Report for the Norwegian Post and Telecommunications Authority

NPT's mobile cost model version 7.1

Model documentation

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1 Introduction

In 2006, a bottom-up long-run incremental cost model ('v4') was constructed and finalised for NPT by Analysys Mason Limited ('Analysys Mason'), with the aim of calculating the cost of voice termination for the GSM mobile operators in Norway. In 2009, an upgrade process was commenced to capture UMTS networks and other market developments within the model – this resulted in the development of draft version 5.1 of the cost model. The purpose of this document is to now explain the revisions made to the version 5.1 model ('v5.1') in arriving at the revised draft model ('v6'), and enable a user to both understand and navigate through the model and its worksheets, inputs and calculations. A small number of changes applied in going from version 6 to version 7.1 following public consultation are also explained in this document.

The upgraded model has been populated in operator-specific confidential versions. A schematic of the model is shown below in Figure 1.1.

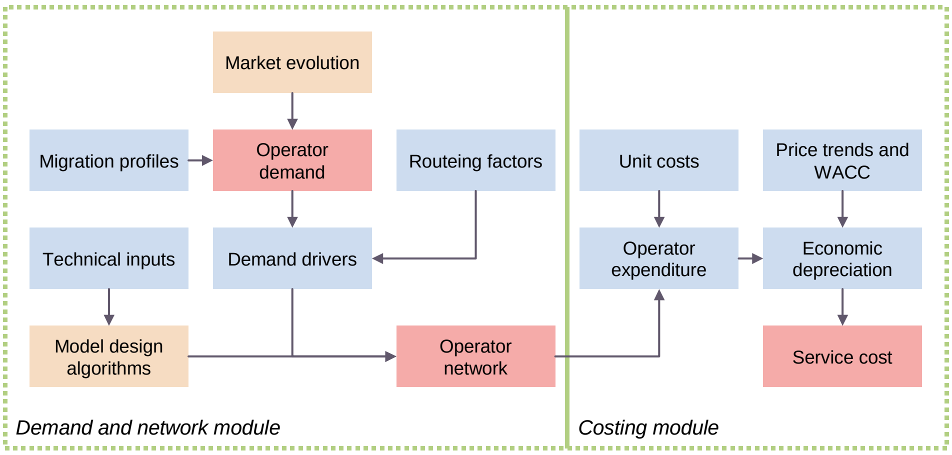


Figure 1.1: Model schematic [Source: Analysys Mason]

This documentation covers the complete model, but should be read in conjunction with the documentation for the v4 release of NPT's mobile cost model.[1]

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

The model documentation includes a number of annexes containing supplementary material:

[1] These materials can be downloaded from http://www.npt.no/iKnowBase/Content/Model_documentation_v4.pdf?documentID=50981

- Annex A provides a detailed description of both the 2G and 3G network design algorithms
- Annex B provides a glossary of the acronyms used in this document
- Annex C summarises the public operator submissions and associated responses
- Annexes D and E summarise responses to confidential operator submissions
- Annex F summarises the changes made to the v5.1 model to derive the v6 model.
- Annex G discusses the Tele2 and Network Norway (CSMG) submission to the public consultation, outlines our solution, and explains the changes made to the v6 model to derive the v7.1 model for NPT's final decision.

2 Installing and running the model

This section describes the basic operation of the model.

2.1 Running the model

The model is presented in an Excel workbook, called *NPT_LRIC_v7.1.xls,* which can be stored in a local directory and opened as a single file. There are no external links to other workbooks. The model should be compatible with all versions of Microsoft Excel (2000, 2003 and 2007). The model must be run slightly differently, depending on whether the output required is the long-run average incremental cost including all mark-ups (LRIC+) or the pure long-run incremental cost of wholesale termination (pure LRIC):

- **LRIC:** Set the calculation mode to "LRAIC" on the *Ctrl* worksheet and press the **F9** (recalculate) key. For some versions of Excel, a full recalculation (**CTRL** + **ALT** + **F9**) may be required. The model has run and calculated when 'calculate' is no longer displayed in the Excel status bar. The model may take approximately a minute to fully calculate, particularly if run on an older computer. Alternatively, press the "Run LRIC" macro button on the *Ctrl* worksheet.
- **Pure LRIC:** In order to run the pure LRIC calculation in the model, click on the button labelled "Run pure LRIC" on the *Ctrl* worksheet. This activates a simple macro to run the model twice, with certain outputs pasted onto the *PureLRIC* worksheet. This calculation will take approximately twice as long to complete.

The *Ctrl* worksheet indicates whether or not the pure LRIC calculation was last executed for the operator currently selected (to remind the user to click the "Run pure LRIC" macro button).

2.2 Model worksheets

The structure of the Excel workbook is detailed below in Figure 2.1. The worksheet names in the model are prefixed (e.g. with "A1_", "B2_") in order to reduce the calculation time.

Worksheet name	*Description*
Ctrl	Allows the user to change the operator and the main market / technical sensitivities
C	Contents sheet
V	A history of the versions of this workbook
S	A guide to the styles used in this workbook
L	Contains basic array inputs such as cost categories, years
Area	Contains basic area and population data
M6	Market scenario sheet - contains all demand, historic and forecast
M	Demand data for selected operator
LifeIn	Contains assumed asset lifetimes
UtilIn	Defines network element utilisation
NtwDesBase	Contains specific network data for each operator choice
3rdOpCov	Calculates the coverage of the third operator network for the demand module
NtwDesSlct	Displays network data for selected operator choice
CovDemIn	Describes the coverage conditions together with the traffic by geotype split
DemCalc	Converts the traffic forecasts into units that are suitable for network dimensioning
BSCMSC	Derives the mapping of BSCs to MSCs in the GSM network
MSCTSC	Derives the mapping of MSCs to TSCs in the GSM network
RNCMSC	Derives the mapping of RNCs to MSCs in the UMTS network
RNCMGW	Derives the mapping of RNCs to MGWs in the UMTS network
RNCPS	Derives the mapping of RNCs to packet-switch routers in the UMTS network
NwDes	Calculates the network requirements for each major element based on demand
FullNw	Collates the required number for each type of network element in each year
NwDeploy	Calculates total items deployed and incremental deployment (including replacement)
DemIn	This sheet simply transposes the service demand array
RF	Contains routeing factors
NwEleOut	Service routeing factors * Total service demand
DF	Contains real and nominal discount rates
CostBase	Lists unit costs by network element
CostTrends	Contains unit capital and opex cost trends, cost index and cost trend weighted output
UnitCapex	Contains the unit capex cost per network element
CapexAdj	Provides adjustments to the capex into the calculation (if required)
TotalCapex	Calculates the total annual capex investment
UnitOpex	Contains the unit operating cost per network element
TotalOpex	Calculates the total annual operating costs
ED	Calculates the economic depreciation by asset
ComIncr	Calculates common versus incremental costs
LRIC	Output sheet of key LRIC results
PureLRIC	Calculates the pure LRIC based on outputs of the model with and without MT traffic
RNom	Converts service costs using economic depreciation into nominal NOK
HC	Calculates the historic cost accounting (HCA) depreciation by asset
RNomHC	Converts service costs using HCA into nominal NOK
SrvCostHC	Calculates service costing using HCA
TA	Calculates the tilted annuity depreciation by asset
Erlang	Interpolated Erlang-B lookup table

Figure 2.1: Description of model's worksheets [Source: NPT cost model, Analysys Mason]

2.3 Description and location of main inputs

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

Control panel Location: *Ctrl* worksheet

Selection of operator and scenarios to be applied to the model.

Market forecasts Location: *M6* and *M* worksheets.

The *M6* sheet captures the market projection inputs for the upgraded model.

The *M* worksheet collates market parameters for the selected operator and allows simple modification of demand by service without adjusting the forecasts in the *M6* worksheet.

GSM roll-out Location: *NtwDesBase* worksheet, rows 337–778

This controls the proportion of area covered by the GSM coverage and infill network in each year.

UMTS roll-out Location: *NtwDesBase* worksheet, rows 780–870

This controls the proportion of area covered by the UMTS coverage network in each year.

Network design parameters Location: *NtwDesBase* worksheet

These parameters control all the operator specific aspects of the network design:

- spectrum allocation
- blocking probabilities
- cell radii
- coverage inputs
- traffic assumptions (call durations, busy hour, call attempts, traffic by geotype)
- maximum frequency reuse pattern
- site sectorisation
- site type deployment (own, third party sites)
- BTS/NodeB capacities
- 2G/3G repeater and tunnel deployments
- 2G and 3G backhaul: split between microwave and leased lines
- BSC and RNC locations
- BSC–MSC and RNC–MSC link capacities
- MSC, MSS and MGW capacities
- MSC, TSC, MSS and packet-switch locations
- proportions of traffic traversing the backbone network
- HLR, SMSC, MMSC, PCU and GSN capacities and minimum deployments.

Most parameters can be modified by the user as required.

Asset lifetimes	Location: *LifeIn* Input of asset lifetimes and planning periods.
Demand driver parameters	Location: *DemCalc* This sheet contains further inputs which are required to convert demand volumes into network drivers: • SMS channel parameters • GPRS/R99 traffic parameters • HSDPA/HSUPA traffic parameters • Subscriber and PDP context registration in GSNs • Routeing factors for the radio and transmission layers of the network • MSC processor, MGW, SMSC and GSN loading parameters.
Equipment costs	Location: *CostBase* Capital and operating cost per unit of equipment in 1992, expressed in real 2005 NOK. These unit costs can be converted to run the model in any real-year currency.
Equipment price trends	Location: *CostTrends* Annual real-term price trend for capital and operating cost components.
Cost of capital	Location: *DF* Pre-tax WACC and inflation.
Network common costs	Location: *ComIncr* Specification of network common costs.

3 Demand assumptions

3.1 Market demand

Market demand is modelled for each mobile operator for historical years, based on data provided by NPT's statistical department and from data provided by the mobile operators in response to the data request. For future years, forecasts are applied in which the market experiences growth in subscribers and traffic. The current market model is on the *M6* worksheet.

3.1.1 Subscribers

The number of registered subscribers in the market is calculated with a projection of future population taken from Statistics Norway (SSB) and the assumed level of penetration of digital mobile services. Separate forecasts for digital mobile subscribers and mobile broadband subscribers have been calculated, as shown below in Figure 3.1.

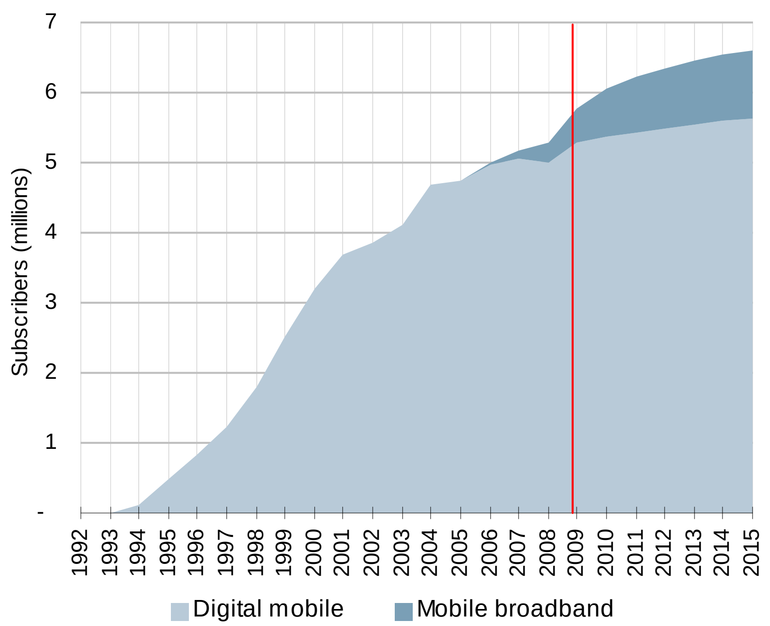


Figure 3.1: Subscriber evolution [Source: Analysys Mason]

Our forecast for mobile broadband uptake is conservative, with penetration reaching almost 20% of the population in the long term.

3.1.2 Voice traffic

Historic traffic levels up to 2005 in the model were left unchanged. All additional historic traffic volumes up to 2008 were sourced from operator data. The forecast traffic demand for each mobile operator is determined by a projection of traffic per registered subscriber multiplied by projected subscribers, with outgoing and incoming traffic forecasted separately. The evolution of usage per subscriber per month is shown below.

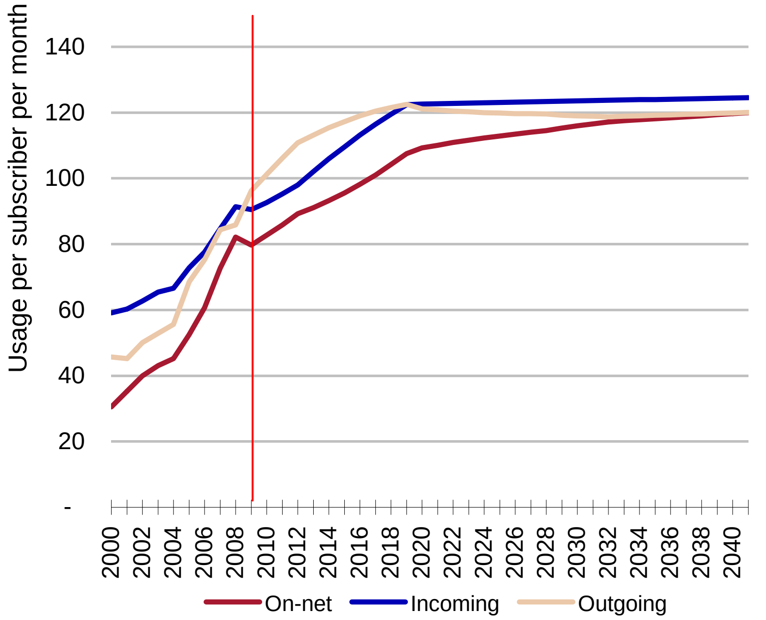


Figure 3.2: Evolution of voice usage in Norway [Source: Analysys Mason]

As in the original cost model, voicemail minutes have been included in total demand. The model currently assumes that all voicemail messages that are deposited on the VMS are picked up, and that the radio network usage of deposited messages is later allocated to the depositing service (e.g. incoming or on-net call).

These forecasts lead to a total usage in the Norwegian market as shown below in Figure 3.3.

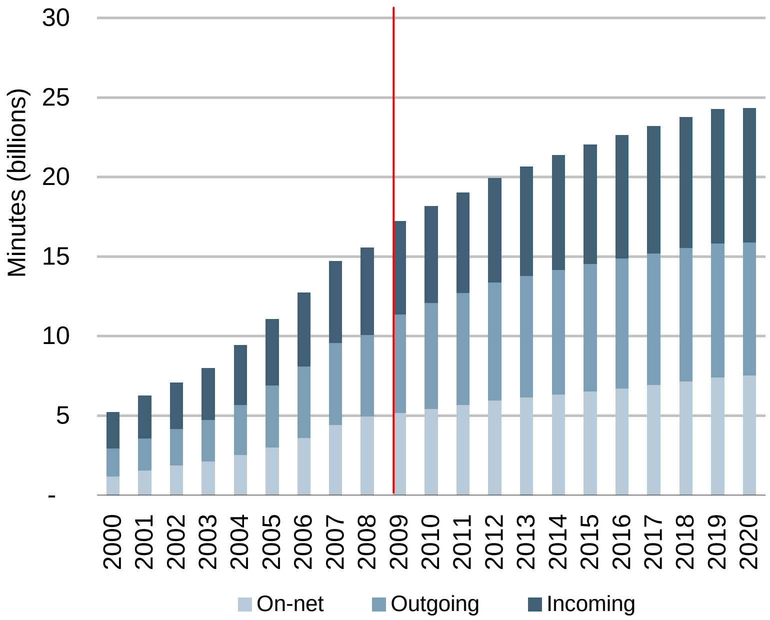


Figure 3.3: Evolution of total voice usage in Norway [Source: Analysys Mason]

3.1.3 Data traffic

Historic traffic levels up to 2005 already in the model were left unchanged. All additional historic traffic levels up to 2008 were sourced from operator data, augmented where necessary by NPT's statistics department. Full-year 2009 information has also been incorporated into the v7.1 model.

The forecast of most significance is that for HSPA (mobile broadband) traffic, which is currently experiencing significant growth in the early phases of take-up. The forecast of total megabytes in Norway that increases by a factor of six between 2008 and 2012, as shown below in Figure 3.4.

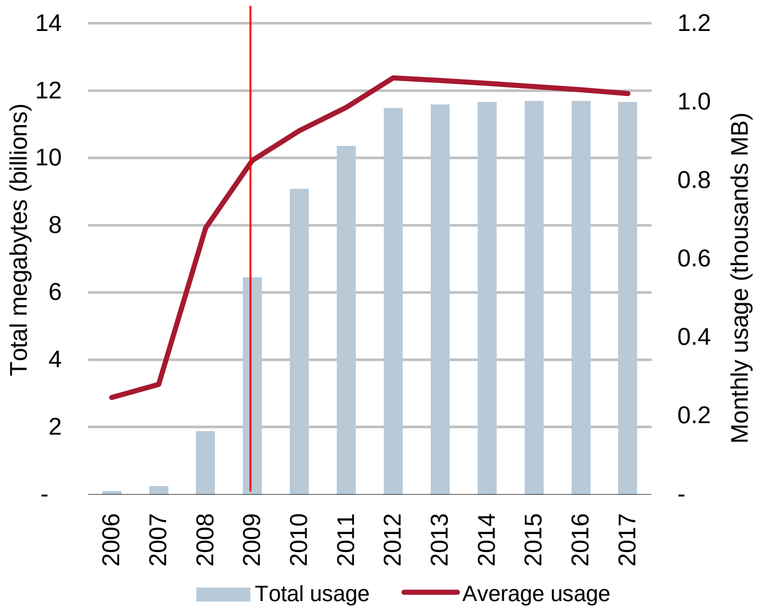


Figure 3.4: Evolution of HSDPA usage in Norway [Source: Analysys Mason]

3.2 Market share

The market share of traffic on each infrastructure operator is projected to eventually reach equalisation at 33%, assuming a third operator entering the market in 2008 and reaching equal market share in the long term, as shown below in Figure 3.5. This forecast is based on the three-player market forecast applied in NPT's original cost model.

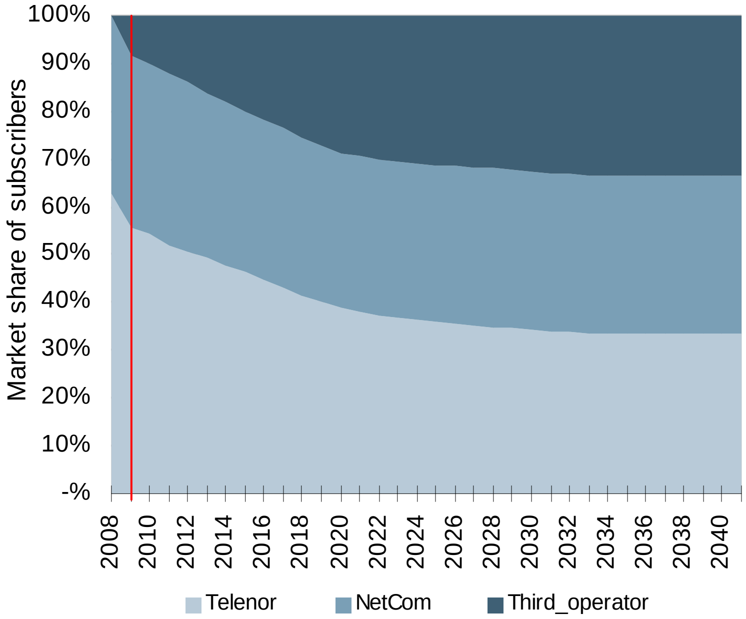


Figure 3.5: Market share evolution [Source: Analysys Mason]

4 Network assumptions

The main assumptions and choices about radio, core and other aspects of the network design are described below.

4.1 Radio network

4.1.1 Geotypes

The model considers each Fylke in Norway as a separate geotype. Data on network coverage by Fylke was supplied to the NPT by each operator through the analysis of each operator's network radio databases.

Each operator has supplied voice traffic data split by geotype, with which the GSM and UMTS voice and low-speed mobile data networks have been dimensioned; HSDPA mobile broadband traffic by geotype has been estimated by Analysys Mason on the basis of a population distribution skewed towards the four major cities in Norway, as shown below in Figure 4.1.

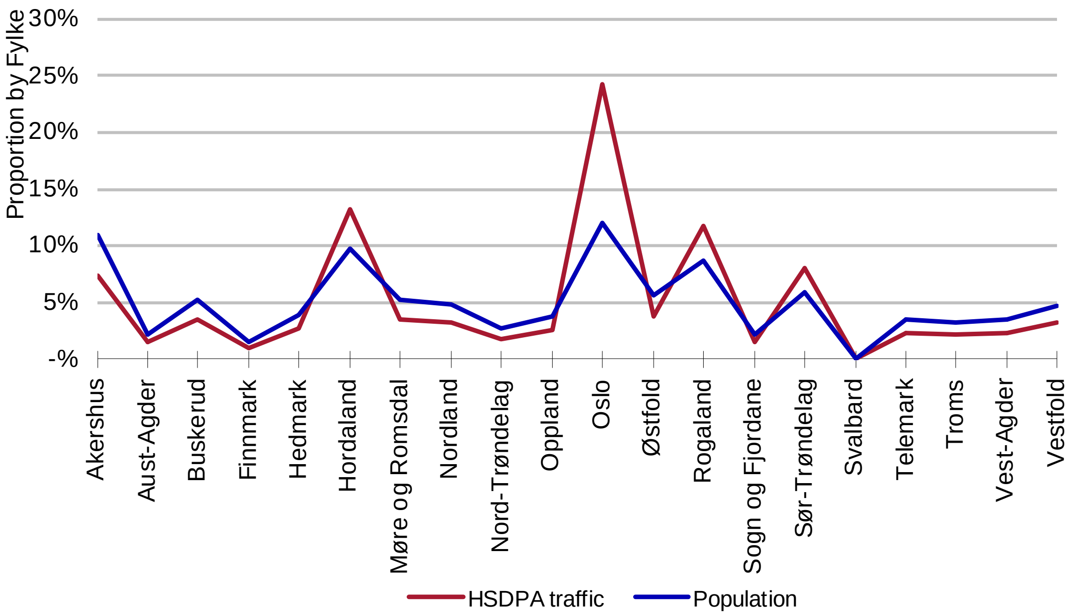


Figure 4.1: Mobile broadband and population distribution [Source: Analysys Mason]

The definition of the geotypes can be found in the *A* worksheet (for geographical parameters) and the *CovDemIn* worksheet (for traffic calculations).

4.1.2 Coverage

Coverage was determined on the basis of the radio database of each of the operator's networks, as submitted to the NPT as part of the data request. From this database, the area covered at a signal strength of –94dBm was calculated: this strength represents approximate outdoor coverage. Coverage calculations were made for the following sets of frequencies:

- GSM900
- GSM1800
- GSM900+GSM1800 (i.e. GSM)
- UMTS.

Indoor coverage, in terms of area and population, reflected by a higher signal strength, is commensurately lower, though not used to drive network deployment in the model except for the initial coverage of the third entrant operator reflected in the v7.1 model.

In the initial network roll-out years, additional sites are assumed to be rolled out to maximise the area covered, with little or no overlap between cells. In the later years, sites are deployed for infill purposes. These sites fill in the gaps in wide-area coverage and improving the contiguousness of the network. They consequently have a lower cell radius, reflecting the smaller uncovered areas which these cells satisfy. This concept is shown in Figure 4.2 for the operators' GSM networks:

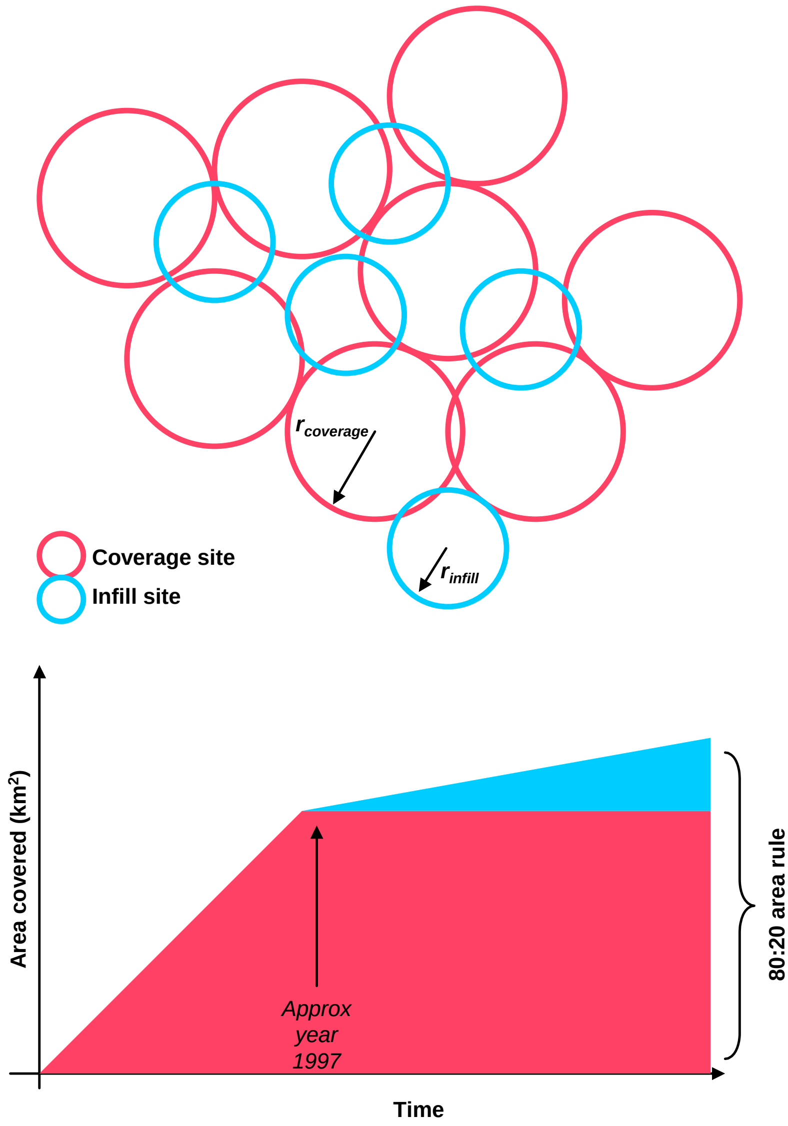


Figure 4.2: Wide-area GSM coverage and infill [Source: Analysys Mason]

The coverage profile of the GSM network is defined for each operator, on the basis of 900MHz frequencies, using the inputs from the original (v4) model. These inputs have been updated for the period 2005–2008 using outputs of the GSM coverage recalculation performed by NPT in 2009.

For the modelled UMTS networks, the approach to wide-area and infill coverage has been modified slightly. The UMTS model assumes the following roll-out process:

- "wide-area" coverage of the **urban** areas in each Fylke is deployed using 2100MHz spectrum
- "infill" coverage of the **urban** areas in each Fylke is deployed using 2100MHz spectrum
- **rural** coverage in each Fylke is deployed using UMTS900 equipment, on the assumption that as GSM frequencies become unloaded, they can be re-farmed for a 900MHz UMTS deployment.

Therefore, the first two parts of this coverage roll-out are similar to the GSM network algorithm, albeit with alternative parameters reflecting the proportion of population (and hence area) and cell radius used for the deployment. The third part of UMTS coverage aims to replicate GSM coverage in order that the GSM network may be shut-down.

This concept is shown in Figure 4.3 below for the operators' UMTS networks. Although the roll-out using 2100MHz spectrum only covers approximately 25% of the Norwegian land area, it reaches more than 90% of the population. UMTS900 is then used to increase the UMTS coverage to equal to GSM coverage, but only covers the remaining 5–10% of population across a large area of the country.

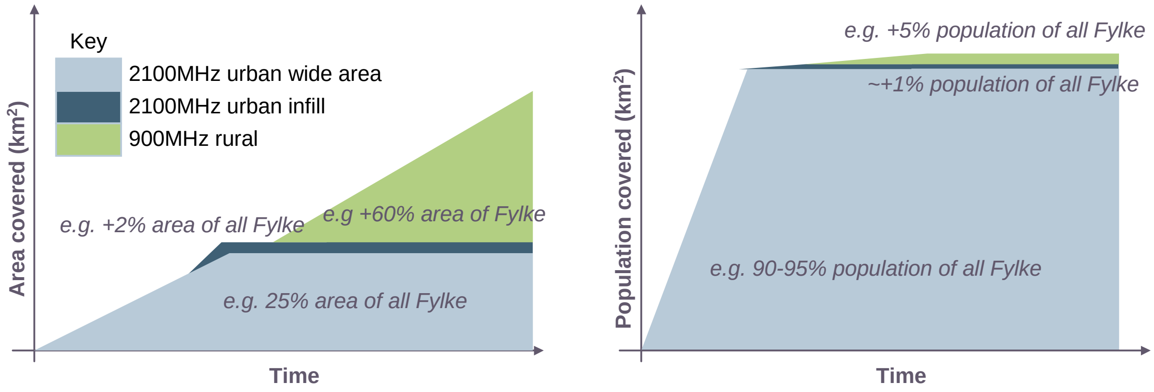


Figure 4.3: UMTS coverage and infill [Source: Analysys Mason]

The parameters determining these calculations can be found in the *NtwDesBase* and *NtwDesSlct* worksheets.

