HLR units required.

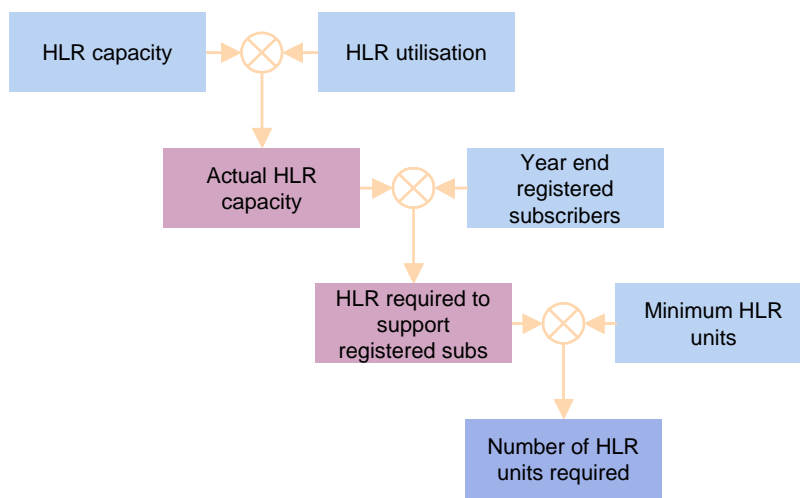


Exhibit 29:
HLR units calculation
[Source: Analysys]

Considering the HLR utilisation, the actual HLR capacity in terms of subscriber numbers is obtained. Since the number of registered subscribers at year-end is the input that drives HLR deployment, the number of HLRs required to support the registered subscribers is calculated by dividing the year-end subscriber numbers by the actual capacity of an HLR.

The number of HLRs deployed is the higher of the number of HLRs required to support the registered subscriber base or the minimum HLR unit threshold.

SMSC

The SMSC deployment is driven by SMS throughput demand. Exhibit 30 shows the calculation flow of the SMSC deployment.

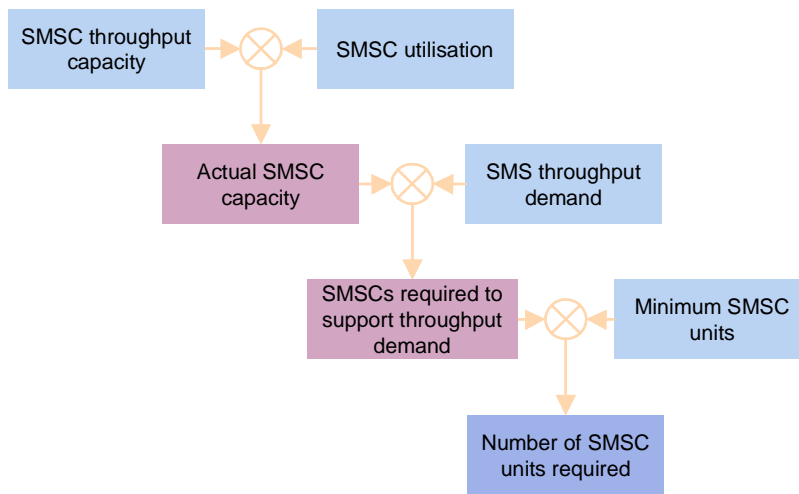


Exhibit 30:
SMSC units
calculation [Source:
Analysys]

Dividing the SMS throughput demand by the actual SMSC capacity gives the number of SMSCs required to support this throughput demand. The number of SMSC units deployed is the higher of either the SMSCs required to support demand or the minimum SMSC unit threshold.

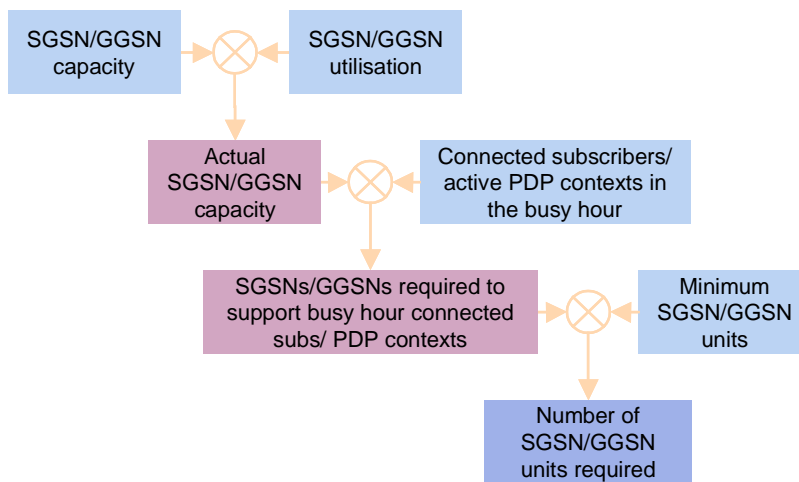
GPRS infrastructure

There are three GPRS infrastructures deployed:

- PCU
- SGSN
- GGSN.