4.1.3 Mobile broadband

In order to offer mobile broadband services using UMTS, the model includes three levels of high-speed packet data service:

- **HSDPA 3.6Mbit/s**: deployed in the first carrier at all UMTS sites using 32 channels per NodeB with 16QAM coding
- **HSDPA 7.2Mbit/s with HSUPA 1.5Mbit/s**: in addition to the first level of service, a proportion of NodeBs are upgraded with an additional 64 channels per NodeB in the second 5MHz carrier to support HSDPA along with 32 channels per NodeB for HSUPA (2 codes × Spreading Factor 4)
- **HSDPA 14.4Mbit/s with HSUPA 1.5Mbit/s**: the model can assume that those NodeBs deployed with HSDPA7.2 are then upgraded after an assumed number of years to use an additional 64 channels per NodeB in the second 5MHz carrier to support HSDPA at 14.4Mbit/s.

4.1.4 Repeater sites

Repeater sites are deployed to serve special areas that cannot be covered by other types of sites. The model considers two types of repeater sites: wide-area repeaters and tunnel repeaters.

Based on a comparative analysis of the deployment actually undertaken by operators in Norway, the number of wide-area repeaters is based on a percentage of sites required for coverage purposes. It is assumed that wide-area repeaters are radio repeaters – i.e. they have a receive and a re-transmit antenna. Repeaters for coverage are deployed separately in the 2G and 3G networks.

Coverage of road and rail tunnels is an important part of Norwegian mobile networks. Given the fact that the number of tunnels in Norway is finite, the number of 2G and 3G tunnel repeaters are both entered into the model as an explicit inputs.

These roll-outs are defined in the *NtwDesBase* worksheet.

4.1.5 Sectorisation and overlay of sites

Radio sites deployed in Norway are mainly for coverage purposes, and traffic levels for the average site are generally low by European standards. As a result, such GSM sites are frequently omni-sectored, with subsequent sectorisation and overlay of DCS1800 spectrum occurring predominantly for capacity purposes only in towns and cities.

Capacity dimensioning is carried out with reference to parameters including:

- radio blocking probability (1% to 5% depending on cell layer)
- approximately 8% of daily voice traffic is in the busy hour (typically 16:00-17:00 on a weekday) and approximately 80% of annual traffic occurs during weekdays
- typical maximum equipment utilisation parameters.

The GSM network is dimensioned using the traffic channel (TCH) Erlang load from voice and GPRS traffic. The process for calculating the GSM capacity, sectorisation and overlay of sites with secondary spectrum is shown below in Figure 4.4.

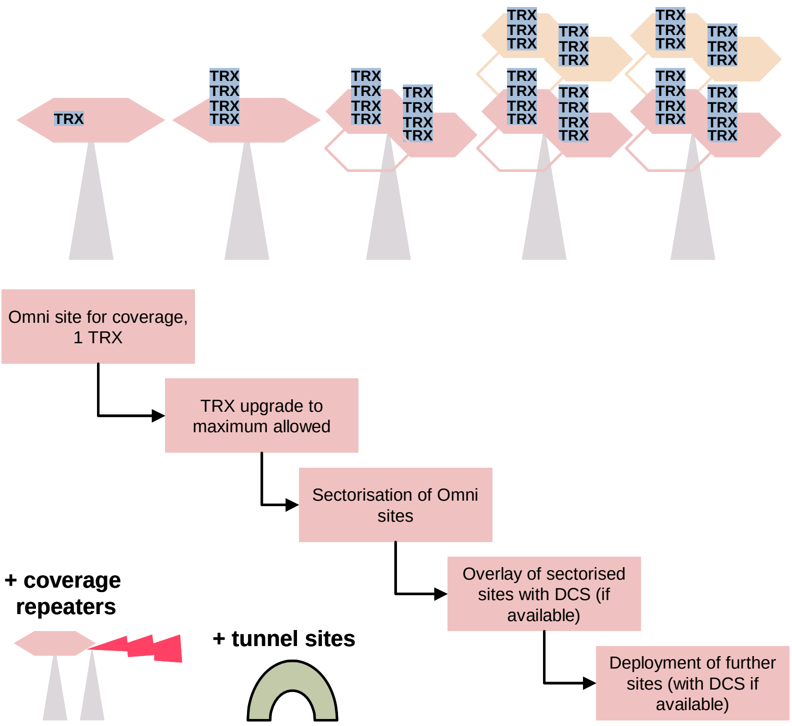


Figure 4.4: GSM radio network deployment [Source: Analysys Mason]

The UMTS network is dimensioned with the Release-99 channel element load produced by voice and low-speed data Erlangs. The UMTS network is expanded with increasing traffic in terms of channel kit (CK) and additional carriers per site. It is assumed that in order to accommodate cell breathing effects, the UMTS coverage networks deployed by the operators are sufficient to carry forecast voice and data traffic loads.

In the case of the UMTS network, 2100MHz sites are deployed predominantly in urban areas and are therefore deployed "fully-sectorised" according to the average sectorisation of 2100MHz sites (between 2 and 3 depending on operator data). In the later years within the model, UMTS900 sites are deployed as omni-sectored sites in rural parts of each Fylke.

The number of sites deployed have been calibrated against operators' actual numbers separately for both the GSM and UMTS networks.

Capacity and sectorisation inputs can be found in the *NtwDesBase* worksheet.

4.1.6 Site types

Operators utilise a mix of shared, third-party and owned sites. The model considers the proportion of three types of site deployment – in order to capture the different costs associated with site acquisition, civil and ancillary equipment. The three types are shown in Figure 4.5.

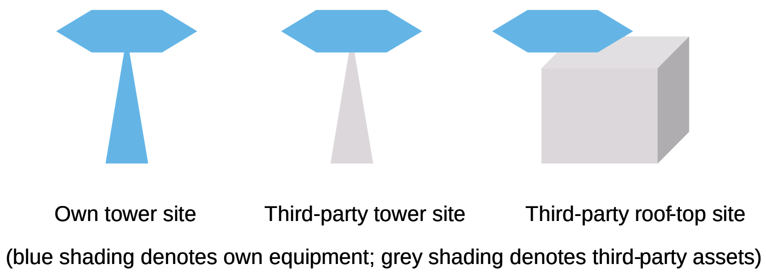


Figure 4.5: Site types [Source: Analysys Mason]

Existing GSM sites may be suitable for adding UMTS NodeB equipment. We specify the proportion of 2G sites suitable for this upgrade (currently estimated to be 85%–100%). For each year in the model, the total number is calculated for:

- sites with only 2G technology deployed (2G-only)
- sites with only 3G technology deployed (3G-only)
- sites with both 2G and 3G technologies deployed (2G/3G).

Site type proportions can be found in the *NtwDesBase* worksheet.

4.1.7 Backhaul configuration

The GSM backhaul configuration is modelled on the basis of the percentage of sites in each Fylke which require microwave (typically 8Mbit/s units, though there may also be some E1 connections) or leased-line (either 64kbit/s or 2Mbit/s E1 links) backhaul. This is shown in Figure 4.6.

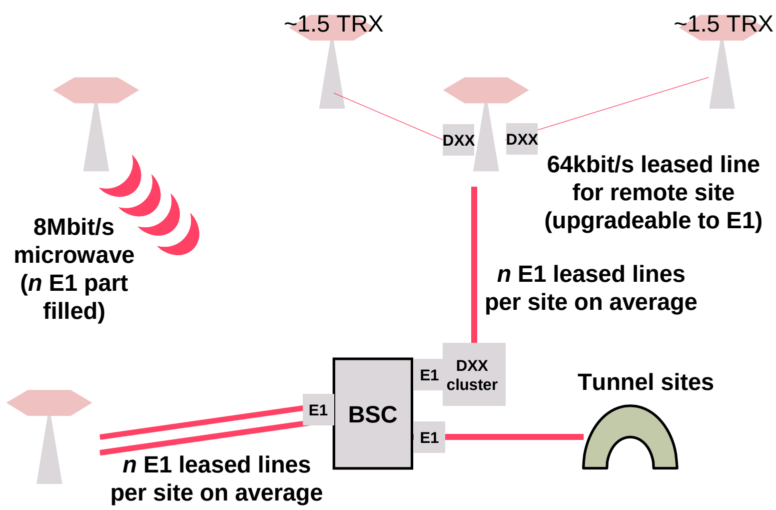


Figure 4.6: GSM backhaul configuration [Source: Analysys Mason]

DXX access nodes are deployed according to 64kbit/s links, and are modelled to persist in the network even when the 64kbit/s links are replaced with a higher capacity E1. DXX cluster nodes are deployed on the basis of a number of access nodes per cluster node. This ratio is based on data submitted by each operator.[2]

The UMTS backhaul configuration is similar, with the exception that 64kbit/s links are not used at all. All NodeB's require at least one E1 for R99 traffic; in addition, the NodeB HSDPA throughput (plus an estimated IP overhead) must be provisioned in the backhaul capacity of each site. This is shown below in Figure 4.7.

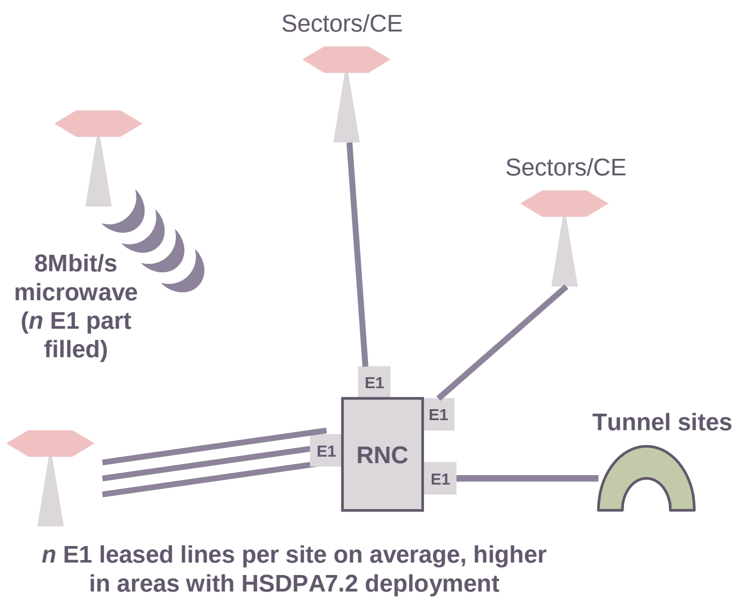


Figure 4.7: UMTS backhaul configuration [Source: Analysys Mason]

These assumptions can be found in the *NtwDesBase* worksheet.

4.1.8 BSC deployment

The number of BSC locations per Fylke is defined over time. For historical years it is based on data supplied by the operators, and for forecast years it is assumed to remain constant according to the last year of historical data.

The number of BSCs are driven by the number of transceivers (TRX) in the network. The TRX calculated in each Fylke are logically mapped onto a particular Fylke's BSC location according to network information supplied by the operators. This is shown on a theoretical basis in Figure 4.8 below.

2 We have not modelled DXX units for NetCom because they do not appear to conform to this deployment logic. Instead, the costs of NetCom's DXX units are included in the cost of other radio and transmission equipments.

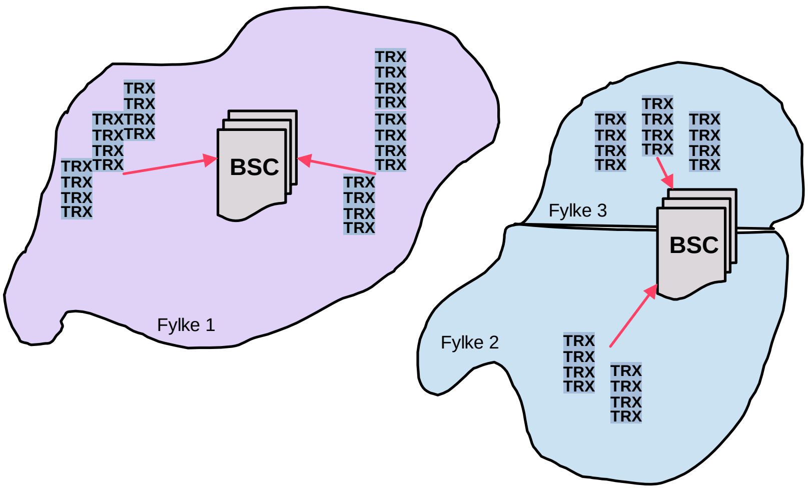


Figure 4.8: BSC deployment [Source: Analysys Mason]

BSC capacity is defined in terms of number of TRXs, as supplied by each operator. The inputs associated with this deployment can be found in the *NtwDesBase* worksheet.

4.1.9 Remote BSCs and associated BSC–MSC links

Remote BSC locations are modelled to occur when the number of BSC locations in a Fylke is greater than the number of MSC locations in that Fylke (each MSC location logically has a co-located BSC location).

In a Fylke in which there are no MSC locations, all BSCs in the Fylker are remote. When there are MSC locations in the Fylke, is assumed that there is one remote BSC per remote BSC location, and all remaining BSC required are co-located with the MSC(s).

Remote BSCs are attached to the nearest MSC – which will either be in the same Fylke, or the nearest Fylke by distance.

The traffic transiting through these BSCs is backhauled to the MSC using E1 leased lines. The length of these E1 links is determined by the Fylke-Fylke distance matrix, or the estimated internal-Fylke distance. This is shown below in Figure 4.9.

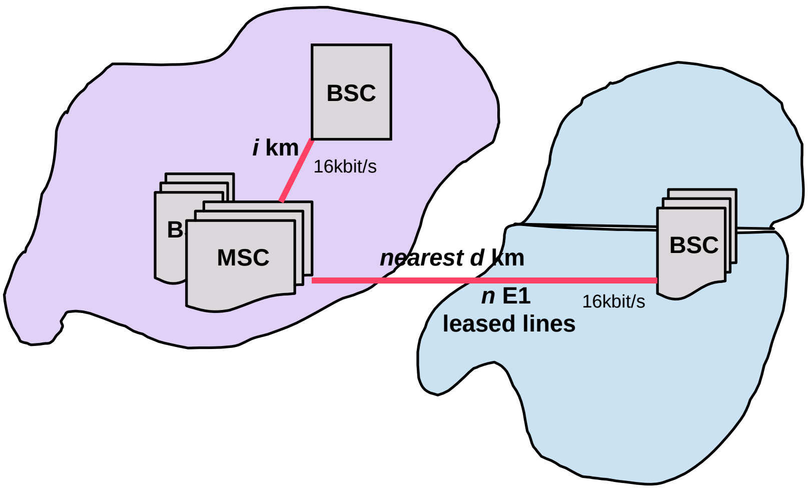


Figure 4.9: BSC–MSC transmission for remote BSCs [Source: Analysys Mason]

4.1.10 RNC deployment

The number and location of RNC switches is specified by Fylke, according to each operator's network topology. Typically, RNCs are only deployed in the major cities of Norway (and possibly in multiple locations in Oslo).

The number of RNCs beyond this initial deployment in the major cities is determined by the maximum of three measures:

- Mbit/s traffic in the voice busy hour (where voice traffic is expressed according to 12.2kbit/s per Erlang, and added to both low-speed and high-speed Mbit/s)
- incoming E1 ports
- number of NodeBs.

Each of these measures is logically mapped onto a particular Fylke's RNC location, in the same way as for BSCs (see section 4.1.8). The inputs associated with RNC deployment can be found in the *NtwDesBase* worksheet.

4.1.11 RNC links to the core network

RNC switches are considered 'remote' when they are deployed in a Fylke without a corresponding voice MSC or MSS switch. Unless specified by the RNC location and MSC/MSS location input matrices, it is assumed that RNC switches are always deployed together in a Fylke – i.e. in one building, and not dispersed throughout the Fylke.

Remote RNCs require connectivity to the core network, with either:

- links to legacy MSC sites for the voice plus data Mbit/s load presented at the remote RNCs
- links to the layered core network, with circuit-switched links to MSS sites for voice load, and packet-switched links to the packet routeing layer for mobile data traffic.

These two types of connectivity are dimensioned in the following ways.

Legacy network — The voice and data Mbit/s passing through each remote RNC is mapped to the nearest MSC switching location (determined by a distance-aware matrix calculation) and dimensioned with either E1 or STM–1 links (subject to a maximum utilisation percentage). Redundant links are deployed for resilience purposes.

Layered network — The voice BHE passing through each remote RNC is mapped to the nearest MGW location (determined by a distance-aware matrix calculation) and dimensioned using STM–1 links (subject to a maximum utilisation percentage). Redundant links are deployed for resilience purposes.

The data Mbit/s passing through each remote RNC is mapped to the nearest packet routeing location (determined by a distance-aware matrix calculation) and dimensioned using STM–1 links, subject to a maximum utilisation percentage.

This layered architecture is illustrated below in sections 4.2.3–4.2.4.

4.2 Core network

For each 2G/3G operator, it is assumed that their networks are deployed in the following order:

- 2G network (radio and core)
- 3G radio network (with software upgrade to 2G MSC layer to handle 3G traffic)
- layered core network, with the shut-down of the legacy 2G core network
- shut-down of the 2G radio network.

The model accommodates both types of core network – i.e. the *legacy* core of meshed MSCs (and meshed TSCs if deployed), as well as a *layered* core with a separate circuit-switched layer (MGWs on a transmission mesh or ring) for voice and packet-switched layer for data (using meshed packet routers and GSNs).

4.2.1 Legacy MSC/VLR deployment

MSC deployment responds to three demand drivers: ports, processing and locations. Processor load is assessed based on the number of calls, SMS and location updates of each type that need to be switched. This determines the number of CPUs required. When the 3G network is deployed, but before the switch to a layered circuit/packet architecture, MSCs must be upgraded to support both 2G and 3G voice and SMS switching. This is modelled as a software upgrade to each MSC.

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.

Finally, the model ensures that the number of MSCs is at least equal to the number of specified MSC locations.

4.2.2 Legacy transit layer

A transit layer may be deployed for high volumes of traffic, and is controlled by the input of transit switching centre (TSC) locations over time. When more than one Fylke contains a TSC, the model switches to a transit layer hierarchy. The transit layer consists of 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. With a transit layer, all MSCs outside the transit layer are linked to two TSCs for redundancy.

4.2.3 Legacy backbone network

The model is able to accommodate two situations: with and without the deployment of a transit layer. The backbone links are assumed to be deployed in STM–1 increments. This is applied to MSC–MSC links (if no transit layer), MSC–TSC links and transit links between TSCs.

The model when there is no transit layer is shown below in Figure 4.10.

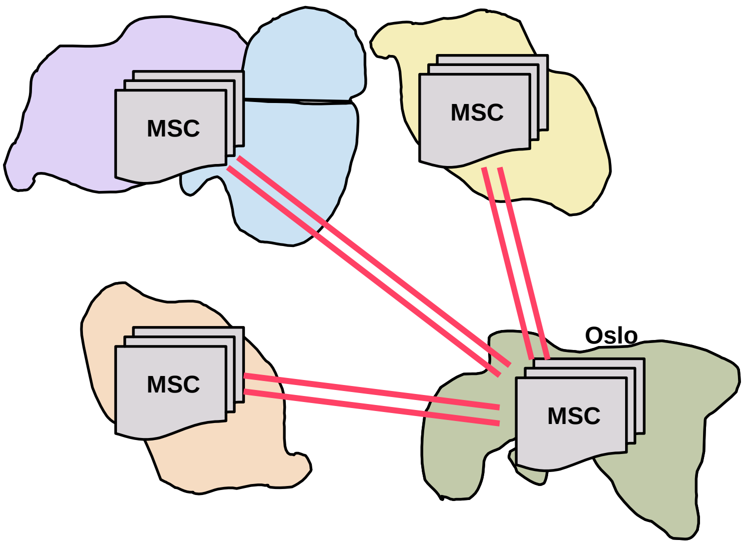


Figure 4.10: MSC–MSC transmission (no transit layer) [Source: Analysys Mason]

For each MSC location outside of Oslo, there is one link into Oslo, with a second link on the same route for redundancy purposes. It is assumed that each MSC acts as a point of interconnection (PoI) with mobile and fixed traffic being routed on and off the network accordingly: there is far-end handover for traffic to the fixed network (M–F), and near-end handover for incoming traffic into the network (F–M and M–M). When there is more than one MSC deployed within Oslo, a ring structure is also deployed to connect them.

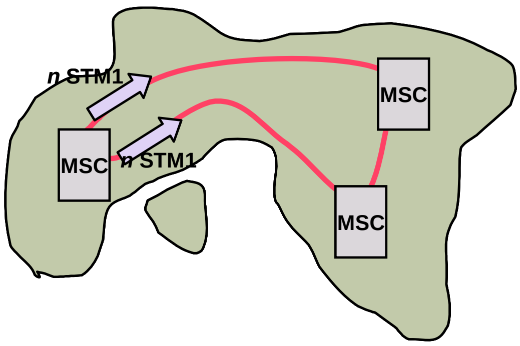


Figure 4.11: Deployment of the Oslo ring when there is no transit layer [Source: Analysys Mason]

For the intra-Oslo MSC–MSC transmission, 3km leased lines per MSC of *n* STM–1 per link are modelled. Their capacity is driven by the amount of traffic that is carried over MSCs in Oslo.

The model calculates the effect of the deployment of a transit layer in a logically similar fashion, displayed in Figure 4.12.

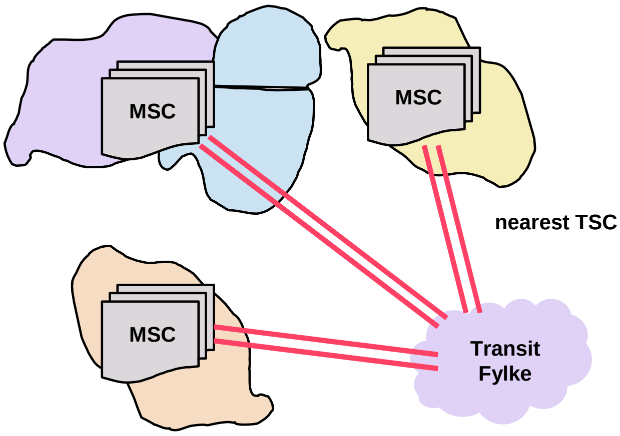


Figure 4.12: MSC–TSC transmission with the deployment of a transit layer [Source: Analysys Mason]

The nearest TSC is identified for each Fylke with MSCs but no TSCs. There is one MSC–TSC link per MSC location, with a second link per route dimensioned for redundancy purposes.

It is assumed similarly that each MSC and TSC acts as a point of interconnection (PoI) with mobile and fixed traffic being routed on and off the network accordingly. There is far-end handover for traffic to the fixed network (M–F), and near-end handover for incoming traffic into the network (F–M and M–M).

A fully meshed TSC layer is modelled with *n* STM–1 units per route. However, the physical structure of the transit layer modelled is that of a national ring and the Oslo ring.

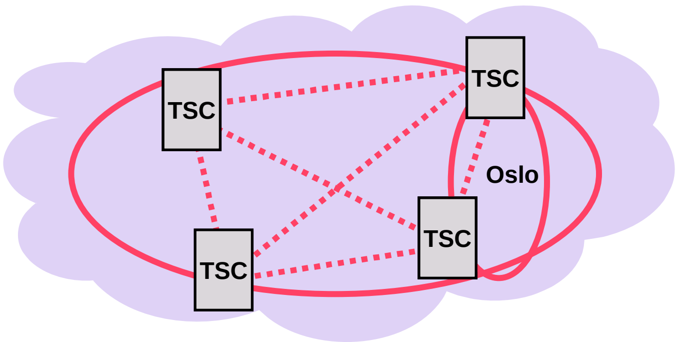


Figure 4.13: Fully meshed transit layer [Source: Analysys Mason]

The length of the rings is calculated from TSC locations, including Oslo.

4.2.4 Layered circuit-switched network

MSS switches are deployed at each MSS site, according to processor load (calls, SMS and location updates) and utilisation. MGW switches are deployed in redundant pairs at each MSS.

Inter-switch and VMS voice Erlangs are used to determine MGW–MGW STM–1 ports between:

- MGW sites within Oslo (if there are multiple MSS locations in Oslo)
- co-sited MGW outside of Oslo
- MGW sites outside of Oslo.

This is illustrated below in Figure 4.14. Physical STM–1 links are only dimensioned between sites.

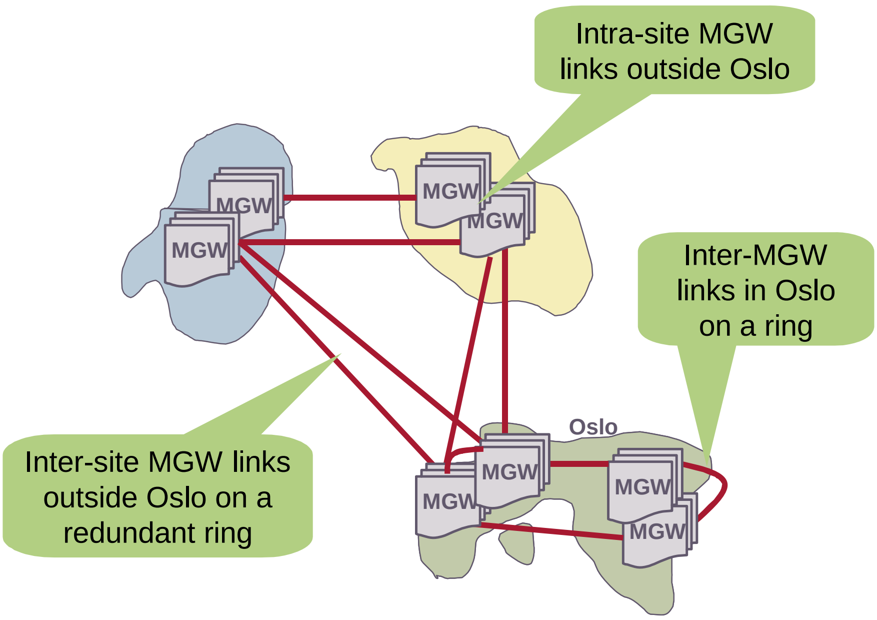


Figure 4.14: Modelled MGW–MGW links and ports [Source: Analysys Mason]

4.2.5 Layered packet-switched network

A packet data router is deployed at each packet-switching location (these may be SGSN switches or IP routers, depending on the choice of network configuration). The proportion of busy hour Mbit/s from mobile data traffic which crosses the packet data network is then used to dimension a fully meshed packet routeing network. STM–1 links connect the RNCs to these packet data routers, as shown below in Figure 4.15.

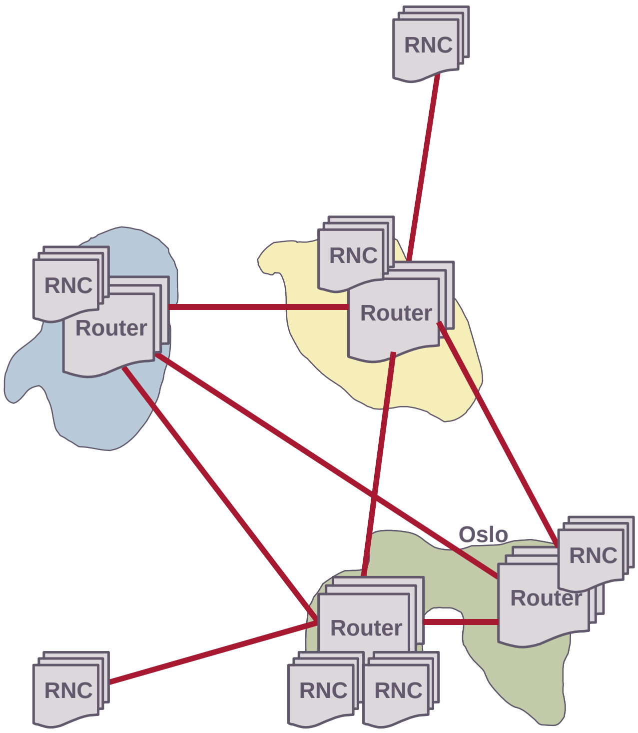


Figure 4.15: Modelled layered packet-switch architecture [Source: Analysys Mason]

4.3 Other network elements

We have included explicit calculations of what we believe are the remaining significant network element deployments: HLR, AUC, EIR, network management systems, licence fees, intelligent network (IN) system, billing system, VMS, packet data and SMS infrastructure.

4.4 Non-network elements

The original (v4) model included explicit bottom-up modelling of retail costs such as marketing and customer care. Ultimately, these costs were used to share business overheads between network and retail functions according to a cost-based equi-proportional mark-up (EPMU). The handset/acquisition component of retail costs was excluded from the business overhead mark-up.

Retail aspects have now been removed in the v6 model. Business overhead expenditure remain in the model, but are now marked-up directly onto network activities using a ratio of 75:25 (derived from the v4 model). This modification has been made to reduce the complexity of the model without materially affecting the wholesale cost results. Business overhead expenditures are now modelled as:

- a fixed annual capital and operating expenditure
- a subscriber-dependent operating expenditure.

4.5 Third operator

In the market forecast for the original (v4) model, we assumed that a third infrastructure operator would enter the market and gain market share parity with the established operators in the long term. In the upgraded (v6 and v7.1) model, we have explicitly dimensioned the network of this new entrant. This network can be selected by choosing "Third operator" on the *Ctrl* worksheet. Several key assumptions have been made regarding the third operator deployment:

- it is a combined 2G/3G operator:
  - GSM is launched in 2008 to cover approximately 98% population of six Fylker with major cities in Norway[3], completed in one year, with 20% of this coverage area completed with in-fill sites
  - GSM is shut down in 2020
  - UMTS is deployed at least 99.99% of population in all Fylker (except Svalbard), using sectorised 2100MHz urban networks and omni-sectored 900MHz rural NodeBs (using the same coverage calculation methodology as for the other operators)
  - UMTS coverage to the initial population covered provides indoor-quality coverage
  - all 2G sites are reused for NodeB deployments
  - HSDPA 3.6 is deployed on all NodeBs
  - A proportion of 2100MHz NodeBs are upgraded to HSDPA 7.2 from 2009 onwards, with 99% of those in Oslo upgraded, 66% of those in Hordaland, Rogaland and Sør-Trøndelag upgraded and 33% of those in Akershus and Vestfold upgraded
  - All HSDPA 7.2 sites are upgraded further to HSDPA 14.4 from 2011
  - the backhaul network uses a combination of microwave links and leased lines
  - BSCs and RNCs are located in each of the six main Fylker
- 8% of daily voice traffic occurs in the voice busy-hour
- 9% of daily HSDPA traffic occurs in the data busy-hour
- voice and non-HSDPA traffic by Fylke is distributed according to covered population
- HSDPA traffic by Fylke is distributed as per section 4.1.1
- a layered architecture is deployed for the core network from launch, with all major switching sites in Oslo.