The number of PCU units installed is equal to the number of BSCs installed.

Exhibit 31 shows the calculations for SGSN and GGSN deployment.

**Exhibit 31:**

SMSC units

calculation [Source:

Analysys]

The calculations for SGSN and GGSN deployments are similar. SGSN deployment is driven by the number of simultaneously attached subscribers in the busy hour, while GGSN deployment is driven by active PDP contexts made in the busy hour.

Dividing their respective demand by the actual SGSN and GGSN capacity gives the total number of units that are required to meet the demand requirements. The number of SGSN and GGSN deployed is the higher of either the number of units calculated to meet demand or the minimum threshold units.

Network management centre

The network management centre is deployed at the start of operations, but it is modelled as a recurring annual capital investment cost.

Voicemail system, IN and billing system

These network elements are modelled as a single functional unit deployed at the commencement of operations.

Spectrum licences

The licences purchased are dependent on the spectrum available. In the Netherlands, the licences available are:

- PGSM licences
- EGSM licences
- DCS spectrum licences.

It should be noted that EGSM spectrum is not modelled.

5 Expenditure calculations

5.1 Purchasing, replacement and capex planning period

The network design algorithms compute the network elements that are required to support a given demand in each year.

In order for these elements to be operational when needed, they need to be purchased in advance, in order to allow provisioning, installation, configuration and testing before they are activated. This is modelled for each asset by inputting a planning period between 0 (no planning required) and 24 months.

In order to calculate the number of assets to be purchased in each year, the model computes the number of additional assets that need to be installed to provide incremental capacity, and includes the amount of equipment that has reached the end of its lifetime and needs to be replaced.

5.2 MEA equipment unit price

The price paid for network assets varies over time. In the LRIC approach, the MEA provides the appropriate cost basis for purchasing. Real term price trends are applied to 2004 prices to reflect the evolution of the modern technology prices. MEA price evolution also provides an important input into the economic depreciation, as explained in Section 6.

6 Expenditure annualisation

This section describes the implementation of the economical depreciation algorithm used in OPTA's mobile cost model. It details both the economic rationale for using this algorithm and the calculations themselves.

6.1 The rationale for using economic depreciation

Economic depreciation is a method for determining a cost recovery that is economically rational, and therefore reflects the:

- underlying costs of production
- output of network elements over their lifetime.

The first factor relates the cost recovery to that of a new entrant to the market, which would be able to offer the services based on the current costs of production.

The second factor relates the cost recovery to the 'lifetime' of a mobile business – in that investments and other expenditures are in reality made throughout the life of the business (especially large, up-front investments) on the basis of being able to recover them from all demand occurring in the lifetime of the business. New entrants to the market would also be required to make these large upfront investments, and to recover costs over the lifetime in a similar fashion to the existing operators. (This is based on the realistic assumption that new entrants to the market face the same systemic barriers to entry as faced by the existing operators, and would not realistically be able to instantaneously capture the entire market of an operator – i.e. the market is less than fully contestable).

These two factors are not reflected in accounting-based depreciation, which simply considers when an asset was bought, and over what period the investment costs of the asset should be depreciated.

Fundamentally, the implementation of economic depreciation utilised in the model is based on the principle that *all (efficiently) incurred costs should be fully recovered, in an economically rational way.*

Full recovery of all (efficiently) incurred costs is ensured by checking that the PV of actual expenditures incurred = the PV of economic costs recovered.

An allowance for capital return earned over the lifetime of the business, specified by the WACC, is also included in the resulting costs.

6.2 Implementation of economic depreciation principles

The economic depreciation algorithm recovers all efficiently incurred costs in an economically rational way by ensuring that the total of the revenue generated across the lifetime of the business are equal to the efficiently incurred costs, including cost of capital, in PV terms.