The third operator is set up using assumptions that are distanced from operator data, allowing this model to be distributed to all industry parties.

4.6 MVNO networks

The mobile virtual network operators (MVNOs) in Norway perform a number of network functions themselves, whilst renting radio access capacity on one of the networks. The exact way in which each MVNO provides this functionality varies – some have dedicated Norwegian

3 We assume Akershus, Hordaland, Oslo, Rogaland, Sør-Trøndelag and Vestfold

facilities, while others lease their activities from other operators outside of Norway. We have modelled the Norwegian MVNOs in the model on the basis of being standalone Norwegian infrastructure-based operators.

The list of operators that can be selected in the model include four MVNOs: Tele2, Network Norway, TDC and Ventelo. It should be noted that when one of these operators is selected, various stages of the network design calculation will not calculate, particularly in the radio layer – this only occurs for elements that are not required by MVNOs, which are then excluded on the *FullNw* worksheet prior to the cost calculation.

MVNOs are modelled with the network elements listed in Figure 4.16 below.

MSC (and associated ports / software)	Intelligent network (IN)
HLR and upgrades	Billing system
GGSN	AUC
SGSN	EIR
SMSC	
MMSC	

Figure 4.16: MVNO assets dimensioned in the model [Source: Analysys Mason]

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 the early years of network deployment (1992–1996) the purchasing of assets for Telenor and NetCom has been redistributed to reflect a 'Phase 1 deployment' as might be contracted to an equipment vendor.

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 Network closure

The model now includes the functionality to reduce and shut down the GSM network as its volumes migrate to UMTS. This shut-down is determined by the voice migration profile on the *M6* worksheet. Currently, this migration is predicted to be complete by 2020 for all infrastructure operators.

The GSM radio and core layers can be shut down separately: this allows the legacy core network to be migrated to a next-generation architecture prior to the de-activation of the GSM radio network. The shut-down of the core network (and launch of a next-generation architecture) can be changed using the inputs at the top of the *NtwDesBase* worksheet.

During the period that traffic is being reduced on a group of network elements (e.g. reducing GSM load as migration occurs), the model contains the functionality for "stranded" equipment to be either:

- kept in the network until the last year of operation and then removed
- removed from the network as traffic load reduces (either in the same year, or 1 year later, or 2 years later).

This functionality is captured by the retirement delay input (sheet *L*) of 0, 1, 2 or "100" years until removal.

The recovery of expenditures on GSM and legacy core equipment is confined to the period of their operation – i.e. UMTS services do not contribute to GSM cost recovery, and traffic after the legacy core shut-down does not recover any of the legacy core expenditures (instead it recovers layered core expenditures).

5.3 MEA equipment unit price

The price paid for network assets varies over time. In the economic costing approach, the modern equivalent asset provides the appropriate cost basis for purchasing. Real-term price trends are applied to 1992 prices to reflect the evolution of the modern technology prices over past and future time. MEA price evolution also provides an important input into the economic depreciation, as explained in section 6. Price trends are populated with Analysys Mason estimates rather than operator data.

The model can now calculate in the real terms currency of any year: this can be changed on the *Ctrl* worksheet. However, unit cost inputs are specified in real 2005 NOK (as per the v4 model).

5.4 Phase 1 distribution of expenditures for Telenor and NetCom

Operators' GSM expenditures only begin in 1993/1994. However, Telenor and NetCom began to install their GSM network structures in 1992. The model also includes a plan-ahead period for each asset, resulting in assets being purchased up to 18–24 months in advance of this date.

Consequently, a Phase 1 expenditure ramp is applied, which re-distributes the purchases that are incurred over the period 1990–1996. The Phase 1 ramp distributes the purchases so that the modelled expenditure profile is in line with that actually incurred by each operator.

6 Annualisation of expenditure

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

6.1 Rationale for using economic depreciation

Economic depreciation is a method for determining a cost recovery that is classed as being economically rational, in that it:

- reflects the underlying costs of production
- reflects the 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, upfront 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 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 present value (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 revenues 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.

PV calculation

The calculation of the cost recovered through revenues generated 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 cash flow, which is equal to the weighted average cost of capital (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 investments 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 the revenues generated by the business. The revenues generated by an asset class are a product of the demand (or output) supported by that asset class and the price per unit demand.

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 modern equivalent asset 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 revenues 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 revenues generated across the lifetime of the operator.

Cost recovery by deployment

The original model captured the migration off the GSM network implicitly, by identifying assets that were GSM-specific assets, i.e. those that were not compatible with the provision of UMTS network services. The total costs of these assets were then recovered using an output profile which only existed for the lifetime of the GSM network and declined in the last years of this lifetime due to the effect of migration, as shown in Figure 6.1 below.

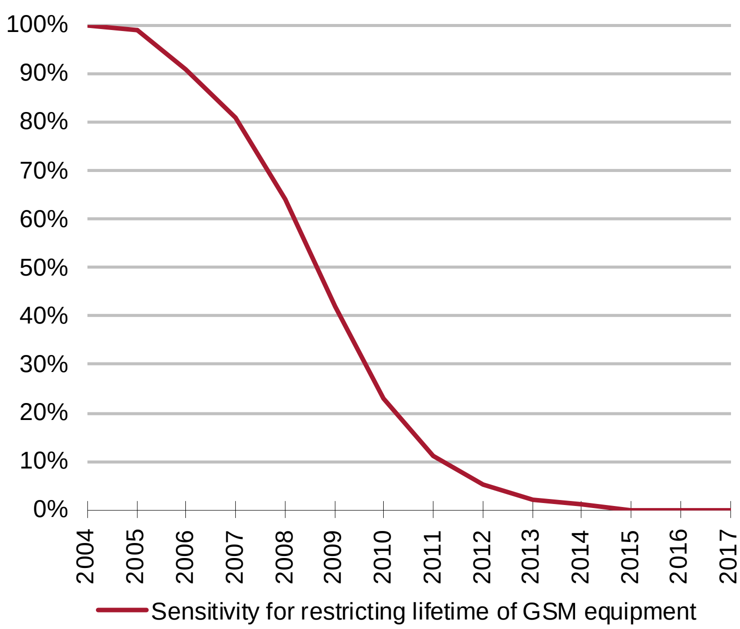


Figure 6.1: Recovery profile for GSM-specific assets in the original model [Source: Analysys Mason]

In the upgraded model, we now capture UMTS networks explicitly. For each 2G/3G operator, it is assumed that their networks are deployed in the following order:

- 2G network (radio and core)
- 3G radio network
- layered core network, with the shut-down of the legacy 2G core network
- shut-down of the 2G radio network.

Cost recovery of assets should only occur during the years in which their respective network layers are active. Hence each asset is identified as being:

- 2G radio
- 3G radio
- legacy core
- layered core
- shared (e.g. 2G/3G sites, SMSC, SGSN, GGSN, etc.).

Cost recovery of assets is then restricted to the periods in which these layers are active, as illustrated below in Figure 6.2.

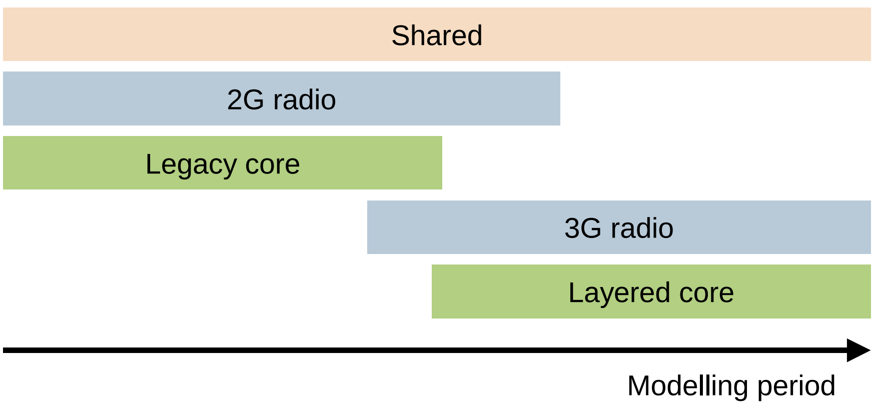


Figure 6.2: Periods of cost recovery by asset type [Source: Analysys Mason]

6.3 Implementation of the economic depreciation algorithm

The economic depreciation algorithm appears in the *ED* worksheet. 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 capex and opex).
- Costs are calculated with reference to network element output – the annual sum of service demand produced by the network element (weighted according to the routeing factor).

6.4 Implementation of HCA depreciation and a tilted annuity calculation

In addition to the economic depreciation algorithm, a historical cost accounting (HCA) algorithm and a tilted annuity calculation are present in the model.

The calculation flow for the HCA depreciation algorithm is set out below in Figure 6.3.

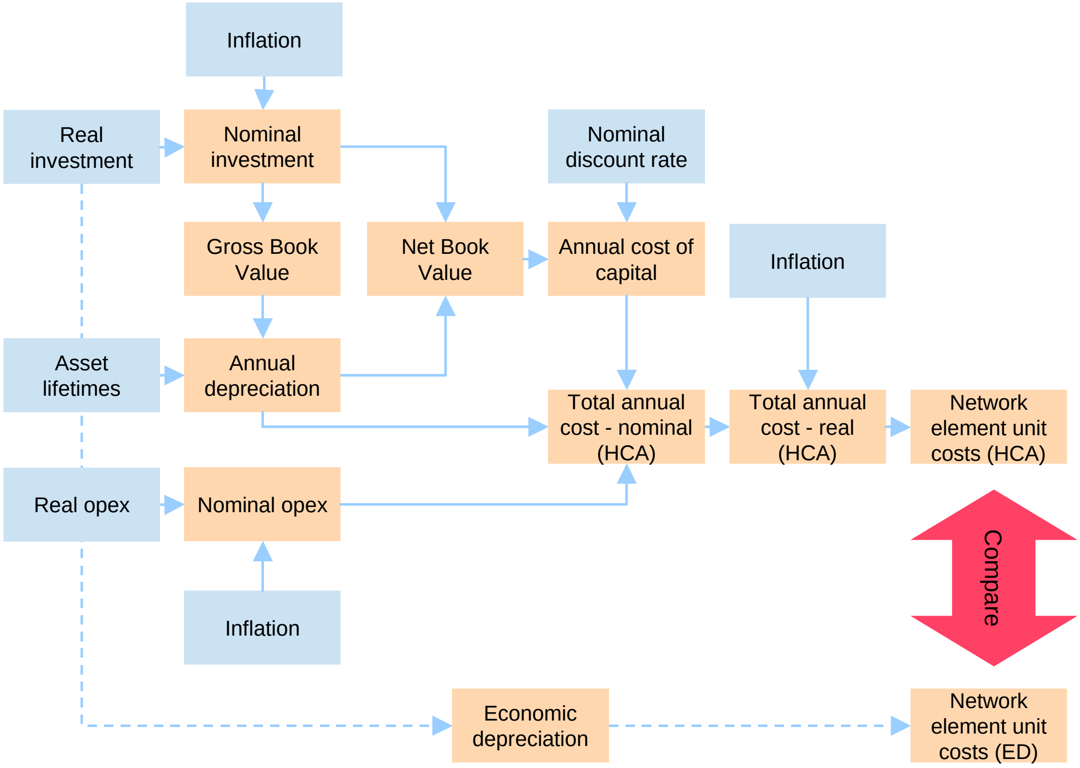


Figure 6.3: HCA algorithm [Source: Analysys Mason]

The HCA algorithm calculates the total nominal annual cost in each year using the annual depreciation from the gross book value of nominal investments; the annual cost of capital; and the nominal operating expenditure. These costs are converted back into real terms, and can be compared with the cost result of the economic depreciation algorithm.

The calculation flow for the tilted annuity depreciation algorithm is set out below in Figure 6.4.

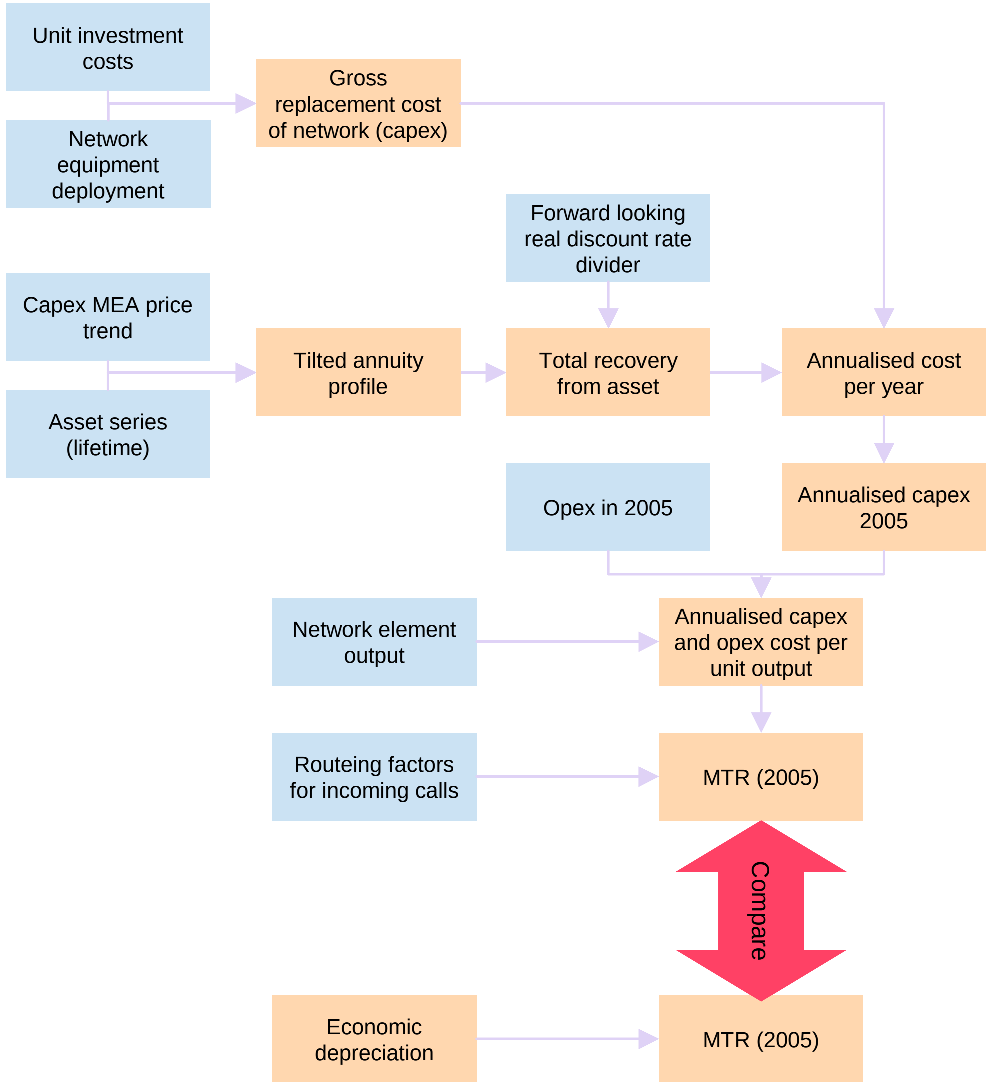


Figure 6.4: *Tilted annuity calculation [Source: Analysys Mason]*

The tilted annuity calculation determines the gross cost of replacing the entire network at 2005 prices. The capital cost recovery profile is tilted according to the forecast capex MEA price trend, resulting in an annualised cost for the year 2008. Taking the incurred 2008 operating cost into account, and dividing by the output of the model, results in a mobile termination rate (MTR) in 2008 which can be compared with the result of the economic depreciation calculation.

7 Service cost calculations

The upgraded model calculates service costs using both long-run average incremental cost (LRIC) and pure long-run incremental cost (pure LRIC) principles, as described below.

7.1 Calculation of LRIC

This calculation is retained from the original model: it takes the total economic costs for each network asset, and applies a network 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. Incremental costs per unit output are calculated for each asset class.

Routeing 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 routeing factors according to the following equation:

$$Cost(Service_k) = \sum_{assets} \text{cost\_per\_unit\_output}(asset_i) \times RouteingFactor(asset_i, service_k)$$

In order to be consistent with the conceptual design approach of the model, the routeing factors are **average traffic routeing factors**.

Network common costs are then marked up onto each incremental service cost in an equi-proportional manner, according to the ratio of common to incremental total network costs. This results in the network LRIC+.

The cost of location updates is added to this network LRIC+, resulting in the LRIC++. Location update costs are the share of MSC/VLR costs associated with tracking handsets around the country. Location update costs are shared amongst received services: incoming calls, on-net calls, incoming SMS messages and on-net SMS messages.

Finally, business overhead costs are shared proportionally between the operator's network and retail operations in the ratio 75:25. The final result of the model is therefore described as the LRIC+++ of termination.

7.2 Calculation of pure LRIC

This requires that the model is run twice: *with* and *without* mobile terminated traffic on the modelled networks. Clicking on the "Run pure LRIC" macro button on the *Ctrl* worksheet will result in the model calculating twice – the total capex and total opex required by asset over time in each case is then pasted on the *PureLRIC* worksheet. The pure LRIC of termination is then calculated as shown below in Figure 7.1.

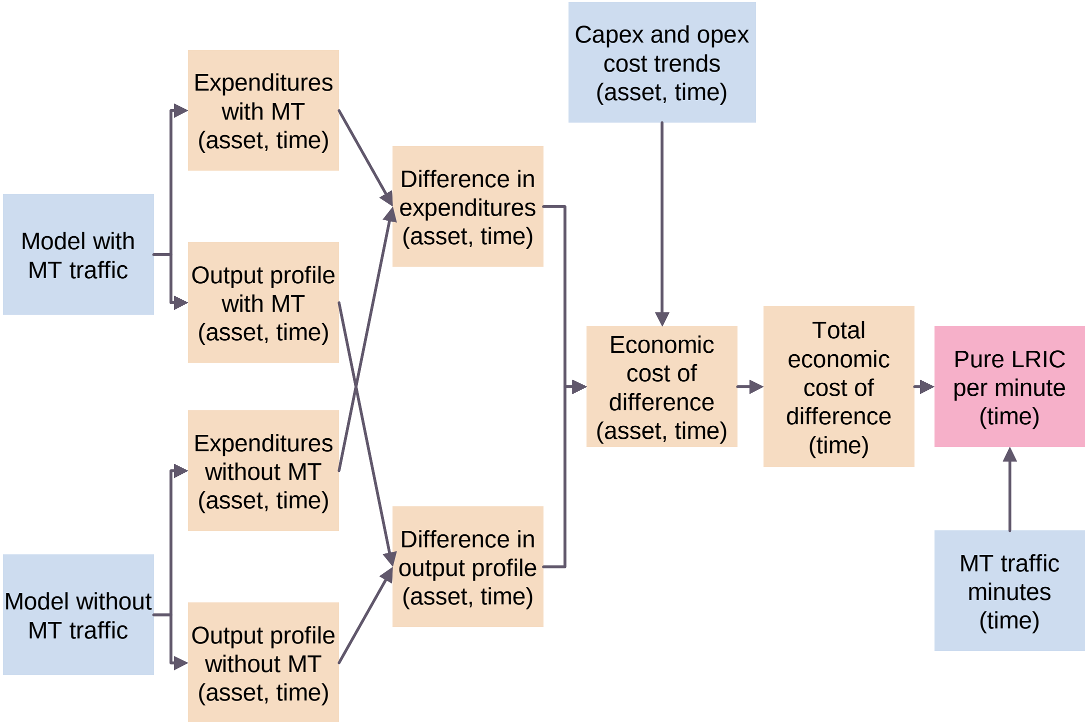


Figure 7.1: Calculation of pure LRIC [Source: Analysys Mason]

The difference in both capex and opex (the *avoidable* costs) is determined from the two model calculations, and economic depreciation is then applied to this difference. This is run separately for capex and opex, in order to use their respective cost trends. The pure LRIC of termination in each year is then calculated as the ratio of total economic cost in that year divided by total terminated minutes.

The model will in fact calculate two flavours of pure LRIC (determined from the *Ctrl* worksheet):

- **'Purest LRIC':** the model uses exactly the same network design assumptions when run both with and without mobile terminated traffic
- **'Pure LRIC':** the network design assumptions reflect some of the consequences of not needing to carry terminated traffic. These include:
  - a smaller-scale deployment of GSM in-fill coverage sites
  - a smaller minimum deployment of 3G radio equipment per NodeB
  - a slight relaxation of the effect of cell breathing in the 3G cell radii.

7.3 2G and 3G allocations

The routeing factor table can be found on the *RF* worksheet. For any particular asset, the routeing factors across all services determine the amount of each asset's output that is required to provide each service.

The major allocations of assets to services are summarised below in Figure 7.2. Where appropriate, the routeing factors for SMS and data are specified in radio minute-equivalents. These conversions are provided on the *DemCalc* worksheet.

Assets	*Voice*	*SMS*	*Low-speed data*	*High-speed data*	*Subscribers*
2G-only sites, BTS, TRX	2G only	2G only	GPRS	–	–
3G-only sites, NodeB, CK	3G only	3G only	R99	HSDPA	–
2G/3G sites	All	All	All	HSDPA	–
BTS backhaul (inc. DXX)	2G only	2G only	GPRS	–	–
BSC equipment	2G only	2G only	–	–	–
BSC–MSC backhaul	2G only	2G only	GPRS	–	–
NodeB backhaul	3G only	3G only	R99	HSDPA	–
HSDPA upgrades	–	–	–	HSDPA	–
HSUPA upgrades	–	–	–	HSUPA	–
RNC equipment	All	All	All	HSDPA	–
RNC–MSC backhaul	3G only	3G only	R99	HSDPA	–
Packet-switch equipment	–	–	–	All	–
MSC / MSS units	All	All	–	–	All
MSC / MSS software	All	All	–	–	–
MGW–MGW links	All	–	–	–	–
MGW	All[4]	All	–	–	–
TSC	All	All	All	–	–
SMSC	–	SMS	–	–	–
MMSC	–	MMS	–	–	–
Intelligent network (IN)	Not outgoing	–	–	–	–
SGSN/GGSN	–	–	All	All	–
NMS	All	All	All	HSDPA	–
HLR/AUC/EIR	–	–	–	–	All

Figure 7.2: Allocations of assets to services in the model [Source: Analysys Mason]

4 On-net weighted the same as incoming minutes

Annex A: Network design algorithms

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

A.1 GSM technologies

A.1.1 Radio network: site coverage requirement

In Norway, GSM900MHz spectrum is used for coverage purposes. EGSM channels can be added to the number of available GSM900MHz channels. To satisfy the coverage requirements, the number of sites deployed has to be able to provide coverage for a certain area defined by Fylke.

The inputs to the coverage sites calculations are:

- total area covered by the mobile operator, by Fylke, for coverage and for infill purposes
- year in which wide-area coverage site deployment is completed
- year in which infill coverage is completed
- cell radii for wide-area coverage for each Fylke
- cell radii for infill purposes for each Fylke.

The model allows for additional future coverage to be modelled. The inputs to the future coverage calculation are:

- forecast additional coverage + infill for each Fylke (these are subsequently modelled as incremental coverage and infill, on the basis of up to 80% area of a Fylke covered by wide-area coverage, with the remainder deployed as infill)
- the year in which the forecast additional coverage + infill is to be achieved
- the degree to which the infill coverage signal strength has changed from 2006 to 2008.

Figure A.1 below shows a flow diagram describing the calculation of macro sites deployed.[5]

5 In all diagrams (F, t) denotes variance by Fylke (F) and time (t).

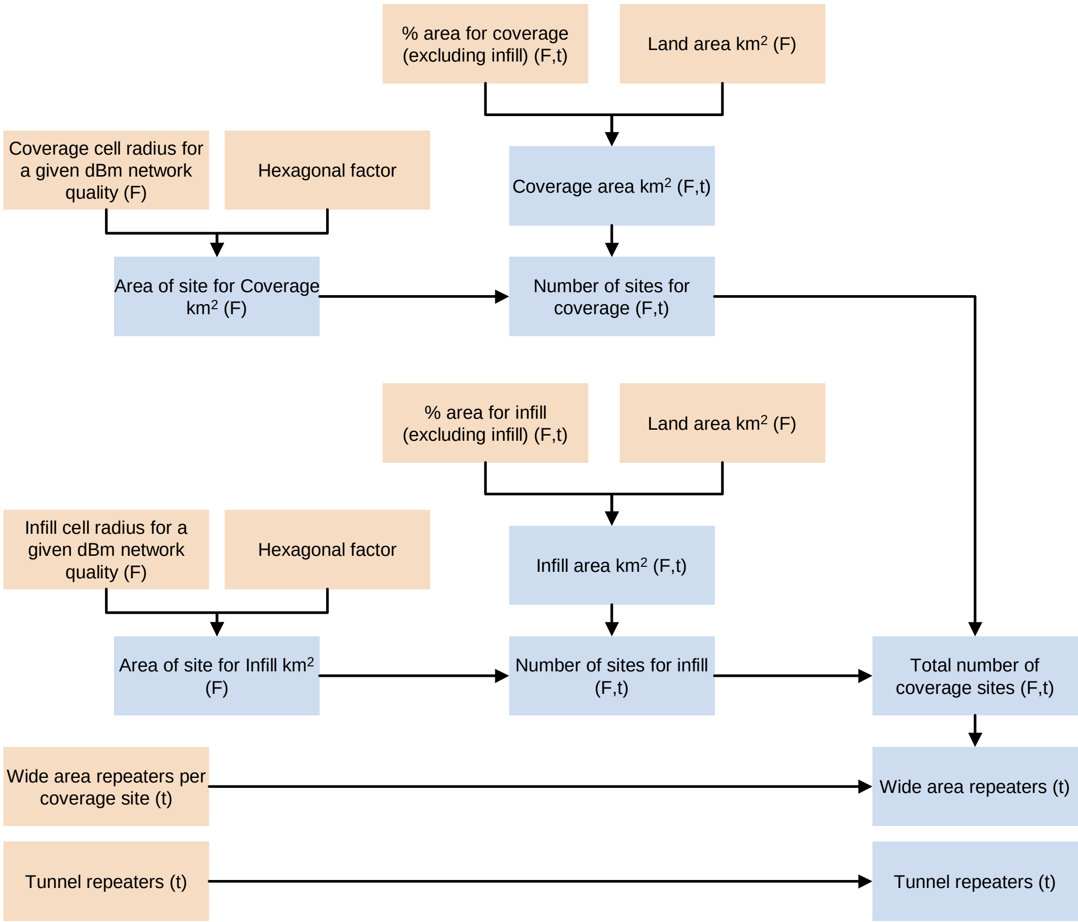


Figure A.1: 900MHz coverage network design [Source: Analysys Mason]

From the site radius, the area covered for a site in a given Fylke is calculated. The total area covered for the Fylke is divided by this site area to determine the number of sites for coverage that are deployed. Similarly the number of sites required for infill purposes is calculated.

The number of wide-area repeaters is calculated as a percentage of the total number of coverage sites in each year. The number of tunnel repeaters is modelled as an explicit input using operator data.

All coverage sites are assumed to be omni-sectored.

A.1.2 Radio network: site capacity requirement

The calculation of the number of additional sites required for capacity purposes involves the following steps:

1. Calculation of the capacity provided by the coverage sites

2. Calculation of the capacity provided by sectorising coverage sites, up to a realistic sectorisation limit
3. Calculation of the capacity provided by overlaying coverage sites with DCS1800MHz spectrum (if available)
4. Calculation of the number of additional sites (including DCS1800MHz overlays, if available) required to fulfil capacity requirements.

Step 1: Capacity provided by the coverage network

The calculation of the BHE capacity provided by the sites deployed for coverage purposes is shown in Figure A.2.

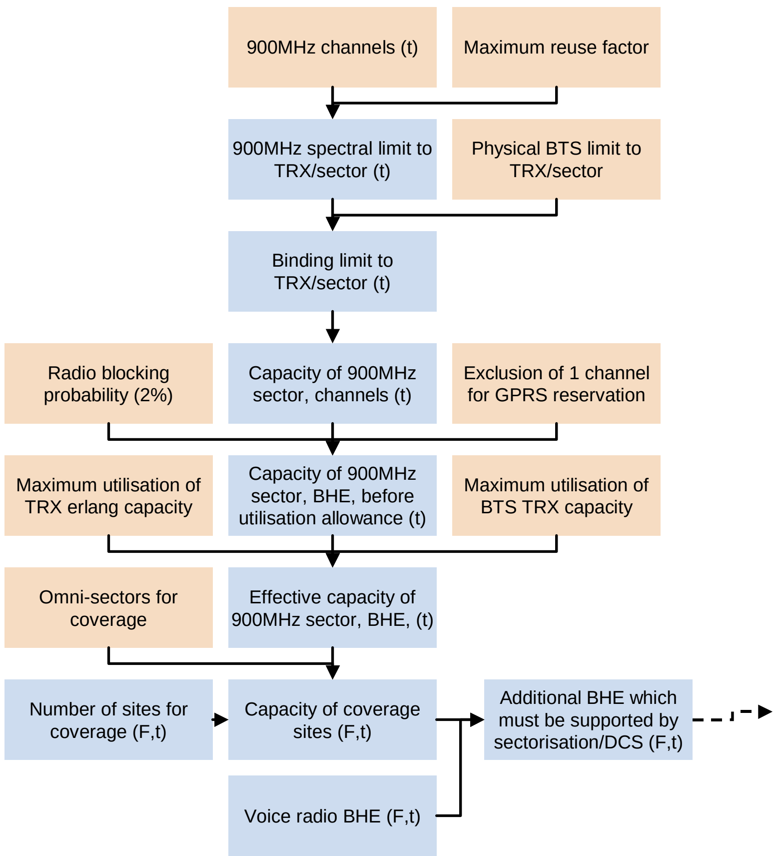


Figure A.2: Calculation of the BHE capacity provided by the coverage network [Source: Analysys Mason]

Before the capacity requirements of the network are calculated, the Erlang capacity for a given sector is determined. The inputs to this calculation are the availability of spectrum, the spectrum re-use factor and the physical BTS capacity.

The spectral capacity is the number of transceivers that can be deployed per sector given a certain maximum spectrum re-use factor. The lesser of the physical capacity and the spectral capacity of a sector is the applied capacity.

The sector capacity in Erlangs is obtained using the Erlang B conversion table. At this stage, one channel of the 900MHz layer is reserved for GPRS. An allowance is made for less than 100% of the BTS and TRX capacity in the calculation of the effective capacity of each 900MHz sector. BTS underutilisation occurs because it is not possible to deploy the full physical TRX complement in every BTS, since BHE demand does not uniformly exist at a small number of sites. TRX underutilisation occurs because the peak loading of each cell at its busy hour is greater than the network average busy hour (to take this into account, an average to peak BHE loading of 150% is used in the calculation of the TRX utilisation, accounting for the fact that the cell busy hour is 50% greater than the network busy hour)[6], and because BHE demand does not uniformly occur in a certain number of sectors.

Given the fact that all coverage sites are assumed to be omni-sectored, the total capacity provided by the coverage sites is calculated. The BHE traffic is split by Fylke according to operator data to generate the volume of BHE traffic which must be supported by coverage, sectorisation or through the overlay with DCS1800MHz sites.

Step 2: Calculation of the capacity provided by sectorising coverage sites

Both Telenor and Netcom provided data with which to calculate the average number of sectors per capacity site. Using the Erlang capacity of a 900MHz sector, the total Erlang capacity provided by sectorising the coverage sites, up to the practical sectorisation limit, is calculated. Using the difference between the additional BHE traffic requirement and the capacity that can be provided through sectorisation, the number of additional sectors required by Fylke over time and the number of additional BHE that must be satisfied by overlaying the sectorised coverage sites with DCS1800MHz spectrum is calculated.

6 The magnitude of this effect being confirmed by the operators' submissions.

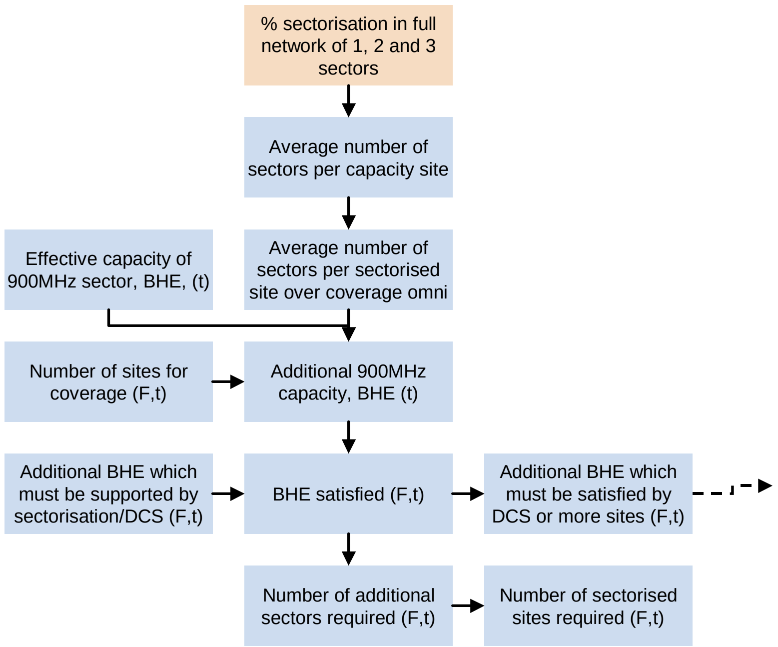


Figure A.3: Calculation of the capacity provided by sectorising coverage site [Source: Analysys Mason]

Step 3: Calculation of the capacity provided by overlaying coverage sites with DCS1800MHz spectrum

Coverage sites that have been sectorised can be further augmented with DCS capacity, if these channels are available, and where demand exists in excess of that supported by sectorisation. We assume that omni-sites remaining for coverage are not overlaid with DCS capacity since they are not located at the hotspots of demand.

The sectorisation proportion of DCS overlays is combined with the DCS per-sector capacity (calculated as before from DCS spectrum, re-use, physical constraints and utilisation parameters). This allows the number of DCS overlays to be calculated according to the BHE demand that must be supported. If all sectorised coverage sites are augmented with DCS overlays, then excess BHE must be supported by new site deployments.

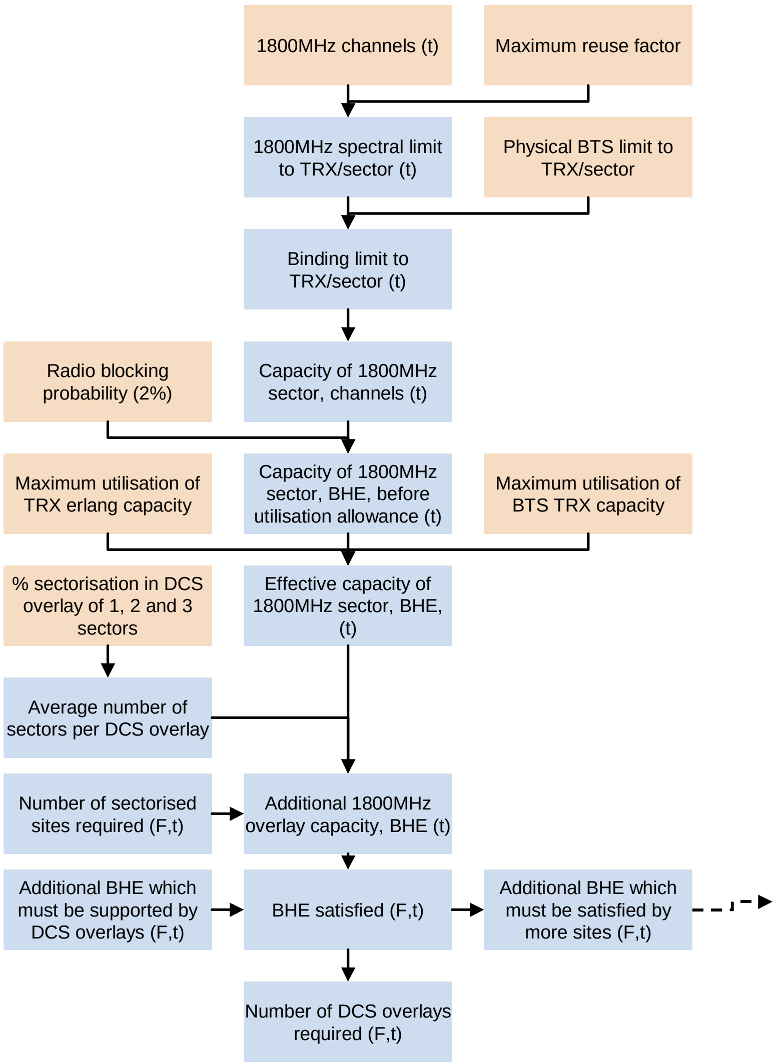


Figure A.4: Calculation of the capacity provided by overlaying coverage sites with DCS1800MHz spectrum [Source: Analysys Mason]

Step 4: Calculation of the number of additional sites required to fulfil capacity requirements

The demand in excess of overlaid and sectorised coverage site capacity determines the number of new sites required. This is calculated by dividing this excess BHE demand by the capacity of a new site. The total effective capacity of a new site is calibrated according to operator data for the sectorisation proportions for 900MHz and 1800MHz sites and calculated using

- the combined effective capacity of a 900MHz and 1800MHz sector until a particular year
- the effective capacity of a 900MHz sector thereafter: i.e. after this point, new sites are only fully sectorised and not overlaid.

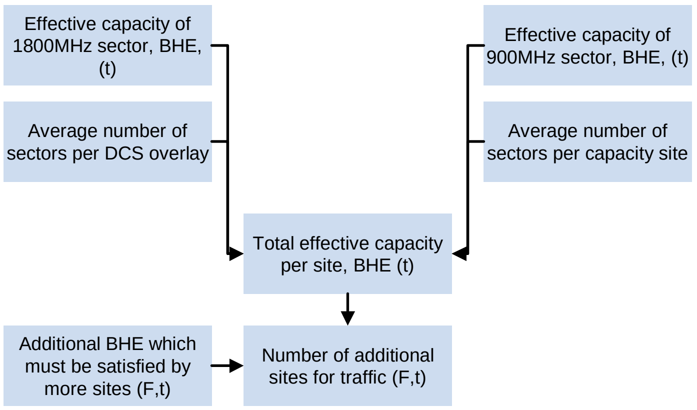


Figure A.5: Calculation of the number of additional sites required to satisfy BHE traffic requirements [Source: Analysys Mason]

A.1.3 Radio network: TRX requirements

To calculate the total number of transceivers required, the inputs required are the BHE traffic and number of sectors for 900MHz and 1800MHz – these are calculated in the previous calculations for the number of sites – and the transceiver utilisation. A minimum number of one TRX per sector is applied. Figure A.6 below shows a flow diagram describing the calculation of transceivers required.

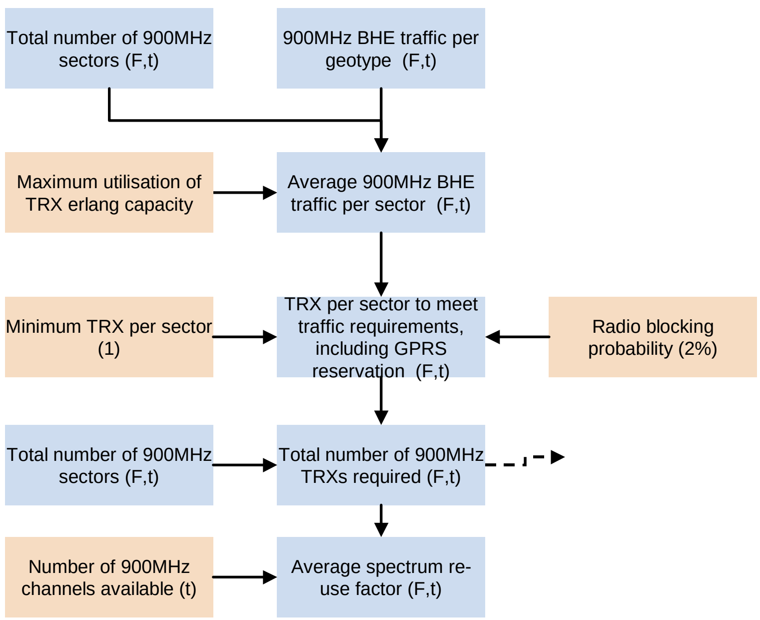


Figure A.6: Transceiver deployment [Source: Analysys Mason]

Note: Figure A.6 displays the calculation flow for 900MHz TRXs. The same principles are applied to the calculation of 1800MHz TRXs.

The number of transceivers required in each sector to meet the demand is calculated taking into consideration the transceiver utilisation and converting Erlang demand per sector using the Erlang B table in to a channel requirement. The one-channel reservation for GPRS is added back in during the Erlang calculation, as well as a signalling channel allowance of one for every two TRXs.

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

The effective spectrum re-use factor is calculated for calibration purposes using the number of available channels at 900MHz and 1800MHz divided by the average number of TRX per sector.

A.1.4 Backhaul transmission

The calculation of the number of backhaul links and the corresponding number of E1 ports required is set out in Figure A.7.

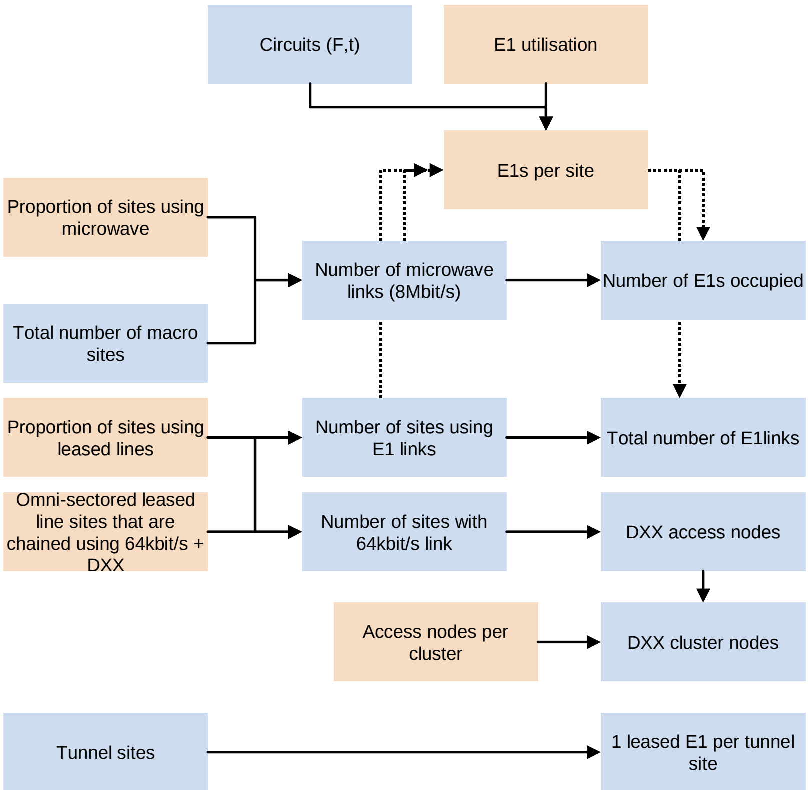


Figure A.7: Backhaul calculation [Source: Analysys Mason]

Step 1: Capacity requirements

The number of E1s required per site is calculated to fulfil the capacity requirements for a backhaul link. 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, which therefore includes GPRS traffic channels. Taking into consideration the co-location of primary and secondary BTS on the same site, the number of channels per site is calculated on the basis of the number of channels per TRX multiplied by the number of 900MHz and 1800MHz TRXs.

Given the maximum capacity of an E1 link and considering the link utilisation, the effective capacity per E1 link is calculated. The number of E1 links required per site is obtained by simply dividing the circuits per site with the actual capacity per E1 link.

Step 2: Backhaul network design algorithms

There are two types of backhaul to be considered in the network: microwave (8Mbit/s links) and leased line backhaul. The percentage of sites which have microwave backhaul is an input into the model.

The number of microwave 8Mbit/s backhaul links is set to be a minimum of one per site. The model allows for more than one 8Mbit/s link per site, though traffic requirements are unlikely to present such a high load. The number of E1 units occupied in each 8Mbit/s microwave link is calculated.

The number of sites using leased lines calculated as the difference between the total sites and the total sites using microwaves. The total number of E1 leased lines required is the multiplication of total macro sites using leased line and the number of E1 required per site (from *Step 1*). Where sites have less than a specified low traffic requirement, a 64kbit/s leased line backhaul may be used.

DXX access nodes are deployed according for 64kbit/s links, and are modelled to persist in the network even when the 64kbit/s links are replaced by higher-capacity E1. DXX cluster nodes are deployed on the basis of *n* access nodes per cluster node.

Tunnel repeater sites are assumed to use only E1 leased-line backhaul and hence are added to the leased-line requirement of the macro layer.

A.1.5 BSC deployment

The structure of the BSC deployment algorithm is set out below in Figure A.8.

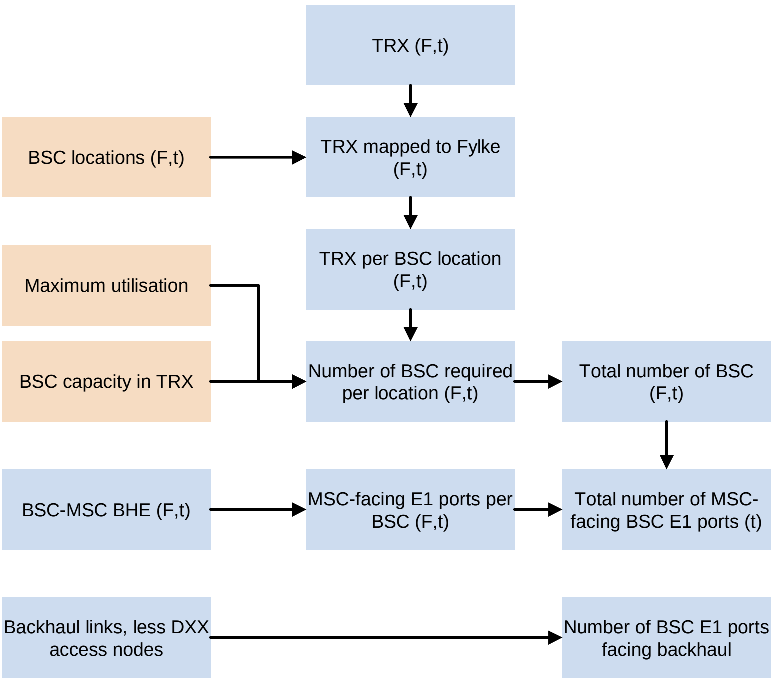


Figure A.8: BSC deployment [Source: Analysys Mason]

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.

BSC locations by Fylke are used as an input to the model using data from the operators. TRXs are mapped onto these BSC locations by Fylke, generating the number of TRX per BSC location. The number of BSC units deployed must be able to accommodate the number of transceivers deployed (see Section A.1.3). Given a maximum capacity of the BSC in terms of TRX, adjusted for maximum utilisation, the number of BSCs required per location is calculated.

BSC–MSC links calculation

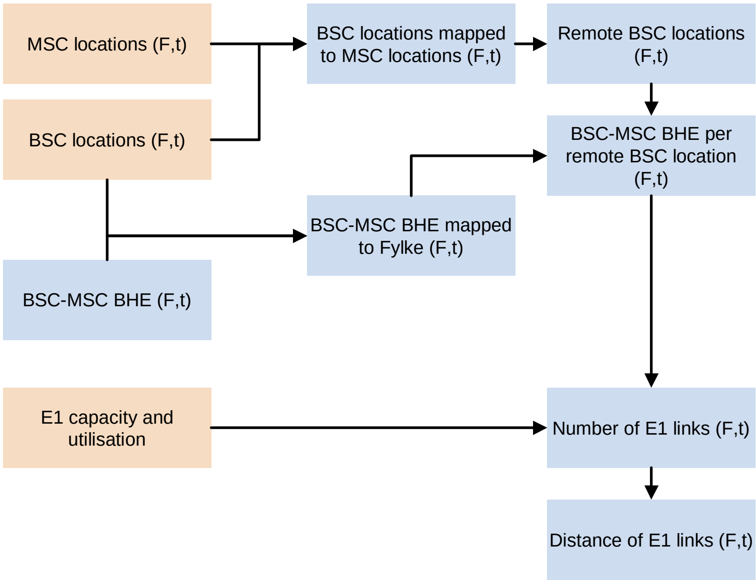


Figure A.9: BSC–MSC remote transmission [Source: Analysys Mason]

A proportion of BSCs are designated as 'remote' (i.e. not co-located with an MSC), and therefore require physical links to the MSC and are located in a separate building in some distant part of the network. Remote BSC locations are modelled to be present when the number of BSC locations in a Fylke is greater than the number of MSC locations in that Fylke (each MSC location logically has a co-located BSC location). In terms of the actual number of remote BSCs, in a Fylke in which there are no MSC locations, all BSCs in the Fylke are remote. When there are MSC locations in the Fylke, it is assumed that there is one remote BSC per remote BSC location.

The traffic transiting through these BSCs is backhauled to the MSC using E1 leased lines. 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 total traffic handled by each remote BSC can be calculated using the total BHE transceiver traffic. The volume of this BHE traffic is calculated according to the ratio of remote BSCs to total BSCs in a Fylke. The average BHE traffic handled by each remote BSC is then converted into a channel requirement using the Erlang table. The number of E1 links is then calculated by dividing this channel requirement by the capacity of an E1 link, adjusted for maximum utilisation. It should be noted that the capacity of the BSC–MSC transmission depends on where the transcoder equipment is located. For remote BSCs, the transcoder is located in the MSC, and so, according to the GSM standard, has a capacity of 120 circuits.

The distance of these links is also an important output of the model as the backhaul costs involve a connection charge per link end and a distance-based cost.

The distances between all of the Fylker is specified in the *NtwDesBase* worksheet according to straight-line distances between the major conurbations in each Fylke, adjusted for route length using a multiplier of 1.3 (accounting for the non-straight line nature of networks given topology constraints). The calculation of the distances of the BSC–MSC links uses this Fylke distance matrix, in combination with the mapping of BSCs locations onto MSCs locations, which is performed in the *BSCMSC* worksheet.

The number of E1 BSC–MSC ports is determined on the basis of the number of BSC–MSC E1 links.

Total outgoing ports for co-located BSCs

Given the total number of co-located BSCs and BHE transceiver traffic, the total number of outgoing ports for co-located BSCs is calculated. The flow of calculation for co-located BSC ports is similar to that shown in Figure A.9 except the transcoder is assumed to be in the BSC (therefore E1 capacity is 30 channels) and the distance of co-located links is not modelled.

Incoming and outgoing ports

The incoming ports to the BSC are ports facing the BTS while the outgoing ports are ports facing the MSC. Figure A.10 below shows the constituents of the incoming and outgoing ports.

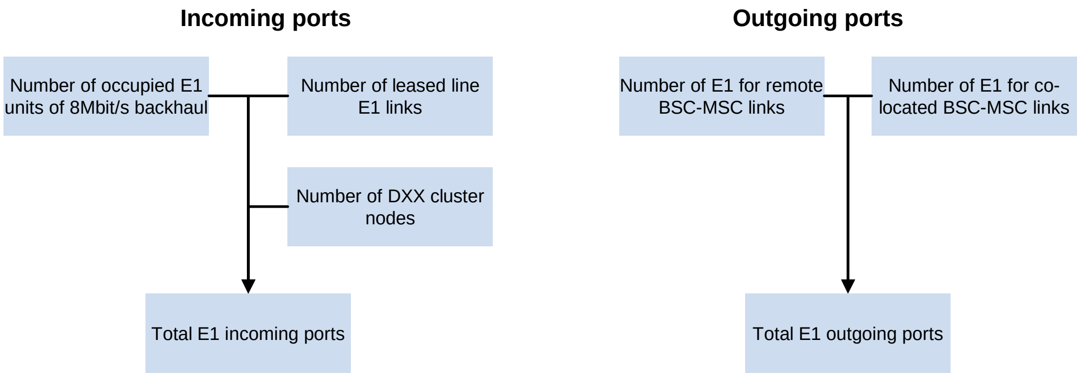


Figure A.10: Total incoming and outgoing ports for BSC [Source: Analysys Mason]

The total number of E1 incoming ports into BSC is the sum of 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.

A.1.6 MSC deployment

Calculation for MSC units to support processing demand

Call attempts are used to drive MSC processor requirements. The average duration of successful calls (on-net, incoming from other networks and outgoing to other networks) has been supplied by both operators as part of the data request. Some call attempts do not result in conveyed minutes (e.g. call not answered, call rejected, voicemail not active, blocked at radio layer). The ratio of total (2G/3G) call attempts per total successful calls is applied to the total number of calls to determine total voice call attempts. The total (2G/3G) number of SMS carried in the busy hour (BH) are also taken into account. These call attempts and carried SMSs are multiplied by a set of routeing factors to calculate the total busy-hour millisecond demand for MSC processing.

To support processing demand, the number of MSC units required is calculated from the CPU capacity, processor utilisation and the demand for MSC processor time. Figure A.11 below shows the sequence of the calculation.

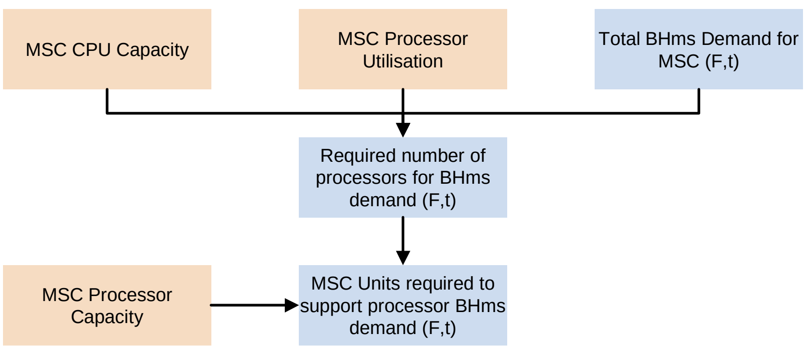


Figure A.11: Calculation of MSC units to support processing demand [Source: Analysys Mason]

Taking into account the MSC processor utilisation, the total number of processors required to meet the demand can be calculated as the total number of busy-hour milliseconds (BHms) divided by the effective MSC capacity.

Ports calculation (BSC/RNC-facing, interconnect-facing, VMS-facing, MSC-facing, TSC facing)

Figure A.12 below shows how the number of incoming and outgoing ports is obtained.

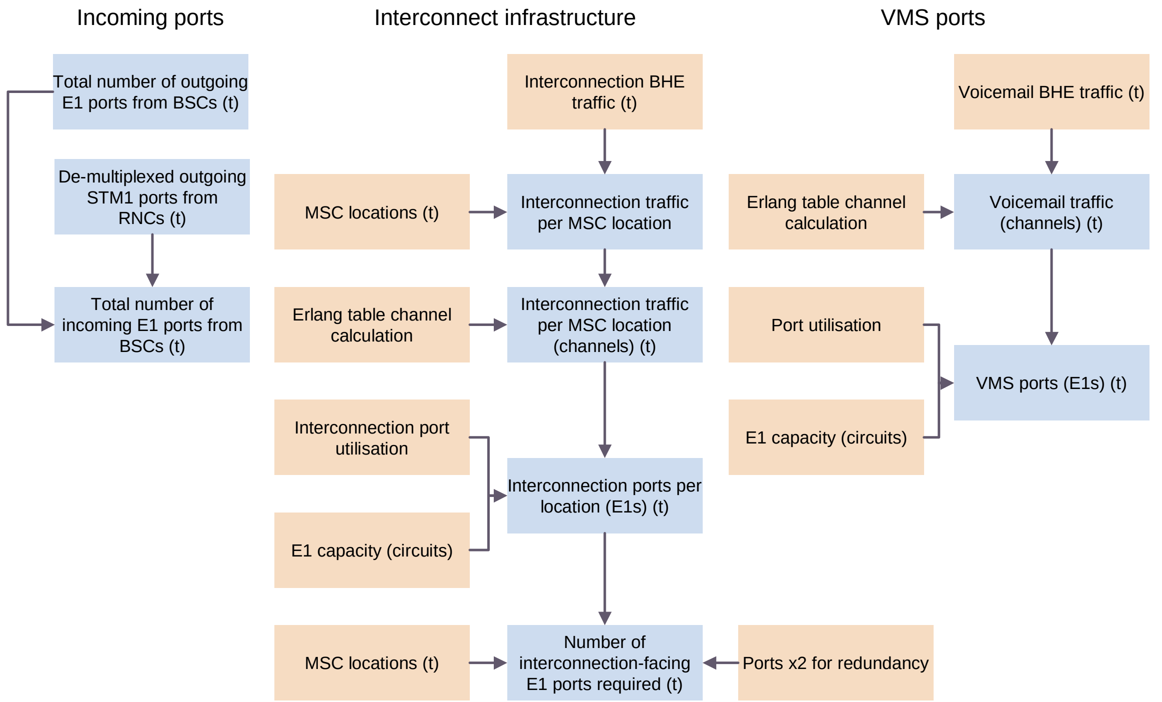


Figure A.12: Without a transit layer – calculation of MSC ports: BSC-facing ports, interconnect-facing ports, VMS-facing ports [Source: Analysys Mason]

The total number of incoming ports in the MSC is simply taken as the total number of E1 outgoing ports from the BSC, as well as the total RNC-facing ports de-multiplexed from STM–1.

The total number of outgoing ports comprises the number of interconnect-facing ports required, the number of VMS-facing ports required (both shown conceptually in Figure A.12) and the number of inter-switch ports required (shown in Figure A.13).

For the interconnection infrastructure, the total number of interconnect-facing ports required to meet demand is obtained by dividing the interconnection BHE traffic at each MSC location (as a channel requirement) with the actual E1 capacity of the port. Full redundancy is accounted for by doubling the number of ports at each MSC location.

The model accounts for two network states when calculating the number of MSC inter-switch ports (and links): without a transit layer, and with a transit layer. These are presented separately below.

Without a transit layer

The calculation of the number of inter-switch ports is detailed below. This calculation takes into account the Intra-Oslo backbone ring, which exists when there is more than one MSC location within Oslo.