More specifically, for every asset class, in every year, the algorithm recovers the proportion of total cost (incurred across the lifetime of the business) that is equal to the revenue generated in that year as a proportion of the total revenue generated (across the lifetime of the business), in PV terms.

Present value calculation

The calculation of the cost recovered through generated revenue needs to reflect the value associated with the opportunity cost of deferring expenditure or revenue to a later period. This is accounted for by the application of a discount factor on future cashflows, which is equal to the WACC of the modelled operator.

The business is assumed to be operating in perpetuity, and investment decisions are made on this basis. This means that it is not necessary to recover investments within a particular time horizon, for example, the lifetime of a particular asset, but rather throughout the lifetime of the business. In the model, this situation is approximated by explicitly modelling a period of 50 years. At the discount rate applied, the PV of a euro in the last year of the model is fractional and thus any perpetuity value beyond 50 years is regarded as immaterial to the final result.

Cost recovery profile

The costs incurred over the lifetime of the network are recovered in line with revenue generated by the business. The revenue generated by an asset class is a product of the demand (or output) supported by that asset class and the price per unit of capacity.

In the modelled environment of a competitive market, the price that will be charged per unit demand is a function of the lowest cost of supporting that unit of demand, thus the price will change in accordance with the costs of the factors of production. Put another way, if a low cost asset could support a particular service, then the price charged for the same service supported by a more expensive asset would be reflective of the costs of the lower cost asset, or else a competitor would supply the service using the lower cost asset to capture the associated supernormal profits.

The shape of the revenue line (or cost recovery profile) for each asset class is thus a product of the demand supported (or output) of the asset and the profile of replacement cost (or MEA price trend) for that asset class.

Capital and operating expenditure

The efficient expenditure of the operator comprises of all the operator's efficient cash outflows over the lifetime of the business, meaning that capital and operating expenditures are not differentiated for the purposes of cost recovery. As stated previously, the model considers costs incurred across the lifetime of the business to be recovered by revenue across the lifetime of the business. Applying this principle to the treatment of capital and operating expenditure leads to the conclusion that they should both be treated in the same way since they both contribute to supporting the revenue generated across the lifetime of the operator.

GSM-specific versus non-specific assets

A number of network assets are identified as being specific to GSM services. These network elements are assumed to be deployed only for GSM service support but will not be compatible with UMTS network services – such as TRX, which cannot support W-CDMA radio signals. The

total costs of these assets are recovered from an output profile that exists only for the lifetime of the GSM licence (15 years) and declines in the last five years of this lifetime due to migration off GSM.

Assets that are non-specific are assumed to serve the same purpose in GSM and UMTS networks – such as backhaul transmission links, etc. The total costs of these assets, including all ongoing replacements, are recovered from a perpetual profile of demand.

6.3 Implementation details

The economic depreciation algorithm appears in the worksheet *EconDep*. The depreciation method implemented in this model has the following characteristics:

- it explicitly calculates the recovery of all costs incurred across the specified time horizon (50 years), in PV terms
- the cost recovery schedule is computed for each asset along the output profile of the asset
- cost recovery is computed separately for capital and operating expenditures (allowing for potentially different MEA price trends of capital and operating expenditures)
- costs are calculated with reference to the network element output – the routing factor weighted sum of service demand produced by the network element in each year.

7 Service cost calculations

The model takes the total economic costs for each network asset, and applies a common cost proportion to that asset class. The proportion of each asset class (cost) that is common is calculated from the input of the number of common assets, which is expressed as a percentage of total assets. Common costs are summed across all assets to calculate a total common cost. Residual incremental costs per unit output are calculated for each asset class.

Routing factors determine the amount of each element's output required to provide each service. In order to calculate incremental service costs, incremental unit output costs are therefore multiplied by the routing factors according to the following equation:

$$Cost(Service_k) = \sum_{assets} cost_per_unit_output(asset_i) \times RoutingFactor(asset_i, service_k)$$

Common costs are then marked-up onto each incremental service cost in an equal-proportionate manner, according to the ratio of common-incremental total costs.

Annex A: Model inputs

This annex provides a full schedule of model inputs. The sources of input values are provided here to assist IG members to understand what information has been used to populate the final model.