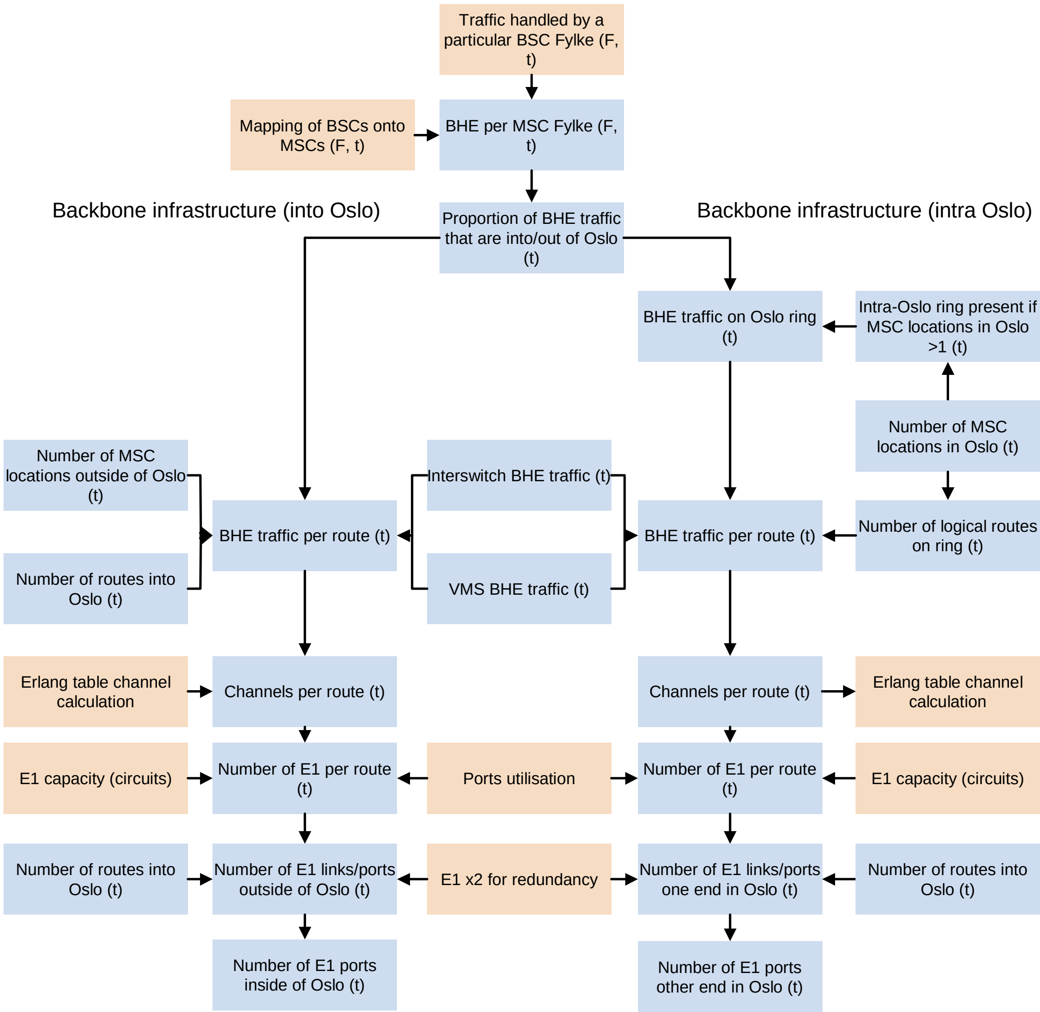


Figure A.13: Without a transit layer – calculation of the number of inter-switch ports [Source: Analysys Mason]

The proportion of inter-switch and VMS traffic carried over the logically fully-meshed intra-Oslo ring is used to dimension the number of E1 links and ports within the Oslo ring, with the remaining traffic being carried from the MSC locations in the other Fylker to Oslo. This traffic dimensions the number of E1 links and ports required outside of Oslo (on MSCs all facing Oslo) and inside of Oslo (on Oslo MSCs facing the MSCs in the other Fylker). Full E1 redundancy is provided.

With a transit layer

When a transit layer is deployed (modelled to occur when TSCs are present in more than one Fylke), the transit layer performs the same function as the Oslo core in the non-transit network. This is shown below in Figure A.14.

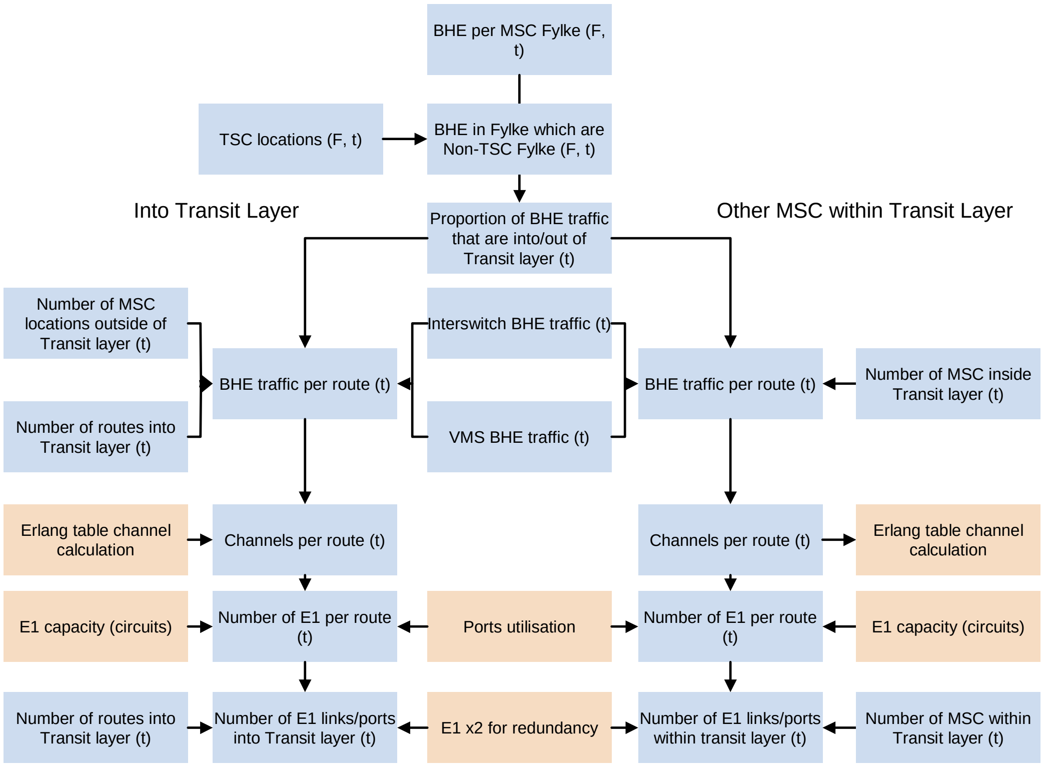


Figure A.14: With a transit layer – calculation of the number of inter-switch ports to the transit layer [Source: Analysys Mason]

BHE traffic is proportioned according to whether or not the MSC lies within a Fylke that contains a TSC. The number of outgoing ports to the transit layer is dimensioned according to the same principles as outlined in the non-transit layer case.

Calculation for MSC units to support port demand

MSC support for ports is based on the total incoming and outgoing ports for the MSC base. Figure A.15 below shows the calculation flow to obtain the number of MSC units required.

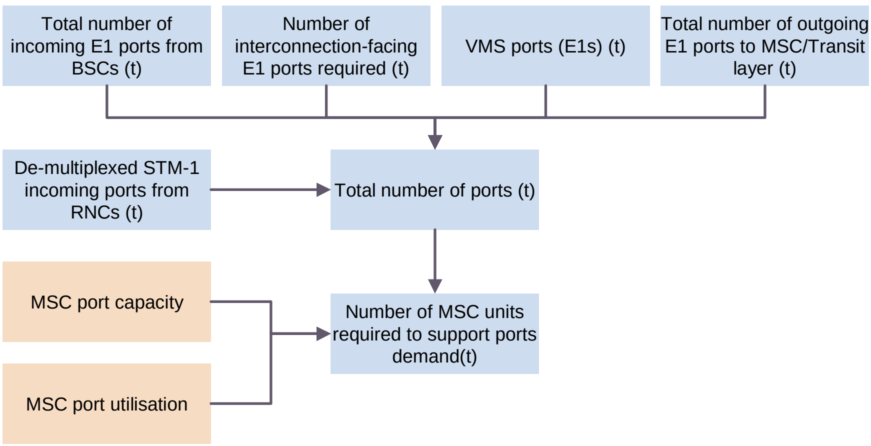


Figure A.15: Calculation of MSC units to support port demand [Source: Analysys Mason]

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

A.1.7 Transit layer deployment

The deployment of a transit layer is based upon the number of TSC locations provided by the operators. A transit layer is modelled to be present when more than one Fylke has a TSC deployed.

One TSC per location is modelled. TSC ports are not explicitly modelled, and are assumed to be included in the TSC unit cost.

A.1.8 Backbone transmission

There are two backbone network design options:

- without transit layer: fully redundant links into Oslo, plus Oslo ring
- with transit layer: fully redundant links in to the transit layer, plus transit mesh.

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. Figure A.16 below shows how the calculations are carried out.

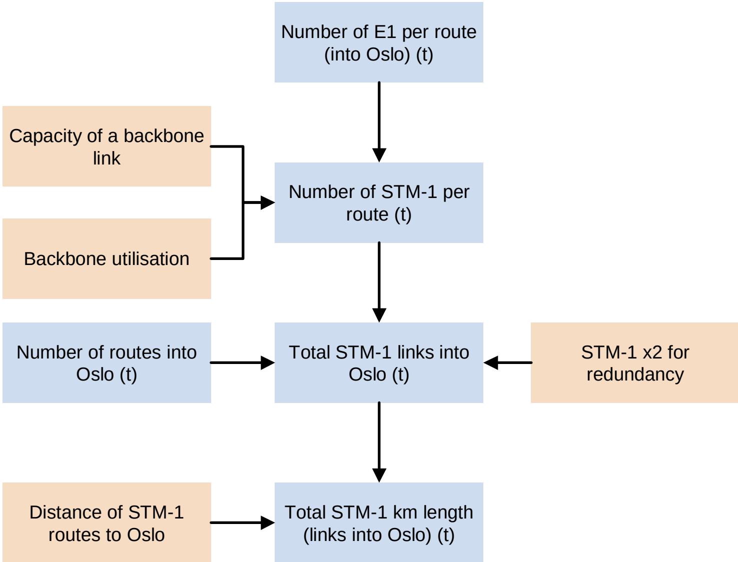


Figure A.16: MSC–MSC links for a network without transit layer [Source: Analysys Mason]

The diagram shows the calculation flow for links into Oslo. This same calculation is used for the total STM–1 links and link lengths for the intra-Oslo MSC–MSC ring.

Backbone links are modelled as STM–1 (155Mbit/s). These can accommodate 63 E1 links, subject to a maximum utilisation percentage.

The number of E1s per route is calculated in the port calculation. The corresponding number of STM–1 units per route is then calculated taking into account the fact that full redundancy is provided on each link. Multiplying by the number of routes gives the total number of STM–1 links into/within Oslo. The distance of the MSC–MSC links into Oslo is based on the straight-line distance (adjusted by a factor of 1.3 to take into account the non-straight line nature of the routes due to topology constraints) from each Fylke containing an MSC location to Oslo. The link lengths for MSC–MSC links within Oslo are assumed to be 3km.

Network with transit layer

The calculation of MSC–TSC links is based on the same principles as outlined above for MSC–MSC links, with the exception that the links are from the MSC location to the nearest TSC location (with redundancy). This calculation was outlined for the port requirement calculation.

Figure A.17 below shows the calculation for the TSC–TSC links.

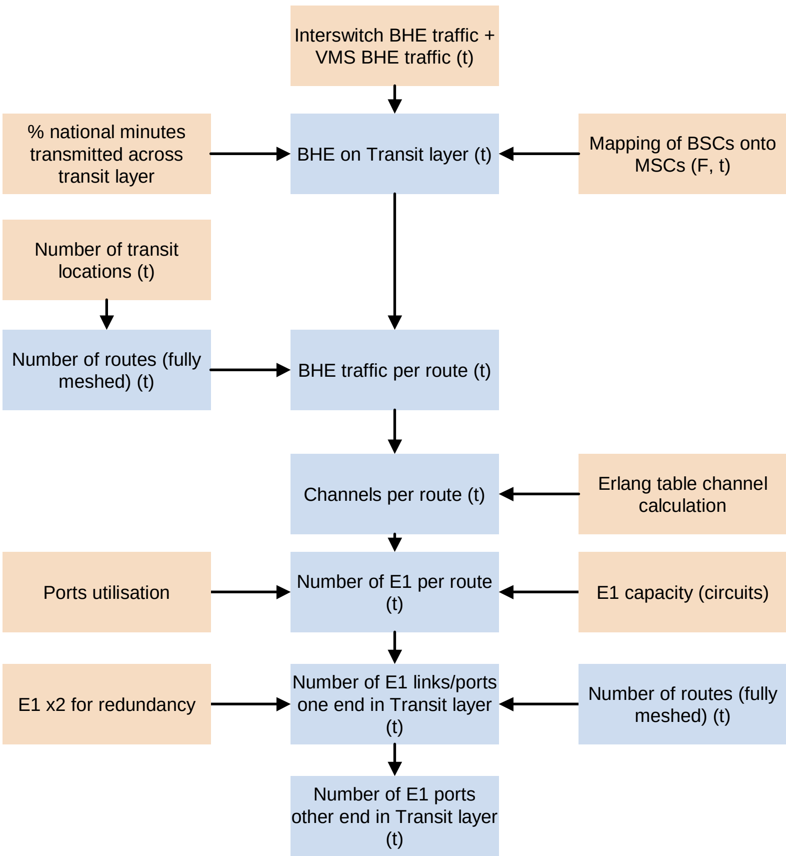


Figure A.17: Total TSC–TSC links for a network with transit layers [Source: Analysys Mason]

The number of TSC–TSC links is calculated directly using the number of transit switches, *S*, with the formula below:

$$l = S\,(S\text{-}1)\,/\,2$$

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

The transit link distances are based upon an average link distance calculated from the total distance between each of the Fylker that contain a TSC location. However, TSC–TSC links are assumed to be carried on a physical ring rather than fully-meshed links, therefore, the length of TSC–TSC links is estimated according to national TSC locations including an Oslo ring if more than one TSC exists in Oslo.

Overall inter-switch transmission links requirements

In summary, when there is no transit layer, the total number of STM–1 links will equal the total number of MSC–MSC links in Oslo plus the total number of MSC–MSC links into Oslo. When there is a transit layer present, the total number of STM–1 links will equal the total MSC–TSC links into the transit layer plus the total number of STM–1 TSC–TSC links.

A.1.9 Other

HLR, EIR, AUC

HLR units are deployed based on *registered subscribers*. Figure A.18 below shows the calculations to obtain the number of HLR units and HLR upgrades required.

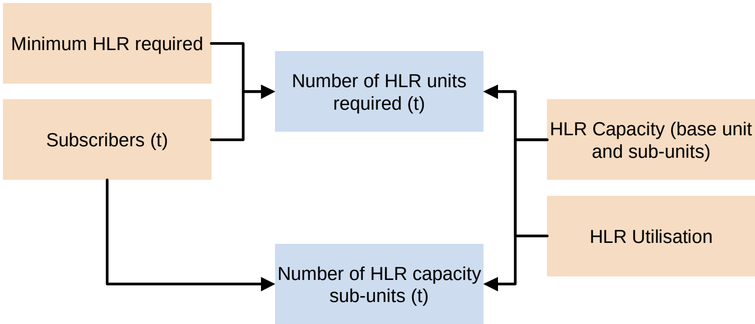


Figure A.18: HLR units calculation [Source: Analysys Mason]

The minimum number of HLR units is deployed from the start of the network. These HLR units have an associated capacity – as stated by each operator. The deployment of AUC and EIR are set to be equal to the number of HLRs in each year.

HLR upgrades are dimensioned on the basis of the number of registered subscribers and the actual capacity of an HLR upgrade.

SMSC (and MMSC)

The SMSC deployment is driven by SMS throughput demand. Figure A.19 below shows the calculation flow of the SMSC deployment.

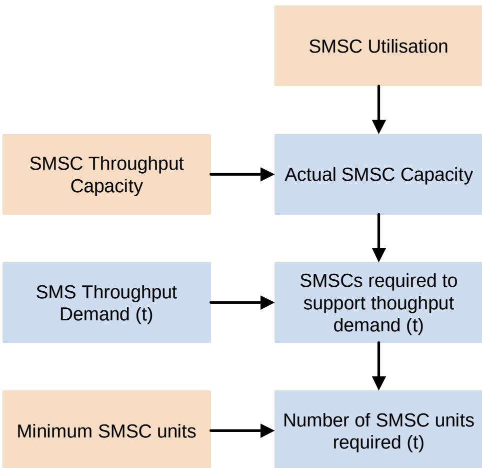


Figure A.19: SMSC units calculation [Source: Analysys Mason]

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 units threshold.

MMSC deployment is driven by MMS throughput demand in an analogous fashion.

GPRS infrastructure

There are three GPRS infrastructures deployed, namely:

- PCU
- SGSN
- GGSN.

One PCU unit is installed to control a defined number of radio sites.

Figure A.20 below shows the calculations for SGSN and GGSN deployment.

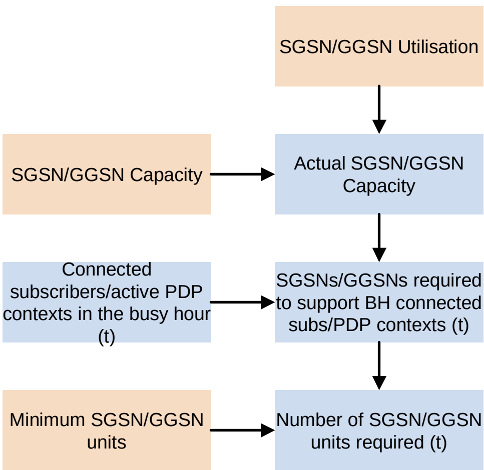


Figure A.20: SGSN and GGSN units calculation [Source: Analysys Mason]

The calculations for both SGSN and GGSN deployment 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 and IN system

The network management centre and IN system are deployed at the start of operations, but are modelled as recurring annual capital investment expenditures.

Voicemail system and billing system

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

Licence fees

The model includes annual and replacement (12-year period) spectrum licence fees. Annual fees are modelled as a cost per BTS, whilst licence investments are input directly (in nominal terms) into the cost model (*NwDes* worksheet).

A.2 UMTS technologies

A.2.1 Radio network: site coverage requirement

UMTS coverage is assumed to occur in three stages:

- **Stage 1**: initial urban coverage using 2100MHz spectrum
- **Stage 2**: infill urban coverage using 2100MHz spectrum
- **Stage 3**: rural coverage using 900MHz spectrum (occurs in the future).

To satisfy the coverage requirements, the number of sites deployed has to be able to provide coverage for a certain area defined for each Fylke. The inputs to these coverage calculations are:

- total area covered by operator by 2008
- total area to be covered by operator by Fylke, for Stages 1–3
- year in which Stage 1 deployment is completed
- year in which Stage 2 deployment is completed
- year in which Stage 3 deployment is completed
- cell radii for Stage 1 coverage by Fylke
- cell radii for Stage 2 coverage as a proportion of Stage 1 coverage
- cell radii for Stage 3 coverage by Fylke.

Figure A.21 below shows a flow diagram describing the calculation of NodeBs deployed[7] for coverage.

7 In all diagrams (F, t) denotes variance by Fylke (F) and time (t).

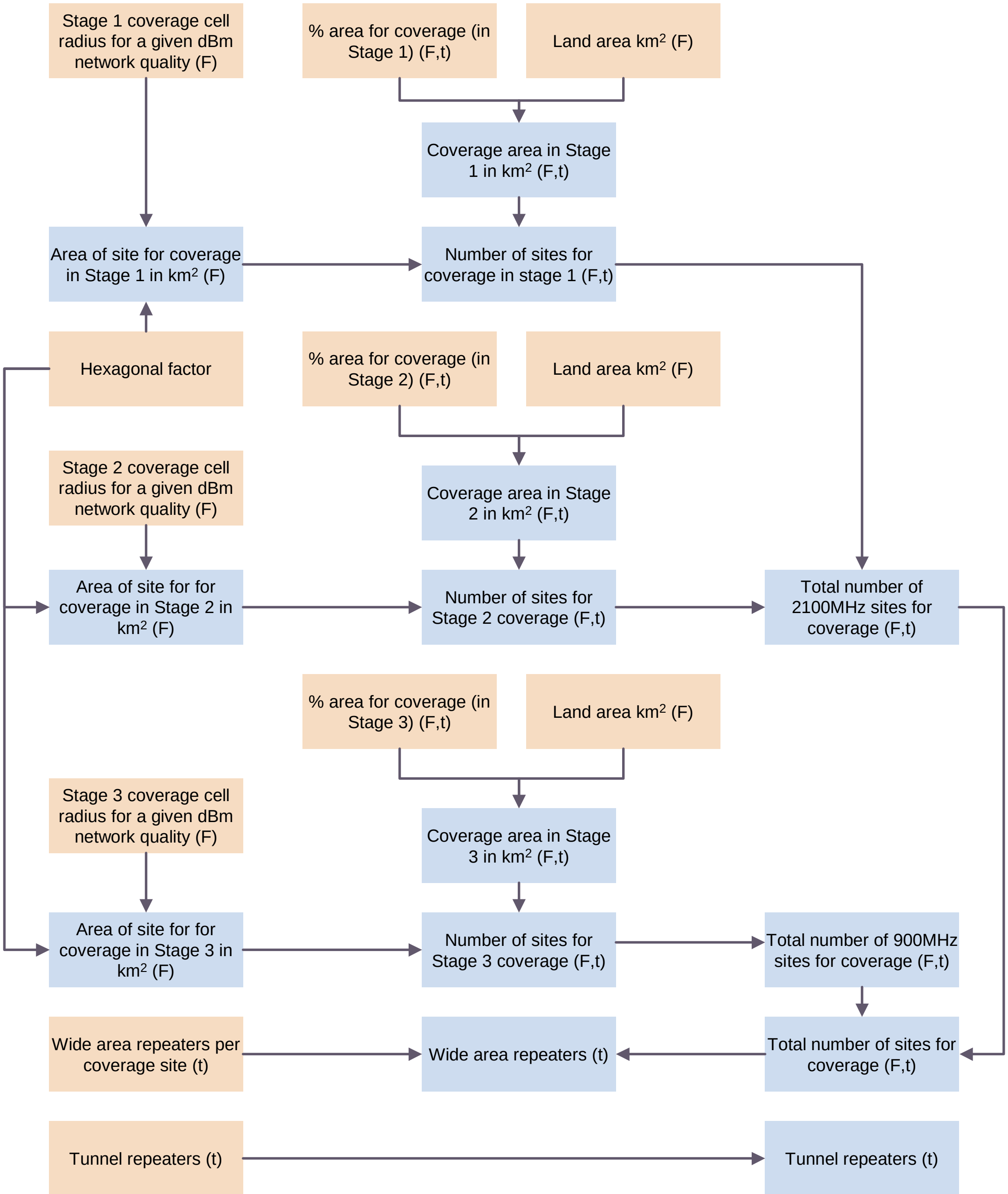


Figure A.21: UMTS coverage network design [Source: Analysys Mason]

NodeB requirements are calculated separately for Stages 1–3. For each of these stages, the NodeB radius is used to derive the area covered by a NodeB in a given Fylke. The total area covered within the Fylke is divided by this NodeB area to determine the number of NodeBs for coverage. The total requirements across all three stages is then calculated for each year by Fylke.

The number of wide-area repeaters is calculated as a percentage of the total number of coverage NodeBs in each year. The number of tunnel repeaters is modelled as an explicit input using operator data.

2100MHz NodeBs are deployed assuming an average sectorisation per site, calculated using operator data. The UMTS900 NodeBs deployed in later years are assumed to all be omni-sectored (i.e. the average sectorisation for UMTS900 is 1).

A.2.2 Radio network: site capacity requirement

Unlike in the GSM network, it is assumed that 2100MHz NodeBs are deployed with full sectorisation, with channel elements pooled at the NodeB. The capacity of the 2100MHz and 900MHz coverage networks are calculated separately.

The calculation of the BHE capacity provided by the 2100MHz NodeBs deployed for coverage is illustrated in Figure A.22 and explained below. The BHE capacity of the 900MHz coverage network is calculated in an identical calculation. The two capacities are then added together to give the total capacity of the coverage network for each Fylke.

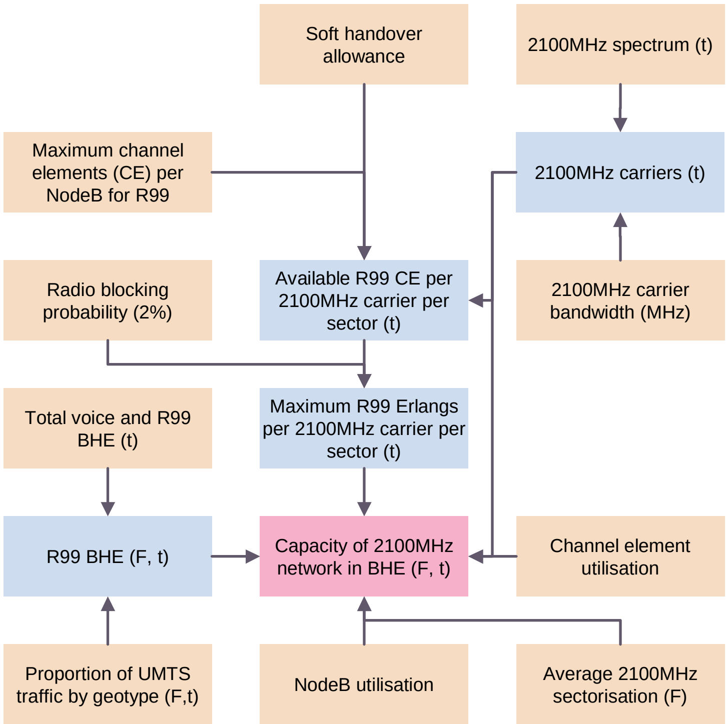


Figure A.22: Calculation of the BHE capacity provided by the 2100MHz coverage network [Source: Analysys Mason]

Before the capacity requirements of the network are calculated, the Erlang capacity for a given sector is determined. The inputs to this calculation are the availability of spectrum, the carrier bandwidth, the maximum number of channel elements (CE) per NodeB and an allowance for soft handover.

The physical sector capacity in Erlangs is obtained using the Erlang B conversion table. In order to calculate the busy-hour loading in each Fylke, the combined BHE from voice and R99 data are split by Fylke using operator data. The total number of sectors by Fylke is calculated using the average sectorisation, and the total capacity of the coverage network is then calculated.

An allowance is made for less than 100% of the NodeB and CE capacity being utilised. NodeB underutilisation occurs because it is not possible to deploy the maximum physical CE complement in every NodeB. CE underutilisation occurs because the peak loading of each cell at its busy hour is greater than the network average busy hour (to take this into account, an average to peak BHE loading of 150% is used in the calculation of the CE utilisation, accounting for the fact that the cell busy hour is 50% greater than the network busy hour), and because BHE demand does not uniformly occur in a certain number of sectors.

Given the large capacity of the deployed coverage network for voice and low-speed data capacity purposes, and the assumed 50% loading allowance for cell-breathing effects, it is assumed that additional sites are not deployed beyond the coverage roll-out. However, a cross-check is included to highlight whether or not this is the case for the modelled network: this check is linked to the *Ctrl* worksheet.

It is also assumed that a proportion of existing (2G) sites are available for NodeB deployments – remaining NodeBs are then deployed on new sites, as shown below in Figure A.23. The total number of 2100MHz NodeBs are then split by sectorisation (1-sectored, 2-sectored and 3-sectored), with the split derived using operator data.

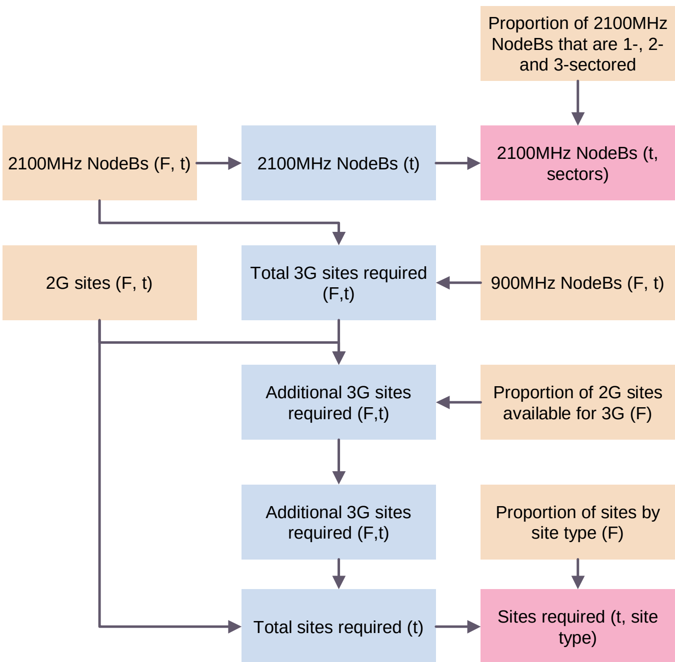


Figure A.23: Total site requirements [Source: Analysys Mason]

A.2.3 Radio network: Channel kit (CK) and carrier requirements

Channel kit requirements are calculated separately for voice/R99 and HSPA, by first calculating the channel element (CE) requirements.

CK requirements for voice/R99

To calculate channel element (CE) requirements for voice and R99 data, the inputs required are:

- total voice and R99 BHE traffic by Fylke
- total NodeB sectors and sites by Fylke (as previously calculated)
- channel element utilisation.

Figure A.24 shows a flow diagram describing the calculation of CE/CK required. Having calculated the number of CEs deployed at each site, the number of carriers required can then be calculated directly.

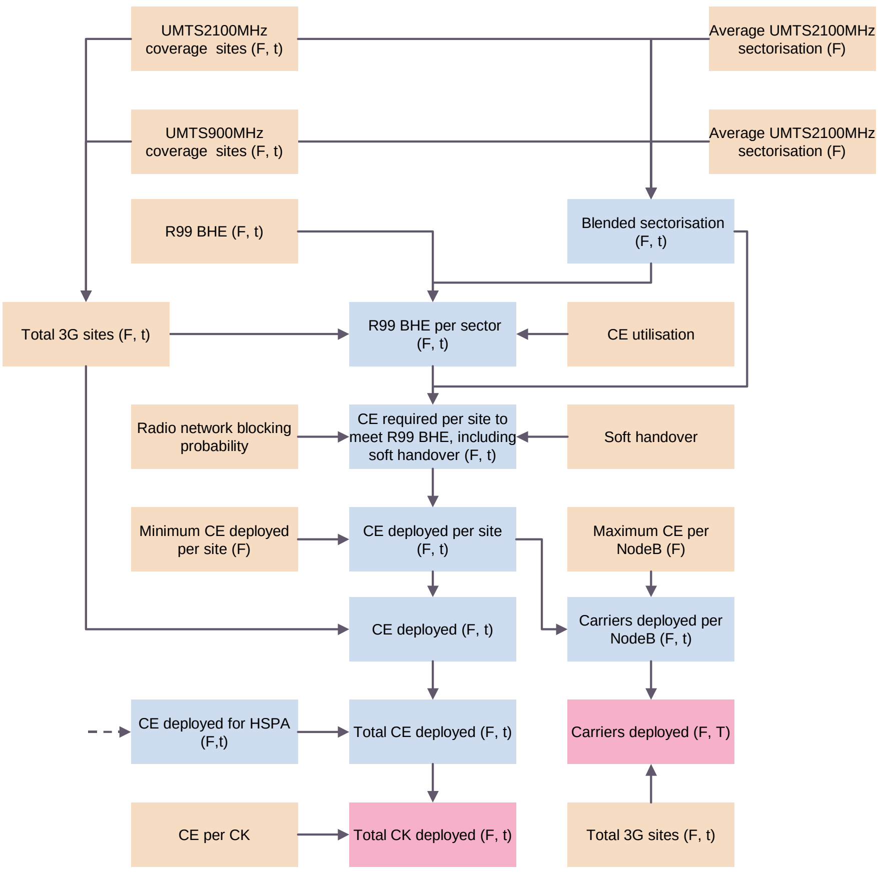


Figure A.24: Channel kit deployment [Source: Analysys Mason]

The blended site sectorisation across the whole 3G network, by Fylke, is calculated as a first step. The Erlang demand per NodeB sector is then derived and converted into a CE requirement per sector using the Erlang B table. This calculation accounts for both CE utilisation and soft handover. The CE requirement per site is then calculated using the blended sectorisation and assuming that a minimum number of 64 CEs are activated on every NodeB. The number of CEs required is obtained by multiplying the number of sites and the CE requirement per site.

The number of carriers required, first per site and then in total, can then be calculated according to a maximum number of CEs deployed per NodeB (128).

CK requirements for HSPA

Four grades of HSPA are deployed in the model: HSDPA 3.6, HSDPA 7.2, HSDPA 14.4 and HSUPA1.5. Each is assumed to be activated in the network from a particular year onwards. It is assumed that HSDPA 3.6 is deployed at every NodeB from launch, whereas HSDPA 7.2 are only deployed at a proportion of sites in each Fylke. In addition, HSDPA 14.4 is deployed a certain number of years after HSDPA 7.2 is deployed as an upgrade to some sites. Channel elements for HSDPA and HSUPA are calculated separately, as shown below in Figure A.27.

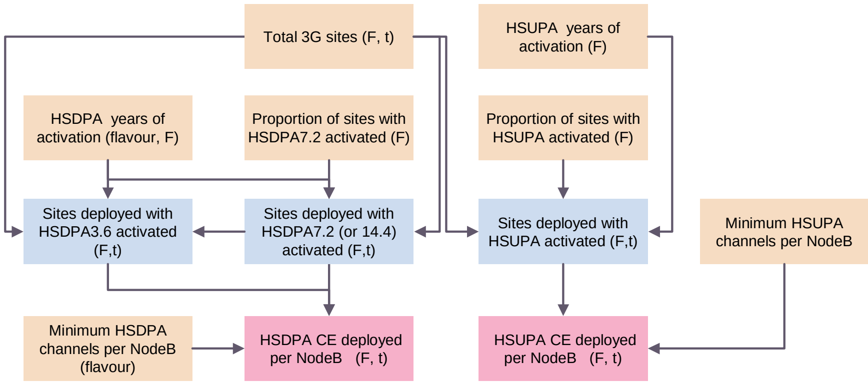


Figure A.25: HSPA channel element deployment [Source: Analysys Mason]

Within each Fylke, the model makes the distinction between sites with HSDPA 3.6 and HSDPA 7.2/HSDPA 14.4.

The model also includes a cross-check to ensure that the deployed HSDPA capability (in terms of average HSDPA rate per NodeB) can support the offered throughput (in terms of average HSDPA busy-hour throughput per NodeB) in all Fylker in all years. This is illustrated below in Figure A.26.

The cross-check assumes underutilisation of HSDPA channel elements that is greater than R99 channel elements. This is because of the greater difference between the cell loading at its maximum and the loading of the average busy-hour for HSDPA compared with that for voice and R99 data. As a result, an average to peak BHE loading of 200% is used in deriving HSDPA CE utilisation.

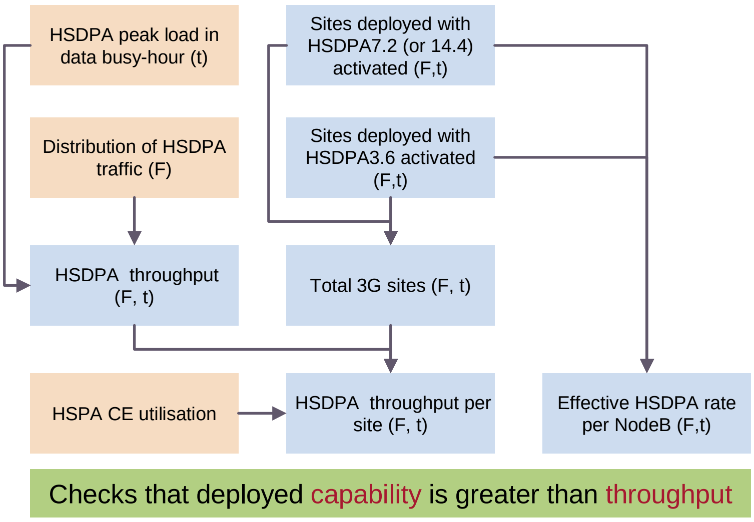


Figure A.26: Verification of sufficient HSPA deployment [Source: Analysys Mason]

This cross-check is linked into the *Ctrl* worksheet and is highlighted in red if the check fails.

A.2.4 Backhaul transmission

The calculation of the number of backhaul links and the corresponding number of E1 ports required is set out in Figure A.28. Requirements for voice/R99 and HSPA are dimensioned separately. The capacity requirements and then the means of deployment are calculated separately.

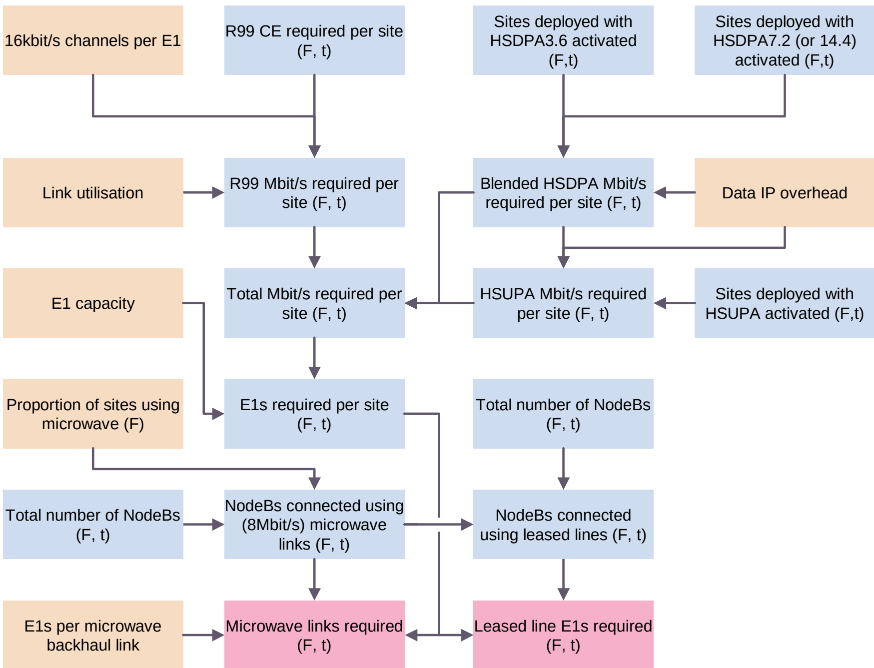


Figure A.27: UMTS backhaul calculation [Source: Analysys Mason]

Step 1: Capacity requirements

The number of E1s required per site is calculated to fulfil the capacity requirements for a backhaul link. The requirements for voice/R99 and HSDPA are considered separately, calculating:

- 120 channels per E1 for voice/R99 CE
- blended Mbit/s requirements for HSDPA/HSUPA, including an overhead for IP.

It is assumed that backhaul requirements for HSDPA are provisioned according to the speed in Mbit/s. In addition, we assume that HSUPA uses the uplink backhaul capacity already deployed for HSDPA, i.e. there is no backhaul deployment dedicated to HSUPA.

The effective capacity per E1 is calculated for voice. The number of E1 links required per site is obtained by simply dividing the circuits per site with the effective capacity per E1 link.

Step 2: Backhaul network design algorithms

There are two types of backhaul to be considered in the network: microwave (8Mbit/s links) and leased lines. The percentage of sites which have microwave backhaul is an input into the model.

The number of microwave 8Mbit/s backhaul links is set to be a minimum of one per site. The model allows for more than one 8Mbit/s link per site. The number of E1 units occupied in each 8Mbit/s microwave link is calculated.

The number of sites using leased lines calculated as the difference between the total sites and the total sites using microwaves. The total number of E1 leased lines required is the product of the total number of NodeB sites using leased line and the number of E1 required per site (from *Step 1*).

Tunnel repeater sites are assumed to use only E1 leased lines and hence are added to the leased-line requirement of the macro NodeB layer.

A.2.5 RNC deployment

The structure of the RNC deployment algorithm is set out below in Figure A.28.

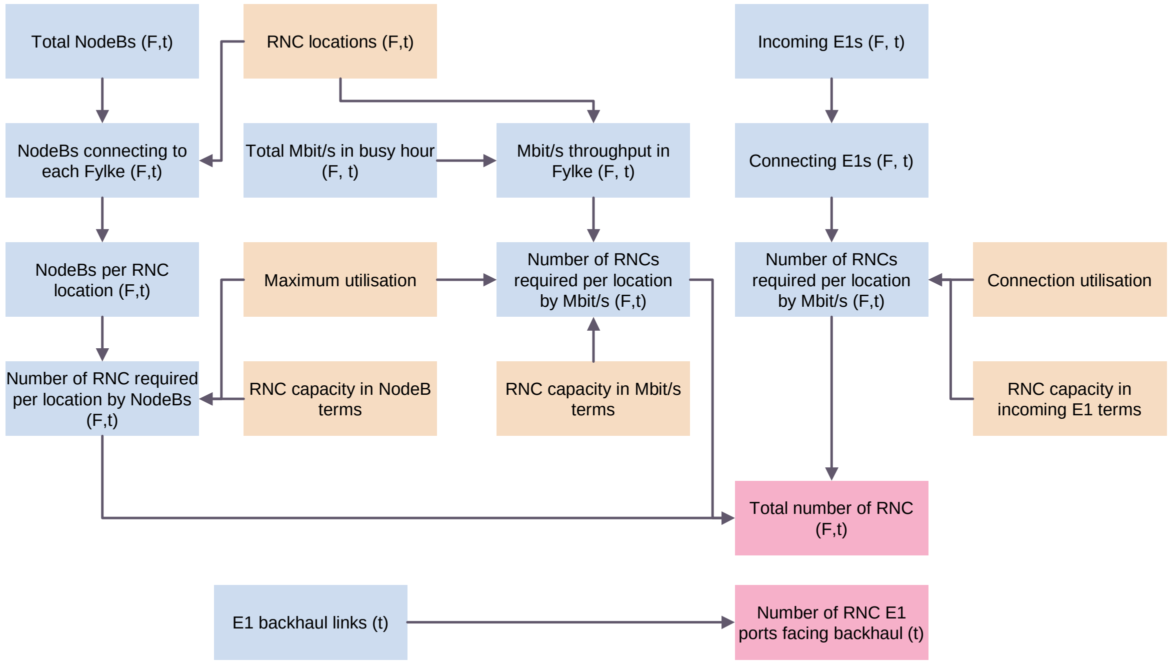


Figure A.28: RNC deployment [Source: Analysys Mason]

RNC units calculation

The number of RNC units required is derived according to the maximum needed to satisfy requirements according to three dimensions: BH Mbit/s, NodeBs and incoming E1 ports.

RNC locations by Fylke are used as an input to the model using data from the operators. BH Mbit/s, NodeBs and incoming E1 ports are each mapped onto these RNC locations by Fylke, generating the total per RNC location. The number of RNC units deployed must be able to accommodate the number of each of these dimensions (see section A.1.3), according to a maximum capacity of the RNC and adjusting for maximum utilisation.

RNC–MSC links calculation

A proportion of RNCs are designated as 'remote' (i.e. not co-located with an MSC or MSS). As a result, they require a physical link to the MSC and are located in a separate building in some distant part of the network. Remote RNC locations are modelled to be present when there are no MSC / MSS locations in the Fylke; it is assumed that there is one remote RNC per remote RNC location.

In the legacy core network, STM–1 links are deployed from remote RNCs back to the parent MSC location, as shown in Figure A.29 below.

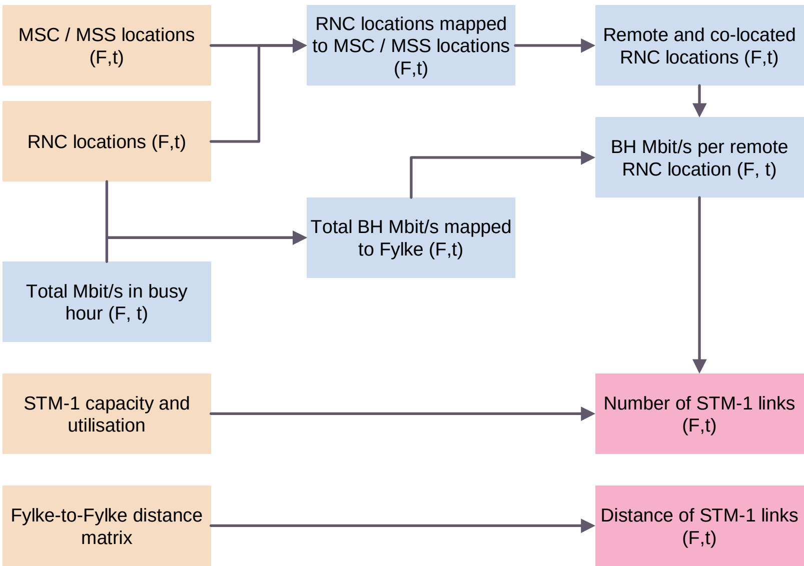


Figure A.29: RNC–MSC remote transmission in the legacy core network [Source: Analysys Mason]

The BH Mbit/s transiting through these RNCs is backhauled to the MSC using STM–1 leased lines. Remote RNCs require physical RNC–MSC links and the total number of these is calculated from the total number of remote RNCs and the link capacity required.

The total traffic handled by each remote RNC can be calculated using the total BH Mbit/s. The average traffic handled by each remote RNC is then converted into an equivalent number of STM–1 links, adjusted for maximum utilisation.

The distance of these links is also an important output of the model as the backhaul costs involve a connection charge per link end and a distance-based cost.

The distances between all of the Fylker are specified in the *NtwDesBase* worksheet according to straight-line distances between the major conurbations in each Fylke, adjusted for route length using a multiplier of 1.3 (accounting for the non-straight line nature of networks given topology constraints). The calculation of the distances of the RNC–MSC links uses this Fylke distance matrix, in combination with the mapping of RNCs locations onto MSCs locations, which is performed in the *RNCMSC* worksheet.

Incoming and outgoing ports

The incoming ports to the RNC are ports facing the NodeB, whilst the outgoing ports in the legacy core network are ports facing the MSC. Figure A.30 below shows the constituents of the incoming and outgoing ports.

The total number of E1 incoming ports into RNC is the sum of microwave and leased line backhaul links, whilst the total number of outgoing ports is calculated from the total number of RNCs and total BH Mbit/s traffic, accounting for minimum deployment, utilisation and redundancy.

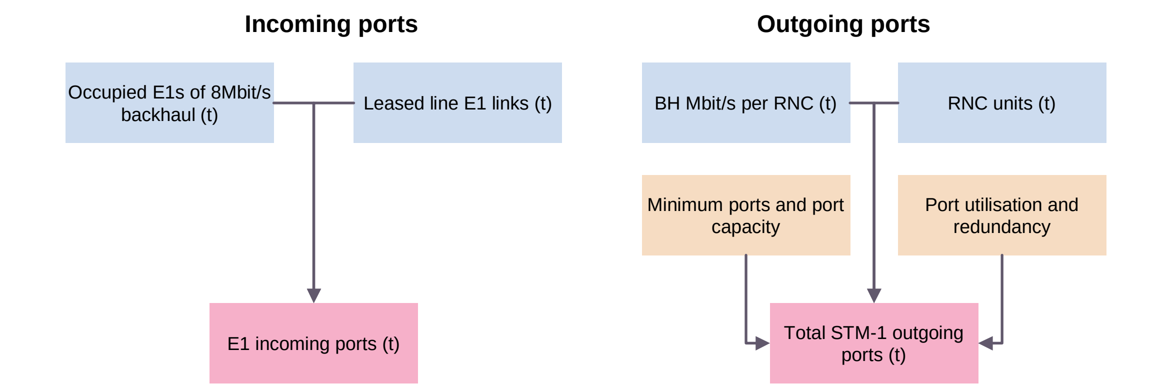


Figure A.30: Total incoming and outgoing ports for RNC [Source: Analysys Mason]

A.2.6 MSC upgrade

When the 3G radio network is deployed, it is initially assumed that the software of every deployed 2G MSC is upgraded in the first year of activation to also handle 3G traffic. RNCs are linked back to these MSCs using STM–1 links, as explained above in section A.2.5. MSCs are also dimensioned on the total busy-hour traffic from both radio networks.

At some point in time after the 3G radio network is activated, it is assumed that a new layered core architecture is deployed, running in parallel for a short period of time prior to the shut-down of the legacy core. This layered core consists of:

- a circuit-switched layer of MSSs, each deployed with pairs of MGWs
- links from the RNC to the MGWs to convey voice traffic
- a fully meshed layer of packet-switching routers
- links from the RNCs back to these routers to convey data traffic.

The calculations that dimension this layered architecture are described in more detail in sections A.2.7 and A.2.8 below.

A.2.7 Layered core: circuit-switched layer

MSS units to support processing demand and MGW

The number of MSS units to support the processing demand is calculated from the CPU capacity, processor utilisation and the demand for MSS processor time in terms of busy-hour milliseconds. This is calculated in an analogous way to the busy-hour millisecond demand for MSC processing, as described in section A.1.6. Figure A.31 below shows the sequence of the calculation.

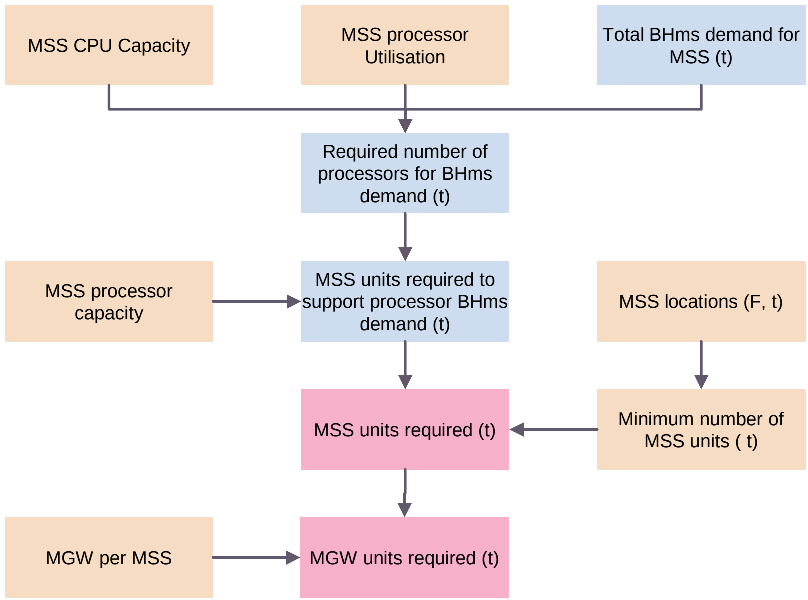


Figure A.31: Calculation of MSS units to support processing demand and MGW [Source: Analysys Mason]

Taking into account the MSS processor utilisation, the total number of processors required to meet the demand can be calculated as the total number of busy-hour milliseconds (BHms) divided by the effective MSS capacity. We have assumed MSS locations by Fylke over time and have also calculated the number needed to meet processing demand – the actual number of MSS deployed is then the larger of the two. From this, the number of MSS within and outside of Oslo is then calculated.

It is assumed that two MGWs are deployed per MSS, meaning that the number of MGWs deployed follows directly, hence the number of MGWs within and outside Oslo can also be calculated.

Inter-MGW infrastructure

The inter-MGW port and link requirements are considered according to three separate cases:

- between MGW sites within Oslo (if there are multiple MSS locations in Oslo): these are assumed to lie on a single ring structure
- between co-sited MGWs outside of Oslo
- between MGWs outside of Oslo: these are assumed to sit on a resilient ring.

The calculation of MGW–MGW links between Oslo sites are shown in Figure A.32 below.

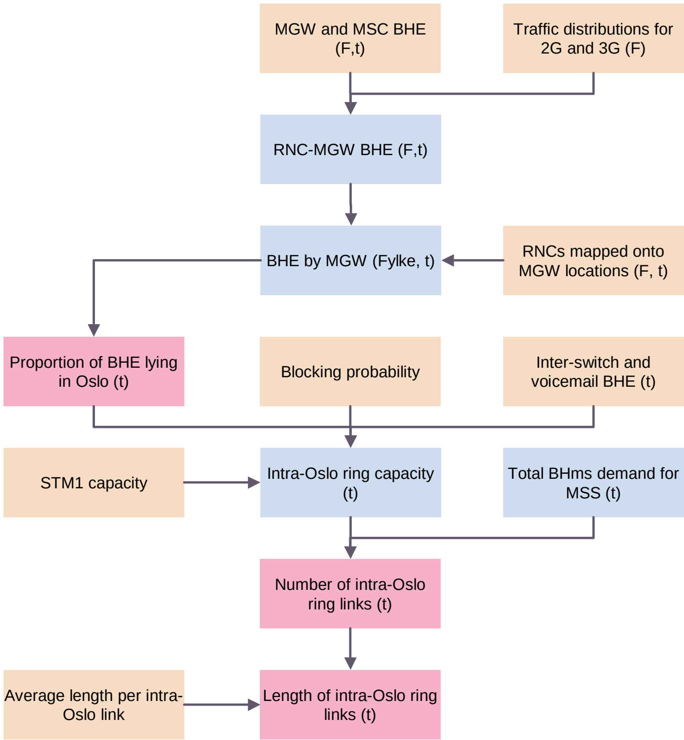


Figure A.32: Calculation of MGW–MGW links between Oslo sites [Source: Analysys Mason]

It is assumed that all of these MGWs lie on a ring structure within Oslo. In order to calculate the capacity required for this ring, the proportion of BHE that occur within Oslo is first determined. To calculate this, the MGW and MSS BHE by Fylke is derived, using the traffic distributions for 2G and 3G. The BHE is then aggregated to the Fylker containing MGWs (the Fylker with MSSs), based on the calculated mapping of RNC to MGW. This allows the calculation of the proportion of BHE not associated with the MGWs in Oslo.

This proportion is applied to the BHE for inter-switch and voicemail traffic and the Erlang B table is used to calculate the number of channel equivalents required on the ring. The number of STM–1 equivalents needed to accommodate these channels is then calculated, accounting for a maximum utilisation percentage. The number of STM–1 links required is this number of STM–1 per ring-link multiplied by the number of links in the ring (i.e. the number of MGWs in Oslo). An average link length of 3km is assumed, to derive the total length of STM–1 links required.

The calculation of MGW–MGW links between non-Oslo sites is shown below in Figure A.33.

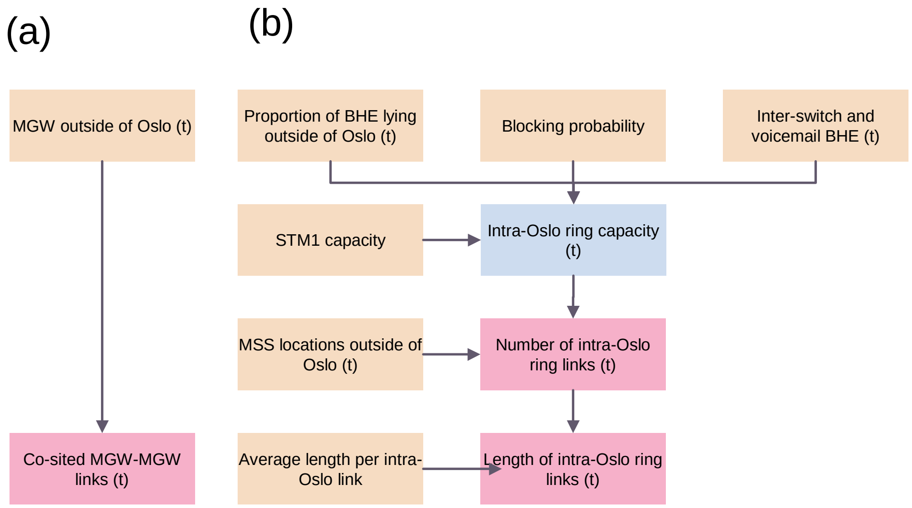


Figure A.33: Calculation of MGW–MGW links between (a) co-sited MGWs outside of Oslo and (b) MGWs outside of Oslo [Source: Analysys Mason]

The links between co-sited MGWs outside of Oslo are assumed to be equal to half the number of MGWs outside of Oslo (i.e. one link per pair).

The MGWs outside of Oslo are assumed to sit on a 'resilient double ring' as detailed in section 4.2.

The capacity of each ring is calculated in the same manner as the Oslo ring, but using the BHE occurring outside of Oslo. The number of STM–1 links on the ring is also derived in the same way. An average link length on the ring is assumed, and this is multiplied by the number of links to obtain the total length of STM–1 links.

MGW ports calculation (RNC-facing, interconnect-facing, VMS-facing)

Figure A.34 below shows how the number of RNC-facing ports is derived.

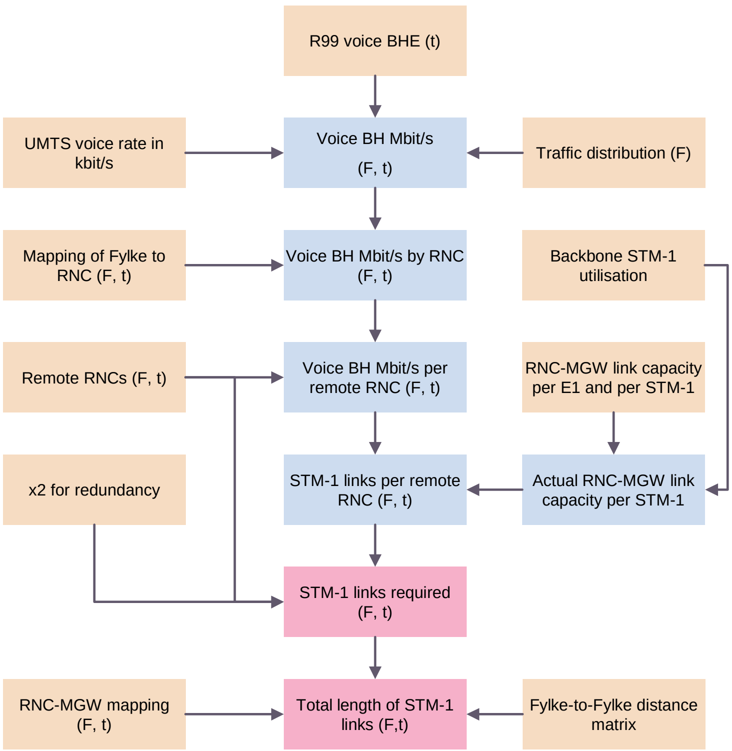


Figure A.34: Calculation of RNC–MGW links [Source: Analysys Mason]

The voice BH Mbit/s by Fylke is calculated by splitting total R99 BHE by Fylke using the 3G traffic distribution and multiplying by a UMTS voice rate of 12.2kbit/s. The BH Mbit/s passing through each Fylke is aggregated by parent RNC, to derive the BH Mbit/s through each RNC in the Fylke. This is divided by the total number of remote RNCs in the Fylke and then divided by the capacity of a STM–1 to derive the number of STM–1 links needed per remote RNC (this is then multiplied by two to account for link resilience). The product of the average number of links per remote RNC and the total number of remote RNCs in the Fylke gives the total number of RNC–MGW STM–1 links.