<i>Worksheet</i>	<i>Input name</i>	<i>Description</i>
Market	Population -Year end	Population growth in the Netherlands has been estimated based on third-party data. Source: CBS
	Digital mobile penetration - Year end	Historic mobile penetration derived from operator data on active SIM cards. Forecast mobile penetration is assumed to grow to saturation within a few years
	Inactive subscribers as a % of active	This is based on data from the operators about the ratio of active vs. registered subscribers, averaged
	Proportion of total digital mobile subscribers that are GPRS data users	Based on historical market data provided by the operators, forecast take up is assumed up to a 15% level
	Market Traffic data per year	The total volume of traffic in the market is extrapolated from historical data assuming a modest level of growth in minutes per subscriber
	Relative call weights	This indicates the propensity of mobile subscribers to call different destination (own network, other mobile, fixed), used to dynamically calculate on-net mobile traffic. Source: Derived from operator information
Lifetime_In	Asset lifetimes	This is based on accounting lifetime data provided by the operators and general principles applied in the mobile industry, including IFRS. MSC and HLR lifetime data is based upon one operator's calculated economic lifetimes.
	Planning lifetime	This is based on discussions with the operators on the lead-time required to deploy network assets
Cov&Dem_In	Wide area coverage - proportion of area (mid year)	This is the proportion of area that is currently covered in the Netherlands. Source: based on operator data, reflecting the level of coverage required by the market today

<i>Worksheet</i>	<i>Input name</i>	<i>Description</i>
	Special site repeater coverage	Average number of repeater sites deployed by the mobile operators
	Traffic Distribution by Area Type	Based on data provided by the operators. Most operators' data is broadly consistent with this input
DemCalc	Average call duration (minutes)	Average of operator data
	Proportion of daily traffic in BH	5pm - 6pm is the busiest hour of the day in the Netherlands. Average of operator data. Most operators' data is broadly consistent with this input
	Proportion of weekday traffic in a year	Weekdays are typically more traffic intensive than week-ends
	Busy days per year	Business weekdays (five days per week minus bank holidays)
	Call attempts per successful call	Some outgoing calls will not result in conveyance minutes (in particular to the fixed network). Parameter is an average of operator data
	Service routing factors	Analysys estimates taking into account routing factor data submitted by operators
Utilisation_In	Maximum utilisations	This is based on data from the operators and an allowance for scorched node calibration Source: averaged operator data and scorched-node calibration
QoS_In	Air interface blocking probability	This is a GSM standard, confirmed by operator data
	Max cell radius, GSM 900, for coverage network	These radii are based on an analysis of actual network deployments of GSM operators (area covered divided by site numbers) Source: averaged operator data
	Max cell radius, GSM 1800, for coverage network	These radii are based on an analysis of actual network deployments of DCS operators (area covered divided by site numbers) Source: averaged operator data
	Urban microcell traffic proportion	Estimate based on scorched-node calibration
NwDes_Para	Area factor	This is based on an hexagonal coverage pattern ($3 \times \sqrt{3} / 2$)
	Minimum transceivers (TRXs) per sector	This is based on operators' actual minimum BTS configurations combined with scorched-node calibration

<i>Worksheet</i>	<i>Input name</i>	<i>Description</i>
	Total channels per TRX	This is a GSM standard
	Sector re-use number PGSM	Source: Analysys estimate, informed by operator data
	Sector re-use number DCS	Source: Analysys estimate, informed by operator data
	Bandwidth of transceiver (MHz)	This is a GSM standard
	Number of sectors per site	This is based on the deployment strategies applied by the operators, combined with scorched node calibration
	Proportion of sites that can be overlaid	This refers to the proportion of sites that can support dual spectrum equipment. Currently set to 100%. Source: Analysys estimate
	Capacity of BTSs (TRXs)	This is the physical capacity of BTSs in transceiver terms
	Proportion of the sites that use microwave backhaul	This is based on the deployment strategies applied by the operators. Source: averaged operator data where applicable to modelled topology
	Maximum number of sites per microwave chain	Microwave backhaul follows a chaining topology, which has a quantifiable maximum depth. Source: averaged operator data where applicable to modelled topology
	Average number of sites per microwave chain	The average depth of these chains is based on actual operator data. Source: averaged operator data where applicable to modelled topology
	BSC, core capacity in TRX	Model BSCs deployed in the Netherlands are able to control 1024 TRXs. Source: selective operator data
	Proportion of the BSC sites that are remotely sited and use local or national leased backhaul	Source: averaged operator data where applicable to modelled topology
	Minimum number of MSC required	This number is set to two for redundancy purposes
	Number of CPUs per MSC	One MSC unit is assumed to mean a processor unit and assorted port cards (we note that a second CPU is present in each MSC for full redundancy protection.)
	Maximum number of 2Mb/s ports per MSC	Modern MSCs deployed in the Netherlands are able to accommodate 600 port cards. Source: averaged operator data where applicable to modelled topology
	Switching buildings and transit switches required	The rule governing deployment of switching buildings and transit layer switches is stated explicitly. Source: averaged operator data where applicable to modelled topology