The calculation of the lengths of the RNC–MGW links uses the Fylke distance matrix, in combination with the mapping of RNCs locations onto MGW locations, which is performed in the *RNCMGW* worksheet.

Interconnect-facing and VMS-facing ports are calculated in an analogous way to the corresponding MSC ports in the legacy core architecture.

A.2.8 Layered core: packet-switched layer

Packet-switch data routers

It is assumed that particular Fylker contain data routers – this is assumed to not change over time, and one router is assumed per location. If there is more than one location across all Fylker, then it is assumed that there is a fully meshed set of links between the router locations.

Meshed links between RNCs and packet-switch data routers (PS)

The calculation of RNC–PS links is based on the same principles as outlined above for RNC–MGW links, but with links from the RNC location to the nearest router location. The mapping of locations is performed in the *RNCPS* worksheet.

The calculations for the total number of STM–1 links required in the mesh linking the data router locations is shown below in Figure A.35.

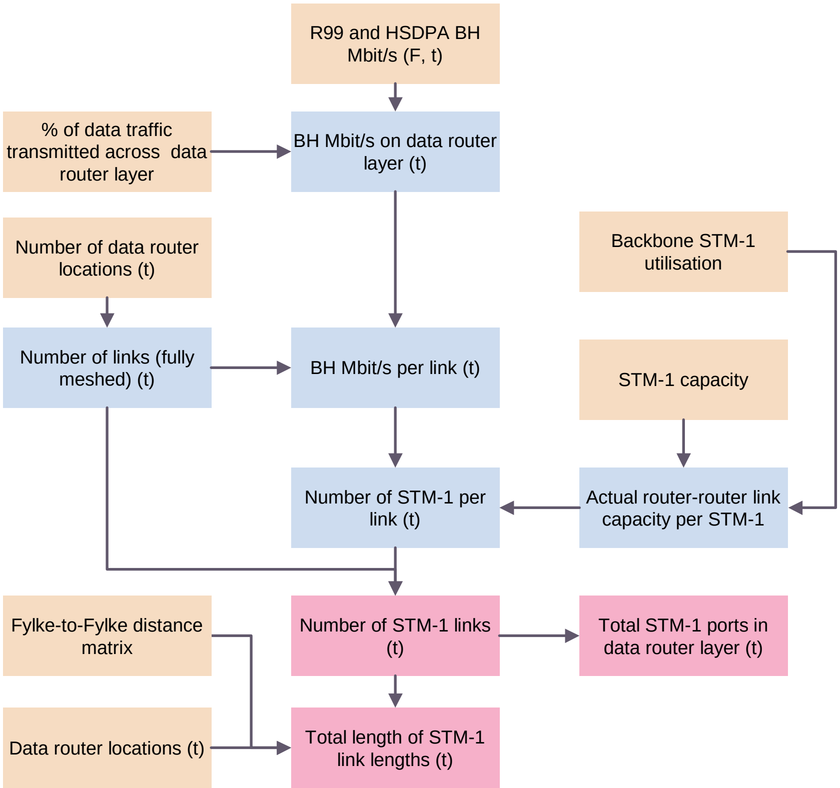


Figure A.35: Calculation of links between data routers in the packet-switch layer [Source: Analysys Mason]

The calculation of the link capacity and port requirements are analogous to those of the legacy TSC architecture, as described in section A.1.7, however, the router links are calculated in STM–1 terms, rather than E1 terms. In particular, the number of links between the data routers (which are fully meshed) is calculated directly using the number of data routers, D, using the formula:

$$\textit{number of links} = D\,(D\text{-}1)\,/\,2.$$

Further, the link distances are based upon an average link distance calculated from the total distance between each of the Fylker that contain data routers.

Annex B: Glossary

Acronym	Meaning	Acronym	Meaning
2G	Second generation of mobile telephony	M-F	Mobile to fixed
3G	Third generation of mobile telephony	M-M	Mobile to mobile
AUC	Authentication centre	MMS	Multimedia message service
BH	Busy-hour	MMSC	MMS centre
BHE	Busy-hour Erlangs	MN	Mobile Norway
BSC	Base station controller	MSC	Mobile switching centre
BTS	Base transmitter station or base station	MSS	MSC server
CCH	Control channel	MT	Mobile termination
CE	Channel element	MTR	Mobile termination rate
CK	Channel kit	MVNO	Mobile virtual network operator
CPU	Central processing unit	NC	Netcom
DCS	Digital cellular system	NDA	Non-disclosure agreement
E1	2Mbit/s unit of capacity	NMS	Network management system
EC	European Commission	NN	Network Norway
ED	Economic depreciation	NodeB	Denotes UMTS equivalent of a BTS
EGSM	Extended GSM	NOK	Norwegian krone
EIR	Equipment identity register	NPT	Norwegian Post and Telecommunication Authority
EPMU	Equi-proportional mark-up	NR	National roaming
FAC	Fully-allocated cost	OLO	Other licensed operator
F-M	Fixed to mobile	PCU	Packet control unit
GGSN	Gateway GPRS serving node	PDP	Packet data protocol
GPRS	General packet radio system	PoI	Point of interconnect
GSM	Global system for mobile communications	PS	Packet switch
GSN	GPRS serving node	PV	Present value
HCA	Historical cost accounting	QAM	Quadrature amplitude modulation
HLR	Home location register	R99	Release-99
HSDPA	High speed downlink packet access	RNC	Radio network controller
HSPA	High speed packet access	SDCCH	Stand-alone dedicated control channel
HSUPA	High speed uplink packet access	SGSN	Subscriber GPRS serving node
IN	Intelligent network	SMS	Short message service
IP	Internet Protocol	SMSC	SMS centre
LRAIC	Long-run average incremental cost	SP	Service provider
LRIC	Long-run incremental cost	SSB	Statistics Norway
LTE	Long-term evolution	STM	Synchronous transport module
MEA	Modern equivalent asset	T2	Tele2
MGW	Media gateway	UMTS	Universal mobile telecommunications systems

Acronym	*Meaning*	*Acronym*	*Meaning*
TCH	Traffic channel	VLR	Visitor location register
TDD	Time division duplex	VMS	Voicemail system
TN	Telenor	WACC	Weighted average cost of capital
TRX	Transceiver unit		
TSC	Transit switching centre		

Figure B.1: Acronyms used throughout the document [Source: Analysys Mason]

Annex C: Operator submissions in developing v6 (public)

C.1 Telenor

> Neither the NetCom nor the Telenor model will be "actual operator models" because NPT has decided to model the market without national roaming. A share of the third operator retail market share is in the model assumed to be carried by NetCom and Telenor, but this traffic is distributed similarly to other traffic. This assumption is evidently not reflecting realities since national roaming traffic only is carried in the remote parts of NetCom's and Telenor's networks (the areas outside the actual coverage area of the third operator). Thus, the Telenor and NetCom models are not actual operator models.

► *Analysys Mason response*

National roaming traffic – a declining share of the retail base of the third operator – is included in the model as traffic carried by Telenor and NetCom. Telenor is correct that this traffic is assumed to be distributed similarly to its own traffic (from 2009 onwards when the third-operator network starts service). However, with general migration off the incumbents' GSM networks, spare capacity will appear across the GSM layer and the impact of carrying national roaming traffic will be lower than the additional traffic volumes would indicate, and could even be zero. Accepting this, we consider that the issue is whether the modelled Telenor and NetCom are materially different from the (actual) Telenor and NetCom if that different traffic distribution were taken into account. In our view, the outcome of the model being materially different from that of Telenor's real situation is not true, given the following:

- There is no (material) national roaming traffic until 2008, and therefore all costing aspects of the GSM network up to the end of 2007 are unaffected. This means that the GSM parts of the cost base are only marginally influenced by the presence of national roaming volumes in the later years.

- The actual national roaming traffic carried by Telenor (and NetCom) in 2008 has been added to the model (it was excluded in the draft v5.1 model because of the difference in third-network launch dates: 2008 in reality, 2009 in the model). However this traffic in the model is explicitly excluded from the radio network dimensioning in 2008 – it is modelled as a separate service for 2008 only, which does not contribute radio BHE. This means that, consistent with the approach to carrying national roaming traffic, the networks of Telenor and NetCom are not required to deploy additional sites, BTS or TRX capacity in cities in response to national roaming volumes, and national roaming volumes essentially remain in remote parts of the network. With our network calibration checks carried out for the latest network data provided for 2008, then this should ensure that the model is not incorrectly sensitive to the actual traffic volume distribution.

- From 2009 onwards, national roaming traffic forms a declining traffic volume for the two incumbents as part of an overall declining share of the market. This volume is carried in the model on a GSM network, which has spare capacity (because GSM volumes are in steady decline due to 2G/3G migration), and carried on a UMTS network, which also has spare capacity (because it has been deployed to serve the expected future loading of UMTS services from the operator's own subscriber base). The proportion of the average incumbent traffic due to national roaming is shown in Figure C.1. It should be noted that when national roaming traffic is at the highest proportion (i.e. in 2009), then the national roaming traffic is distributed most similarly to the incumbent's own traffic (i.e. still within many cities and urban areas because the third entrant roll-out has yet to reach out into further regions). When national roaming traffic is at the smallest proportion of volumes, then national roaming is most 'remote'.

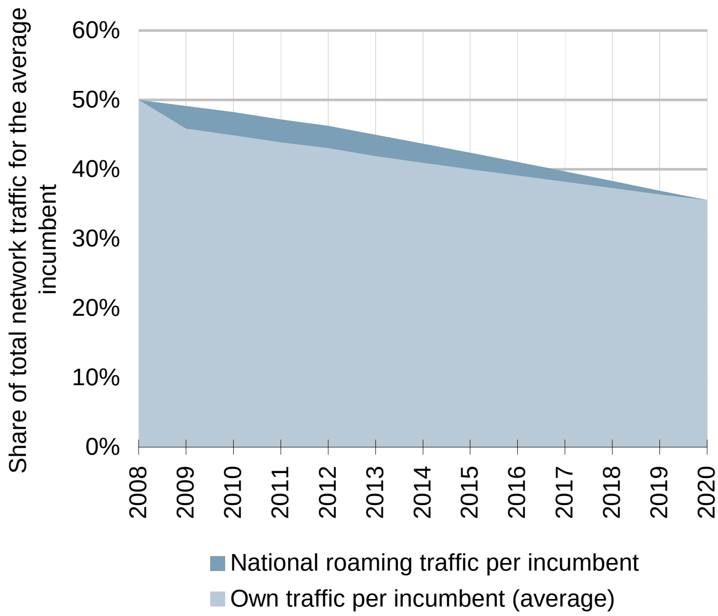


Figure C.1: National roaming traffic for an average incumbent [Source: Analysys Mason]

- The majority of radio network equipments (sites, BTS, NodeBs) are fully retained in the network (with capex, ongoing replacement and opex) even if demand volumes decline (as would clearly be the case going from 2008 to 2009 when the third entrant starts service). This means in particular that the majority of the 2G network deployed at the peak of 2G demand (i.e. around 2007–2009) is retained until 2020, even though the distribution of declining traffic is non-uniform compared to the traffic distribution pre-national roaming at the peak of traffic load.

- To indicate the materiality of this national roaming traffic distribution point, the model can be run with no national roaming traffic, by setting the third-operator network share to be equal to its retail market share (equivalent to costing the incumbents with only their own traffic). The LRIC+++ of termination for Telenor in this case is higher by 2% from 2009 to 2010. As such, we estimate the **maximum** possible sensitivity to the (complete loss of) national roaming volumes is 2%. Therefore, given the economies of scale from carrying national roaming traffic in the network, we consider that the impact of smaller adjustments to the model as a result of *distributional changes to own versus national roaming traffic* will be much less than 1% and would not increase the LRIC+++ cost of serving traffic on the network.

Costs associated with data services

The model estimates a cash flow of costs, op-ex and cap-ex. These costs are attributed to various services so that all relevant costs are covered (in NPV terms) over the modelling period. The economic depreciation algorithm is designed in order to ensure cost recovery in this sense.

The model yields cost recovery profiles for data services that clearly are out of line with what we observe in the Norwegian markets (as well as most other mobile markets). As an example, if we look at costs recovered by services carried by the 3G network in the period 2010 – 2042, data (R99 + high speed) accounts for 40% - 50% of cost recovery in NPV terms. If we look at 3G cost recovery in the year 2009 the pattern is the same. According to the model data will account for ca. 50% of 3G revenues. This is in contrast to current revenue shares for operators where data typically account for 5% - 10% of revenues.

In the model itself, the focus is on cost recovery by service. However, in the conceptual design document it is explicitly stated that the allocated cost are to be interpreted as prices/ revenues per unit:

In the modelled environment of a competitive market, the price that will be charged per unit demand is a function of the lowest prevailing cost of supporting that unit of demand, thus the price will change in accordance with the costs of the modern equivalent asset for providing the same service function. 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 modern equivalent asset price trend) for that asset class.

The modelling assumptions are based on observed data usage and forecasts of data usage in the coming years. Necessary network capacity to carry the data volumes is significant. The growth in data usage is driven by the current and forecasted price level for data services in the end user market. As indicated above, current data prices generate 5 – 10% of revenues (and not 40%). This is evidently inconsistent. If data had been priced according to the model results, current data use would have been prohibitively expensive, and demand would have been significantly below the volumes we observe today. In Telenor's opinion, NPT has two possible ways to ensure that the model become consistent:

Alternative 1: Use data volumes in the model consistent with the model results, i.e. make forecasts of data usage based on the assumption that the retail price of using data services are 4 – 6 times higher than the price we observe in the market today.

Alternative 2: Develop other algorithms for cost allocation so that the data cost recovery becomes aligned with market realities.

► *Analysys Mason response*

Firstly, it should be noted that the model covers network expenditures, and a share of business overheads allocated to network services. The model does not include retail expenditures. Therefore, any comparison of the model results to actual revenues must be made in the understanding that the distribution of retail cost recovery may be different to that presented in the network cost model. In developing the results of the cost model, we apply no requirement as to how any retail costs may be recovered by retail services, nor do we suggest that all network services should be priced in the retail market according to the model results. The purpose of the model is to calculate the network cost for mobile termination minutes as the basis for NPT's cost-based pricing of wholesale termination.

Telenor assert that "if data had been priced according to the model results, current data use would have been prohibitively expensive, and demand would have been significantly below the volumes we observe today". Telenor suggest therefore that the model recovers more costs per megabyte than Telenor achieves in practice. As quoted in Annex D, Telenor assert that "it is not the case that the modelling results are marginally wrong".

We detail our response in Annex D due to the use of confidential Telenor data.

In conclusion, we reject Telenor's suggestion that the calculated LRIC+++ cost of mobile termination is incorrect as a result of the allocation of cost to data services, and maintain that our allocation of network costs to data is reasonable for the purposes of setting the basis for wholesale voice call termination charges.

Market share third operator

The model assumes a retail market share for the hypothetical third operator of ca 15% in 2009. The (voice) market share for the third operator is converging towards 33% in 2040. This profile is based on the projections of third operator growth in version 4 of the model, combined with current market shares of Tele2 and Network Norway. Telenor considers the assumed evolution of retail market shares as plausible.

In the model it is assumed a significant difference between the retail market share and the wholesale market share for the third network operator. According to the conceptual design document this difference is driven by three variables:

· Third operator 2G coverage

· Third operator 3G coverage

· 2G – 3G migration in the market.

This is explicitly stated in page 14:

"We shall estimate the rate of transfer to the third entrant on the basis of its network population coverage and the 2G-to-3G migration rate of subscribers in the market."

This is in contrast to the information provided in Analysys Mason presentation August 18: where it is indicated on slide 23 that the difference between retail and wholesale market shares are also driven by two additional variables:

· Proportion of own traffic on 2G

· Proportion of own traffic on 3G

According to the presentation, these variables (only the 2G variable is explained) are included because: There is limited capacity in the operator's 2G layer, therefore only a limited proportion of usage can be carried by the third network compared to national roaming.

Telenor's interpretation of this statement is that NPT assumes capacity constraints in the third operator network within the area where the third operator has coverage. This is not a plausible assumption. Why should the third operator invest in a network that is capacity constrained from day one? An economically rational network roll out would be to install sufficient capacity to carry all "own" traffic where the network has coverage. Furthermore, in the LRIC model, the network of the (hypothetical) third operator is dimensioned to carry the traffic that is being assumed. Thus the postulated capacity constraints are neither founded in a rational network roll-out strategy, nor in the hypothetical third operator network.

Finally, the implemented calculation of third operator market share in the spreadsheet is neither consistent with the conceptual design nor the formula in the August 18 presentation of the following reasons:

1. The formula includes a variable "Average 2G proportion" (line 63). It seems that this variable corresponds to Proportion of own traffic on 2G from the August 18 presentation. The formula does not deploy a variable corresponding to Proportion of own traffic on 3G, instead the 3G calculation includes (1 – avg 2G prop). There is no reason to believe that the available capacity in 2G and 3G, relative to retail market shares and network coverage, move exactly similarly, but in opposite directions. Furthermore, the assumed average 2G proportion in the spreadsheet decrease steadily over time indicating that the 2G network of the third operator becomes increasingly more capacity constrained (e.g. 70% in 2010 and 30 % in 2016). This is implausible.

2. The coverage assumptions in the formula for calculating market shares differ from the assumed population coverage in the same model. There is a systematic downward bias. According to sheet A5_NtwDesSlct, 2G population coverage is 52%, whereas 50% is assumed in the market share formula. Furthermore there seems to be a 1 year offset in the 3G market shares. According to sheet A5, the third operator obtains 3G population coverage of 81% in 2010 and 90% in 2011, whereas the market share calculations assumes 70% in 2010 and 80% in 2011.

Furthermore, the percentage of the third operator's traffic that is on-net will be greater than its percentage of population coverage as in general usage tends to be more concentrated than population and in particular the customer acquisition efforts of the third operator are more focussed on the urban areas in which they have more on-net traffic than in uncovered areas.

Telenor urges NPT to implement market share calculations consistent with the conceptual design document. Thus (only) the following variables are taken into account when calculating third operator network market share:

· Third operator 2G coverage

· Third operator 3G coverage

· 2G – 3G migration in the market.

If NPT is of the opinion that such calculations results in too rapid growth in the wholesale market share for the third operator, compared to their expectations, then it is a indication that the assumed network roll out (coverage) for the third operator is too optimistic relative to NPT expectations.

At the meeting on 22 September, NPT/Analysys confirmed that the obvious way to calculate the wholesale market share of the third operator is to let it be a function of 2G coverage area, 3G coverage area and 2G – 3G migration (i.e. share of 2G and 3G customers). Thus, the wholesale market share of the third operator should be calculated by the following formula:

Wholesale share = retail share * [2G share * 2G coverage + 3G share * 3G coverage]

Aspects of Telenor's roaming agreement with Network Norway were also discussed.

► *Analysys Mason response*

Analysys Mason has revised the calculation of the network market share profile of the third operator; the retail market share profile of the third operator has not been altered. Also, the population coverage of the third operator is calculated separately on the *3rdOpCov* worksheet, so that it automatically applies to the network market share calculation.

The market share is now calculated based on the formula:

Retail market share × [(Proportion of handsets that are 2G) × (2G coverage)] + [(Proportion of handsets that are 3G) × (total coverage)]

The '*total coverage*' term is used in the formula for 3G handsets because 3G handsets can access both 2G and 3G coverage (where complementary).

This revised network share (v6) is higher than that applied in the draft model (v5.1) – we conclude it is broadly valid to accept that if the third operator covers x% of the Norwegian population with its network, then it should carry at least x% of the traffic offered by its subscriber base. These market shares are shown below in Figure C.2.

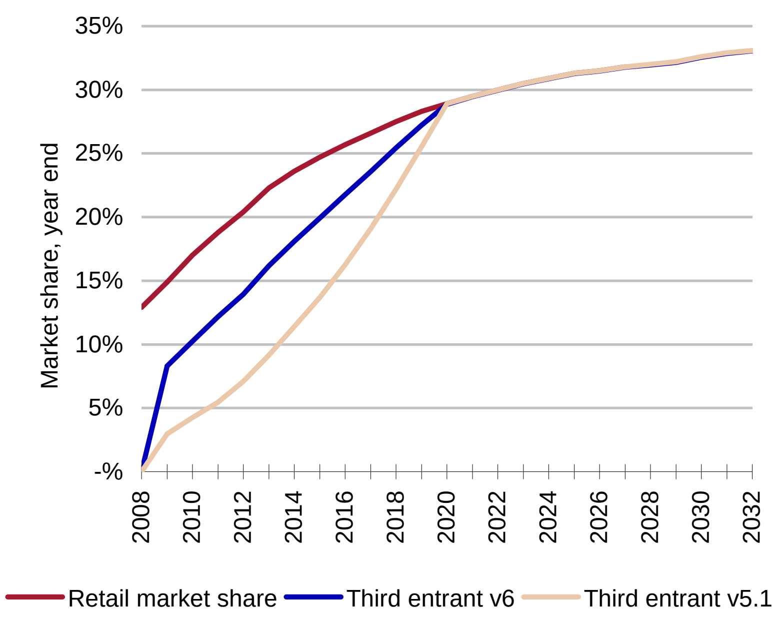


Figure C.2: Comparison of market shares for third operators [Source: Analysys Mason]

As a result of this adjustment, the third operator's network may become traffic-driven early on in its evolution, and may be required to deploy additional capacity within its coverage area.

Investments by third operator financed by current MTR margin

Network Norway and Tele2 are in the current regulatory period allowed to have a termination rate significantly above the symmetric rate of Telenor and NetCom. The rationale for this asymmetry is that it is supposed to generate revenues sufficient to cover the investment costs of building a third network with 75 % population coverage. This is explicitly stated in the Ministry's decision. As an example, consider the Network Norway appeal decision, page 21:

Based on a holistic evaluation of the situation and a weighting of interests with regard to the circumstances discussed in the chapter above, the Ministry finds it appropriate to establish as a governing objective that the higher revenue for the new network builders should basically be equivalent to the investment costs of building a third mobile network. The Ministry assumes a mobile network that is intended to cover 75 per cent of the population by the end of 2011 as is set out in Mobile Norway's business plan and which the companies have referred to in their appeals. The Ministry considers it appropriate to permit Tele2 and Network Norway a milder form of regulation up until the accumulated higher revenue matches the investment costs.

It is important to have in mind that Network Norway and Tele2 extract the higher termination revenues on a significantly larger volume than what is reflected in the third operator LRIC model since they have a considerable volume through MVNO agreements.

It follows from the Ministry's decision that the capex of a network with 75% population coverage is covered by the current termination margins. Thus, NetCom, Telenor Mobil and the fixed operators are currently financing the network rollout for a third operator with 75% population coverage. Then it is inconsistent to include this cost in the cash flow of the third operator. It is even possible to argue that the cost associated with 75% population coverage should be included in NetCom's and Telenor's cost cash flows.

Telenor is of the view that the capex associated with 75% population coverage should be disregarded in the cost cash flow of the third operator in the LRIC modelling. This can be implemented e.g. by hard coding capex unit costs to zero in the relevant period. Otherwise, players in the Norwegian market will contribute to the network roll out of the third operator twice. First by the full financing scheme due to the Ministry and then via cost allocation rules in the LRIC model where a certain part of investment costs are allocated to call termination.

► *Analysys Mason response*

The model is capable of calculating costs on a number of different bases (e.g. LRIC+, pure LRIC) as necessary for NPT's price-setting activities. The model has been extended so that variants of cost can also be calculated, as described by Telenor above. In summary, the model can now calculate the costs of the third operator in the situation where some roll-out costs are recovered elsewhere (e.g. by asymmetric termination).

We do not comment on the relevance of these results for price setting. Further details of the model modifications are provided in Annex F.2.

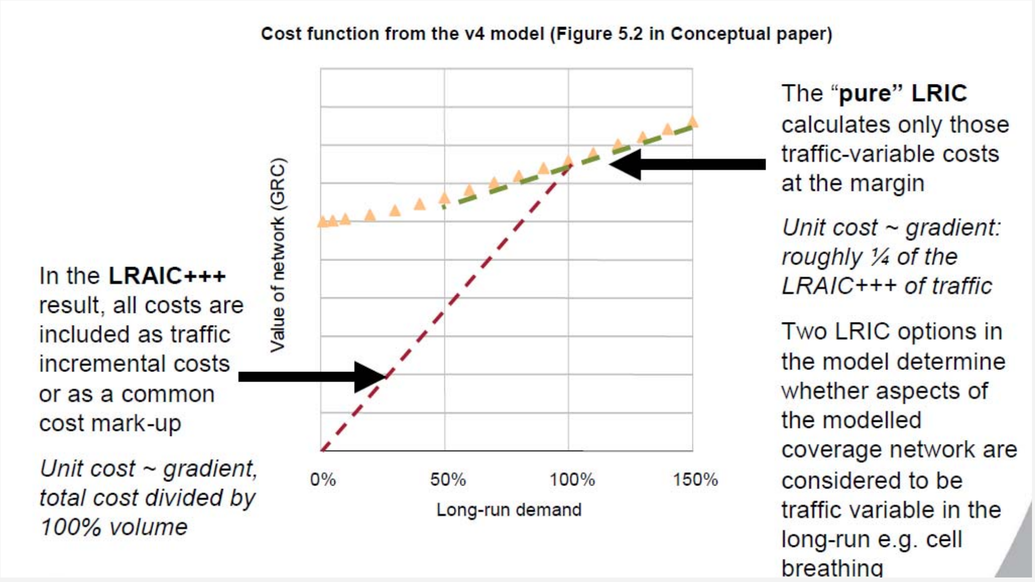
Economic depreciation

Telenor notes that NPT intends to retain the previous model's economic depreciation calculation to recover incurred network expenditures over time. In 2006 Telenor pointed out and documented that the economic depreciation calculation used in that model had comprehensive weaknesses and flaws. Nevertheless, NPT adopted this economic depreciation calculation disregarding Telenor's comments.

Telenor emphasises that the same weaknesses and flaws that were pointed out by Telenor in 2006 apply just as much to this new model. The formula for allocating costs over time proposed by NPT has some properties that are very "uneconomical", in particular the emphasis on historic events. Events in the past have an effect on the allocation of costs into the infinite future. For a more complementary description of the weaknesses and flaws of the economic depreciation formula, we refer to Telenor's written responses in 2006 and the R&D Research Note 11/2006 "A note on Economic depreciation" by Bjørn Hansen and Helene Lie Røhr.

Telenor notes that in the new model the economic depreciation calculation is used for both LRIC and pure LRIC. Telenor is somewhat taken aback by the lack of attention and reflection regarding the appropriateness of this economic depreciation used on calculation of pure LRIC. The weaknesses and flaws pointed out by Telenor apply even stronger for calculation of avoidable costs. Furthermore, assumptions underlying the calculations in the model are not consistent with the conceptual design document.

In the Analysys Mason presentation to the industry dated August 18, the following illustration is used to explain the relation between LRIC and pure LRIC:



Volume demand is measured along the horizontal axis and the value of the network in terms of gross replacement cost (GRC) is measured along the vertical axis. According to the figure explanation, unit costs (i.e. pure LRIC) is the gradient; the slope of the green dotted line. The slope of this gradient is given as the difference in gross replacement cost with and without mobile termination divided by terminated volume. This is in contrast to the approach taken in the model.

The model calculates cash flows with and without the terminated volumes. The difference (the delta) is considered as the avoidable cost cash flow. The economic depreciation algorithm is then deployed on this "delta" cash flow. This is the criticised inter-temporal average cost where historic events (i.e. way back in the nineties) typically have a significant effect on the current and future pure LRIC of termination. This is inconsistent with the conceptual design where it seems like the delta in gross replacement cost (a current cost concept) is the relevant numerator in the calculation of pure LRIC.

Furthermore, as an alternative to the method used in the model, one can calculate annual costs in the model by deploying the economic depreciation algorithm on the cash flows with and without the terminated volumes. The difference in economic annual cost is then the total cost of termination in a given year. This approach would be more in line with the illustration above, but it would be annualised economic costs along the vertical axis. According to Analysys Mason this is not a good approach because it may result in negative cost of termination in some years. This reinforces Telenor's critic of the economic depreciation algorithm used by NPT. How is it possible that economic costs in a certain year is lower with than without terminated volumes? That does not make sense. This is a strong and concrete illustration of why the depreciation algorithm is flawed.

NPT does not take account of the cost approaches in the model with LRIC and pure LRIC calculated on different bases. A reasonable alternative approach should be to use pure-LRIC as the basis for calculating LRIC, with the application of mark-ups to the pure-LRIC costs. NPT should establish LRIC costs based upon a mark-up to pure LRIC and consider this as a reasonable alternative.

► *Analysys Mason response*

We do not repeat our conclusions on the economic depreciation calculation from the previous process in 2006 and 2007. Figure 5.2 from the Conceptual Design Document was adapted for the extract returned by Telenor to illustrate the calculation of pure LRIC. The cost function refers to network GRC; however, as Telenor explains, the model does not calculate pure LRIC using GRC. Instead it uses (the difference in) the present value of network expenditures. As such, this diagram incorrectly states the cost function axis in GRC terms, which should read "*Illustrative PV of network expenditures.*"

Analysys Mason rejects Telenor's assertion on the lack of attention in this area: time has been spent understanding the interaction between economic depreciation and pure incremental costs in our mobile cost models, including NPT's v5.1. Only in simple or certain types of models (e.g. single year, static depreciation calculation) will the pure LRIC calculation of avoidable costs function in a uniform way. In models that are developed to be more complex (e.g. reflecting the actual time-evolution of operators, using non-uniform demand profiles) then calculating the avoidable cost of one particular service will require investigation.