<i>Worksheet</i>	<i>Input name</i>	<i>Description</i>
	Minimum number of HLR HLR capacity	This number is set to two for redundancy purposes Modern HLRs deployed in the Netherlands are able to hold 1 000 000 registered subscribers records. Source: selective operator data
	Backbone links capacity	Operators in the Netherlands typically operate their own backbone network, for which the unit capacity is assumed to be STM-1
	Minimum number of SMSCs	This number is set to two for redundancy purposes
	Throughput of SMSC (messages per second)	The number of messages that can be handled by the SMSC - operators configurations differ and a single parameter has been selected
	GGSN capacity (active PDP contexts)	The number of simultaneous contexts that can be opened - operators configurations differ and a single parameter has been selected
	Minimum number of GGSNs	This number is set to two for redundancy purposes
	SGSN capacity (connected subscribers)	The number of simultaneous users that can be attached - operators configurations differ and a single parameter has been selected
	Minimum number of SGSNs	This number is set to two for redundancy purposes
RouFacs	Cost allocating routeing factors for each network element and service	These parameters have been derived from earlier inputs and calculations in the model, and determine which services bear the costs of network elements and to what (numerical) extent
CostTrends	Unit capital cost trends	Averaged operator data on bottom-up unit prices and their price trends
	Unit operating cost trends	Averaged operator data on bottom-up unit prices and their price trends
DiscFacs	Real discount rate	Source: Analysys WACC calculation
UnitCapex	Unit capex cost per network element	Average top-down and bottom-up operator data
UnitOpex	Unit opex per network element	Average top-down and bottom-up operator data
Com_Incr	Proportion of assets that are common	Analysys estimates. See conceptual approach document for further discussion

Annex B: List of updates to model following IG-II presentation

The IG-II presentation briefly described the rationale and assumptions applied in the draft model. Prior to the model release, a small number of approaches and parameters were refined. These revisions are listed in this annex.

Slide 30 “Site deployment choices vary by spectrum available: for coverage...”

- All macro sites deployed, for both coverage and capacity, are considered to be tri-sectored
- Minimum TRX/sector deployments in urban and suburban areas have been increased from one per sector to two per sector. This parameter remains one TRX/sector in rural areas.

Slide 40 “Planning period varies by asset type”

- Licence fee expenditures are assumed to have a 24 month planning period (i.e. 1 January 2004 for 1 January 2006 launch).

Annex C: List of structural changes to the model following IG-II

- Corrected link to SMS BH proportion
- Adjusted algorithm for achieving coverage across urban, suburban and rural areas
- Recalibrated all radio network parameters
- Adjusted spectrum re-use calculation to be based on frequency band rather than amount of spectrum
- Option to allocate MSC costs according to switch counting rather than processor loading routeing factors
- Option to allocate radio network costs according to signalling and conveyance rather than voice equivalent minute routeing factors
- Added cost elements for NMS, VMS, IN, billing system and business overheads (network share)
- Implemented common and incremental asset identification to enable equal-proportionate mark-up of common costs
- Added exogenous step to mark-up location update costs to received events (calls and SMSs)
- Added exogenous step to transform cost results into nominal currency.

Annex D: List of changes to the model following IG-III and bilateral operator meetings

- Lifetime of MSC and HLR adjusted to calculated economic lifetime
- Set maximum re-use to be 16 for PGSM and DCS spectrum types
- Recalibrated all radio network parameters based on coverage requirements set out in the conceptual design
- Adjusted market share profile
- Adjusted business overhead cost level to reflect a standalone mobile network operation
- Adjusted DCS spectrum fee for PGSM operators to be paid in year 3 and released in year 5
- Adjusted unit cost inputs to take into account one operator's delayed data
- Added option to include various coverage network assets in the common cost mark-up (a scenario not selected as the base case)
- Adjusted licence allocations and spectrum fee amounts.