As a result of our work in this area, we have concluded that whilst the full-time-series economic depreciation method fits well with the calculation of LRIC+++ costs over the lifetime of the modelled mobile businesses, it is less suited to calculating avoidable costs in some situations. In particular, this unsuitability arises when the avoidable increment of demand is not a uniform proportion of demand over time (as is the case with wholesale mobile termination supplied over Telenor's and NetCom's networks). As Telenor has submitted, this results in (undesirable) increased inter-temporal effects, which means that while costs may be (overall) lower without wholesale termination, cost recovery is also moved forwards/backwards in time according to the profile of residual demand applying to each network element. With data services more important in the later years, this can mean that costs without wholesale termination are postponed more into the future relative to the all-service calculation. As such, *unconstrained* pure incremental costs can be very low or negative in later years.

Therefore we believe that an alternative calculation of pure LRIC is required. We adopted an alternative approach in the draft v5.1 cost model issued to industry parties. In this situation, the pure LRIC is calculated from the (present value) difference in network expenditures arising from the removal of the wholesale termination volume, *constrained* over time so that the underlying equipment price trends apply also to the pure LRIC components of cost (just as these price trends apply to the LRIC+++ components of cost). We consider it reasonable that the calculated pure LRIC is directly constrained by the equipment price trends for the same reason that the LRIC+++

should reflect the (declining) underlying costs of supporting traffic volumes with network equipment.

It is plausible (counter to Telenor's suggestion above) that the removal of mobile termination volumes causes certain costs to be higher than otherwise: as an example, we could consider radio sites and ancillary costs, which have an increasing site cost trend (as in the revised v6 model). Removing termination volumes may result in some sites being deployed later in time – with rising site costs, it could indeed appear (in particular years) that costs were higher without termination. However, over the lifetime of the network, as in our pure LRIC calculation, this effect does not dominate the overall cost calculation and the pure LRIC is calculated to be a small (positive) value per minute when compared to the LRIC+++.

As a cross-check to our calculated pure LRIC for Telenor, we have estimated a pure incremental cost result by:

- starting with Telenor's LRIC+++ of mobile termination per minute
- removing the +++ mark-ups for overheads, location updates and network common costs
- removing the contribution to the remaining LRIC of network elements that are assumed to be insensitive to traffic volumes (e.g. core switches and inter-switch transmission)
- comparing the resulting sub-components of LRIC with the pure LRIC calculated by our method.

This comparison (chart provided in Annex D) shows two important conclusions:

- the **level of cost per minute** calculated by our pure LRIC method **is similar** to that obtained by starting from the (accepted) LRIC+++ result and removing common and traffic-insensitive cost components
- the **trend over time** in the pure LRIC cost **is similar** to that obtained by starting from the LRIC+++.

Consequently, we believe that our primary method of calculating the pure LRIC is reasonable and justified, and a suitable basis on which NPT could consider setting pure-LRIC-based rate regulation.

Third operator LRIC relative to roaming cost

The third operator has two basis ways of producing mobile services, either it can build a mobile network and produce the traffic itself, or it can buy traffic within a national roaming agreement. The third operator will choose between these two options, and combine these options in a way that economize the corporate profitability.

This principle will lead to the fact that the third operator will seek to build own network in areas where the traffic volume is sufficient to bring the unit cost below their alternative cost. The alternative cost is given by the prices in the national roaming agreement. The prices today in the national roaming agreement between Telenor and Network Norway are far below the HCA cost by services in 2009 and the years ahead. This seems strange all the time the third operator is expected to economize the corporate profitability. Telenor encourage NPT to investigate these circumstances and ensure that assumptions in the new LRIC model are in accordance with operators expected actions in the market.

► *Analysys Mason response*

We agree with Telenor's view that it is important to compare the costs calculated for the third network with the corresponding prices that might be available through national roaming agreements.

However, it is necessary to compare these costs across all services (voice, SMS and data), since we expect that there may be incentives for host operators to agree higher/lower prices for particular services, and as Telenor explain under the heading of "data services," it is evident that some retail services provide more margin over the network cost than other services. Thus it is relevant to compare the third operator results across all of the services carried. As an example, voice prices may appear closely comparable (indicating a relative balance for build or buy decisions within a third entrant's business) whereas SMS service prices may be unprofitable for a nationwide provider relying on national roaming for SMS.

A chart comparing the third operator's costs and Telenor's national roaming prices is provided in Annex D.

Costs related to frequencies

It seems that 3G licence fee payments not are taken into account in the new LRIC model. Telenor invested 200 million NOK for the 3G licence in 2000, and we assume that renewals of the licence will include new payments by Telenor in the future. As far as we understand the new LRIC model these costs are not included in the model.

The LRIC calculation assumes that all traffic migrates to 3G by 2020, i.e. the 2G network are being closed from the same point in time, and that payment of 2G annual licence fees ceases in 2020. But coverage by UMTS 900 is assumed from 2011 as traffic is migrated off 2G and spectrum is re-farmed. This means that the 900 frequencies are utilized after 2020, and that both annual licence fees and renewal costs for the frequencies should be included in the new model.

► *Analysys Mason response*

Regarding the issue of 3G licence fee payments, a new asset called "3G licence fee payments" has been included in the model. This asset has an associated capex of NOK200 million, first paid in 2002 and every 12 years thereafter. In real terms, licence fees are assumed to be constant.

Regarding the issue of 2G licence fees, the "2G licence fee payments" and "2G annual licence fees" assets have had their fees split up to reflect costs related to GSM and to UMTS 900:

- Fees (both one-off and annual) estimated to correspond to a 2×5MHz carrier have been transferred from the 2G licence assets to the 3G licence equivalents in the relevant year. These costs are then recovered over the lifetime of the 3G network
- Fees for the remaining GSM spectrum are only charged for and recovered during the lifetime of the GSM network.

The "3G licence fee payments," "3G annual licence fees" and "2G annual licence fees" assets previously had 'asset smoothing' applied on the *FullNw* worksheet. This led to an underestimation of the licence fees over time. Asset smoothing has been switched off for these three assets, and therefore periodic licence fees are re-incurred in full every 12 years.

Capacity costs

The model provides for additional capacity first by increasing TRX's, sectorisation and then by adding new sites. However, each of these is at a uniform cost (i.e. so each new site costs the same as the previous new site). However, the real effect of traffic concentration is to require new capacity and sites in areas where it is increasingly difficult to find appropriate sites and for which the costs increase significantly. The impact of these real-world constraints are that the additional cost of new sites is increasing, and the effective capacity provided by those sites is falling. Telenor expects that this will be taken into account in the new model.

► *Analysys Mason response*

In response to both this comment and the one below, we have included a real-terms positive cost trend for the radio assets in the model. This will reflect the fact that capacity-driven sites acquired in later years have a higher real-terms cost than those in earlier years.

Whilst we have implemented an increasing site cost trend, we have not reflected the suggestion that "the effective capacity provided by those sites is falling". While site availability may be reducing, we believe there is no strong reason to assume that sites installed for capacity have materially reducing capacity. For example, radio equipments such as BTS and TRX (900 and 1800, dual band equipment and antennas, etc.) are becoming smaller and antenna technology is improving all the time (particularly for environmentally-sensitive areas and shared sites), and so there should not be significant capacity constraints to later sites caused by the limitations to site availability.

Asset price trends

All the asset price trends used in the model are either flat or negative. In Telenor's view is this not a good reflection of reality, as civil works makes up a significant part of network assets, and we would expect these to have a positive price trend. Telenor anticipates that NPT will change the inputs in the model and introduce non-flat asset trends for labour-intensive assets.

Telenor has not sufficient detailed information in the accounting systems to illustrate that there are increasing costs of finding new capacity sites. Regardless of information, this is however a valid point. Capacity sites have to be located at ever more specific geographic locations in order to function optimally in combination with the existing network topology. This leads to both cost and capability effects; owners of potential capacity site locations are in a very strong bargaining position towards mobile operators and can demand higher rentals and compromises in site design and location limit the extent to which these sites can deliver their theoretical capacity.

According to Norwegian Statistics there has been a positive trend on labour cost related to road construction: http://www.ssb.no/english/subjects/08/02/30/bkianl_en/tab-2009-08-21-01-en.html. This information supports Telenor's view that labour-intensive assets in the model should have a positive price trend.

► *Analysys Mason response*

In addition to the data from Statistics Norway on the construction cost index for road constructions indicated above, we have also identified another set of indices on the construction costs for works in offices and commercial buildings[8] between 2000 and the present. In particular, the latter provides an indication of the increase in costs for administrative expenses, labour costs and materials relevant to civil, ancillary and utility works. The compound annual growth rate (CAGR) of these indices, in real terms, are summarised below in Figure C.3:

Source	*Index*	*CAGR*
Road constructions	Total costs	2.8%
Works in commercial buildings	Total costs	3.4%
	Administrative expenses	1.8%
	Labour costs	2.2%
	Materials	4.3%

Figure C.3: CAGR in real terms between 2000 and 2009 by index [Source: Analysys Mason calculated from Statistics Norway]

Based on these trends, we have therefore amended the capex and opex cost trends in the model as follows:

- Site acquisition and civil works now have a capex trend of +2% (based on the trend for labour and administrative costs)
- Radio ancillary equipment now have a capex trend of +4% (based on the cost trend of materials)
- Radio sites now have an opex trend of +2% (based on the cost trend of labour)
- Switching sites also have a capex and an opex trend of +2%.

8 http://www.ssb.no/bkiror_en/

Business overheads have not been adjusted on the basis that the mobile operators have significant incentives to maintain their own level of efficiencies in this part of their business.

These trends are set in place for the period 2000–2013 in the model.

Costs related to decommissioning of 2G

Telenor is not convinced that costs related to decommissioning of 2G are taken into account in an adequate way in the LRIC calculations, and invite NPT to explain this relation.

► *Analysys Mason response*

This issue was discussed in the previous modelling project: Telenor has not advanced further information in addition to restating its opinion. Telenor has, however, supplied some decommissioning costs for radio sites (see Annex D), which indicate that the cost to decommission a site is a minor proportion of the modelled cost to acquire the site in the first place.

Consequently, we still believe the model contains sufficient costs to account for any decommissioning costs faced by Telenor. As before, the purchasing algorithms of the model continue to invest in the **periodic** replacement and operating expenditures of expiring network elements in all years of the modelled GSM network, including in the later years when the network is planned to be decommissioned (the model invests over NOK1billion during 2018, 2019 and 2020 in dedicated GSM equipment, all of which will be removed from the network by the middle/end of 2020). This continued replacement expenditure for new assets is unlikely to occur in a real network facing decommissioning, and therefore is retained in the model to reflect any decommissioning costs.

MVNO

Telenor is surprised at the high level of LRIC and pure LRIC calculated for the generic MVNO. Telenor invites NPT to explain these calculations more explicitly.

► *Analysys Mason response*

The 'generic MVNO' has a market profile set up to acquire 5% of the market in all years and was shared with all parties, but primarily for Telenor and NetCom to transparently observe the MVNO calculations. It is not the MVNO equivalent of the third-operator calculation and is for illustrative purposes only. The pure LRIC calculation for the MVNO results in a very low cost (close to zero) because the model assumes a single mobile switch that is not modelled to be sensitive to MVNO traffic volumes. We have not examined in detail whether the MVNO switch infrastructure is a fixed cost (as the model assumes) or more variable in the long run (which would mean a higher MVNO pure LRIC would be calculated, closer to the LRIC).

C.2 NetCom

SCENARIO ANALYSES

We refer to the invitation, third paragraph, saying that NPT will carry out scenario analyses in which the third network operator to a different extent establishes a separate network in parts of the country and makes use of national roaming in mobile networks to obtain coverage beyond their own network. It also appears that NPT has made computations showing that the costs with resting on national roaming will not be significantly higher than the costs of version 5.1 for the third network operator.

► *Analysys Mason response*

Computations involving national roaming prices have not been issued to industry parties for consultation due to the confidential nature of national roaming agreements. The cost calculations for the third network operator indicate that two results for voice traffic are broadly comparable:

- the costs of the third operator with full national coverage
- the costs of the third operator with sub-national coverage blended with current national roaming prices.

This indicates that the modelled third operator is not operating outside of reasonable economic boundaries with respect to voice costs/prices. The comparison for SMS and data services suggests the same conclusion. The basis for setting wholesale termination rates will be the definitive results from the issued cost model; scenarios and other tests carried out by NPT and Analysys Mason serve to validate the reasonableness of the calculation, but do not form a basis for setting prices. As such, it is considered unnecessary and distracting to submit various permutations, scenarios and options for industry comment.

C.3 TDC

Market share

The model has provided for a market share of the generic MVNO at 5% of the Norwegian mobile market. Market share is one of the major parameters for defining the cost for a mobile company. TDC would like to underline that we are and will stay only at the business market. It is not a part of our strategy to move over to the consumer market. Hence our number of subscribers will be lower than a full scale MVNO. We have attached a updated outline of our marked share.

► *Analysys Mason response*

This market share has been implemented in the TDC model on the *M6* worksheet.

MVNO cost Analysys Mason has set up a list for us showing the cost elements included in the model. In addition to the elements on this list the following elements should be added: MSC, MSC ports, Backbone links, Business overhead mark up.

► *Analysys Mason response*

The generic MVNO calculation is modelled with an MSS and MGW pair rather than the MSC architecture, i.e. only one of these configurations is required in the long term. With regard to backbone links, MVNOs do not need these links in their architecture for the purposes of MVNO network activities, given their small, centralised network switch. As all telecoms providers interconnect in Oslo, and all mobile networks have main switches in Oslo, there is no requirement for MVNO-host traffic exchange to require a national backbone transmission network. We have re-reconciled the MVNO costs to include relevant business overhead assets.

Depreciation lifetime On the basis of the actual economic lifetime of the equipment in our network the time of depreciation must be shorter. In Denmark the depreciation time is shorter than what our model now shows, and we request that the model is updated with depreciation values more like HCA.

► *Analysys Mason response*

Figure C.7 below summarises the asset lifetimes provided in the public versions of the LRIC models built by Analysys Mason for PTS[9] in Sweden and NITA[10] in Denmark, as well those in the v6 mobile LRIC model for NPT in Norway.

9 http://www.pts.se/upload/Ovrigt/Tele/Bransch/Kalkylarbete%20mobilnät/Final-PTS-model-public-version-020608.zip

10 http://en.itst.dk/interconnection-and-consumer-protection/lraic/filarkiv-lraic/lraic-pa-mobil/horing-4-september-2007/Modeludkast%20v.1.1.zip

Norway	*years*	*Denmark*	*years*	*Sweden*	*years*
Own tower acquisition, civils	15	Owned macro site	25	Site acquisition, preparation and lease	25
Third-party civils, site ancillary	10	Third-party site	20		
2G/3G cells, TRX/channel kit, DXX, HSDPA upgrades	8	GSM BTS, TRX, NodeB, carriers, channel kit	10	2G/3G cells, TRX/channel kit	10
Other backhaul links	8	Backhaul links, access point	10	Backhaul links/upgrades	10
BSC/RNC base unit, ports	8	BSC/RNC base unit, ports	10	BSC/RNC base unit, ports	10
2G MSC, 3G MSS, 3G MGW, TSCs, ports	8	2G MSC, 3G MSS, 3G MGW, associated ports	10	2G MSC, 3G MSS/MGW, ports	10
BSC/MSC sites	20	MSC/remote BSC sites	25	MSC sites	25
MSC/MSS software	3	MSC/MSS/NMS software	5	2G. 3G MSC software	5, 7
VMS, HLR, AUC, EIR, SMSC, billing system	6	IN, VMS, HLR, AUC, EIR, SMSC, MMSC, MNP	8	VMS, HLR equipment, SMSC, IP transmission, network management centre	10
TSCs	20	Transit switches	10	Tandem/transit	10
PCU, GGSN, SGSN, packet data routers	8	GPRS/EDGE-PCU, GGSN, SGSN	10	PCU, GGSN, SGSN	10
IN, network management system	annual capex	Billing system, network management system hardware, content platform	8	Interconnect interface, switching support plant, switch building preparation	10
HLR software	6			HLR software	2

Figure C.4: Asset lifetimes (years) in public Scandinavian LRIC models [Source: Regulator websites]

The most material factors for the cost of voice termination are in the lifetimes for the radio sites, which are 5–10 years shorter in the current Norwegian model, and in the lifetimes for major mobile network BTS, NodeB, BSC, RNC and MSC equipment (around 8 years in the Norwegian model compared to around 10 years in the other two models).

These comparisons indicate that the depreciation period for assets in the NPT model are conservative when compared with the other Scandinavian jurisdictions, and there is no indication that additional reduction in lifetimes would be appropriate.

Based on a consideration of a range of factors (including two topics related to site replacement discussed confidentially with Telenor), NPT also considers it appropriate and broadly conservative to maintain its existing site lifetimes of 15 years for owned sites and 10 years for third-party sites.

C.4 Ventelo

Mobile broadband:

Telenor has 233.000 mobile broadband subscribers and a market share of 59% according to Q2 2009 financial reports. This implies a total market size of 392.000 mobile broadband subscribers. The forecast in the model is too low as it shows 400.000 subscribers by year end 2009. We estimate the volume for 2009 year end to state 500.000 subscribers. We also believe the saturation level of the market will exceed 1.500.000 subscribers.

► *Analysys Mason response*

The NPT market data for mid-year 2009 is 380 000 subscribers, an increase of almost 120 000 subscribers since the end of 2008. Therefore, a year-end 2009 subscriber base of 500 000 appears reasonable and we have revised our forecast accordingly. We have compared our penetration forecast with that developed by Analysys Research[11] and it appears to be broadly consistent, as illustrated below in Figure C.5. Therefore, we have kept the modelled saturation level for mobile broadband at 20% of the population.

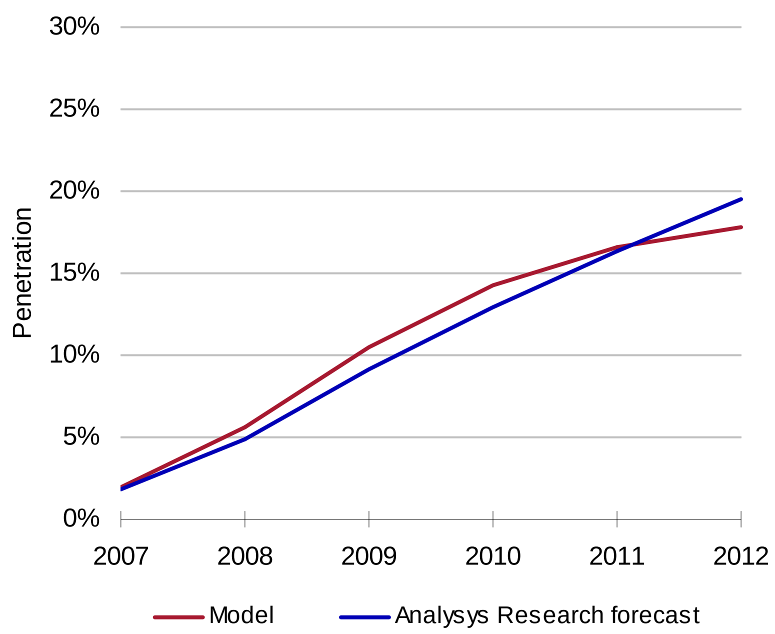


Figure C.5: Mobile broadband penetration of population in Norway [Source: Analysys Research]

In addition, we assume that the average usage for mobile broadband is too conservative in the model. Our conclusion; either the base for pricing of voice is too high or the base for pricing mobile broadband too low.

11 Mobile broadband in Europe: forecasts and analysis 2009–2014, May 2009

► *Analysys Mason response*

We have updated the mobile broadband traffic per user values using NPT's mid-year 2009 market information. In our view, this update indicates that our projection of 2000 HSDPA megabytes (and 500 HSUPA megabytes) per user per month may slightly overstate broadband volumes in the near future. The forecasts in the two models are illustrated below in Figure C.6, with the forecast now increasing to only 1600MB per subscriber per month (plus 400 HSUPA megabytes).

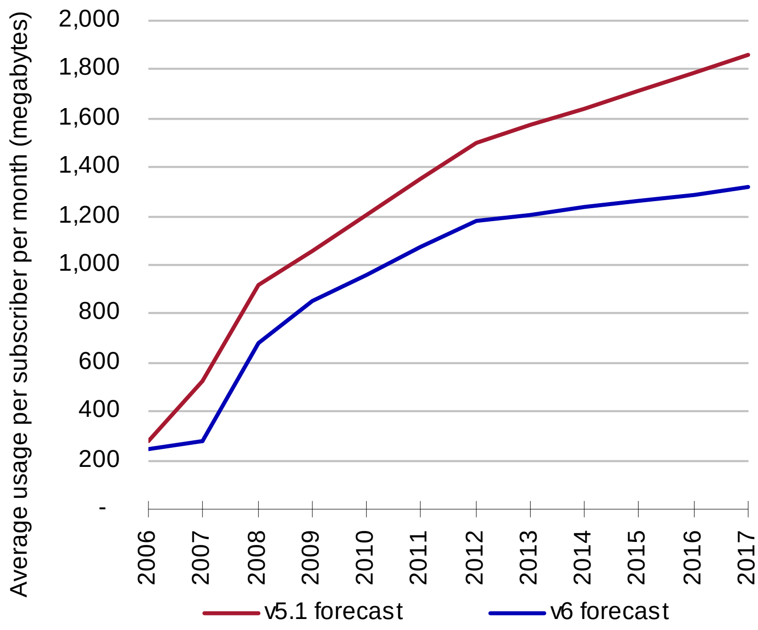


Figure C.6: Market average high-speed data usage per subscriber per month forecast in the version 5.1 and version 6 models, excluding Nordisk/ICE [Source: Analysys Mason]

The NPT market data indicates that average usage per subscriber has not changed significantly when considered in six-month periods since 2007, as shown below in Figure C.7. In particular, growth in total usage is being driven more heavily by the increase in subscribers rather than increase in usage per subscriber. This has been reflected in the model forecasts, with a lower growth usage forecast and an accelerated take-up in devices.

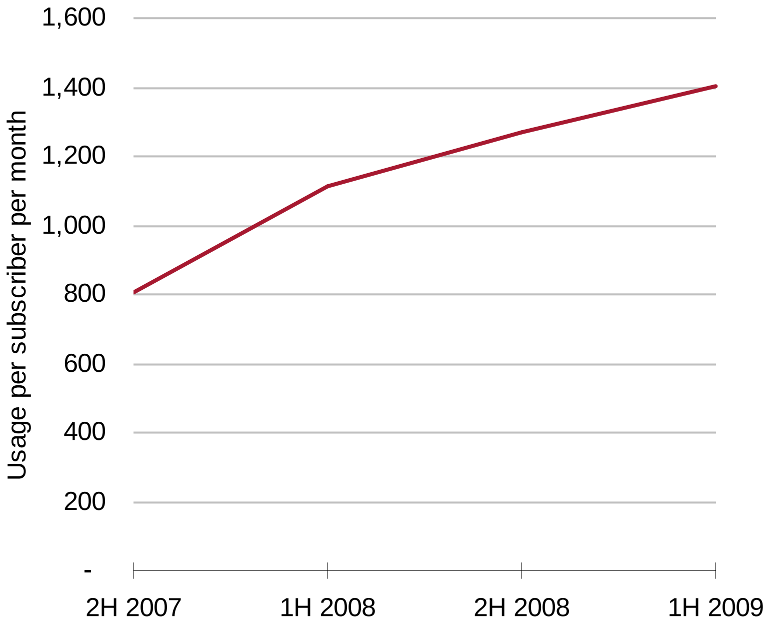


Figure C.7: Market average high-speed data usage per subscriber per month [Source: NPT market data]

We have compared our forecasts of mobile traffic with those from Analysys Research[12], as illustrated below.

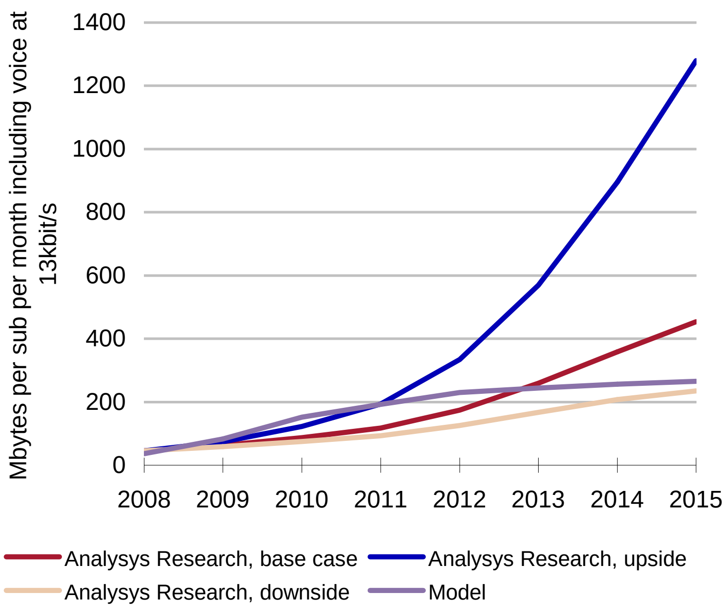


Figure C.8: Average data usage per subscriber per month in Western Europe versus the model forecast [Source: Analysys Research]

This shows that our average usage in the model is conservative compared to other forecasts. While significantly higher forecasts for traffic can be envisaged, these amounts of data traffic for all subscribers would likely require LTE deployments.

12 Wireless network traffic forecasts, October 2008

Annex D: Operator submissions in developing v6 (Telenor confidential)

See separate file.

Annex E: Operator submissions in developing v6 (Ventelo confidential)

See separate file.

Annex F: Model adjustments from v5.1 to v6

In this section, we describe the adjustments made to the structural calculations of the v5.1 model, including the correction of some minor aspects of the model.

F.1 Model corrections

Licence payments

The formula for future 2G licence renewal fees on the *NtwDesBase* worksheet has been corrected to remove the incorrect inflation uplift.

A 900MHz licence fee for the third operator has been included. This fee is assumed to be NOK100 million paid in 2008 and renewed every 12 years. The licence fee is paid in 2008 and is a "shared 2G and 3G" asset for the third operator.

A new asset called "3G licence fee payments" has also been included in the model, and treated as a common cost. This asset has an associated capex of NOK200 million for both Telenor and NetCom, first paid in 2002 and every 12 years thereafter. These fees are provided in the *NtwDesBase* worksheet. In real terms, licence fees are assumed to be constant.

The "2G licence fee payments" and "2G annual licence fees" assets have had their equivalent fees split into two parts, so that the fees related to the spectrum used for GSM and for UMTS 900 are recovered separately:

- fees (both one-off and annual) equivalent to a 2×5MHz carrier have been transferred from the 2G licence assets to the 3G licence on the relevant date. These costs are recovered over the lifetime of the 3G network
- fees (both one-off and annual) for the remaining GSM spectrum are only charged for and recovered during the lifetime of the GSM network.

The "3G licence fee payments," "3G annual licence fees" and "2G annual licence fees" assets previously had 'asset smoothing' applied on the *FullNw* worksheet. This led to an underestimation of the licence fees over time. Asset smoothing has been switched off for these three assets so that licence fees are re-incurred in full according to their periodic input. In addition, the "2G licence fee payments" and "3G licence fee payments" fees are now cumulated (in real terms) prior to being entered into the *FullNw* worksheet. This ensures that the correct level of periodic fees appear in the correct years in the *NwDeploy* worksheet.

GSM900 channel availability

On the *NtwDesBase* worksheet, the 900MHz channels available for Telenor and NetCom are reduced after 2011, to reflect their transfer to UMTS 900.

Calculation of R99 channels per carrier per sector

We have corrected the formula on the *NwDes* worksheet that calculates the number of R99 channels per carrier per sector that are available on both the 2100MHz carriers and 900MHz carriers. In relation to this correction, we have also amended:

- the related calculation of the number of 2100MHz carriers
- inputs related to minimum channel deployments for NodeBs on the *NtwDesBase* worksheet.

Routeing factors

On the *RF* worksheet:

- the measures for MGW STM1 ports facing RNC, circuit layer RNC-MGW STM1 backhaul links and circuit layer RNC-MGW STM1 kilometres have been revised to be "3G backhaul 16kbit/s voice circuits"
- the measure for RNC-MSC/MSS STM1 backhaul links and RNC-MSC/MSS STM1 kilometres has been revised to be "3G backhaul 16kbit/s voice+data channels"
- the routeing factors for the SMSC have been corrected to be for the 2G and 3G SMS services only
- the routeing factors for the "Site licence fees annual opex (per site)" have been corrected to include 3G services as well.

Calculation of LRIC+++

On the *LRIC* worksheet, the calculation of total network costs for the derivation of the LRIC+++ has been amended to ensure that only network costs are captured.

Third-operator market share profile

The market share for the third operator in the base case is now calculated as the retail market share multiplied by the proportion of subscribers that receive service on its own network in that year. The latter is calculated as:

[(Proportion of handsets that are 2G) × (2G coverage)] + [(Proportion of handsets that are 3G) × (total coverage)].

National roaming minutes

The original model did not include the national roaming minutes for 2008 from the operator submissions. In order to accommodate these minutes, we have defined four new services:

- incoming 2G NR voice in 2008
- outgoing 2G NR voice in 2008
- incoming 3G NR voice in 2008
- outgoing 3G NR voice in 2008.

These services only have volumes in 2008, according to the submitted operator data. We have defined routeing factors for these services on the *RF* and *DemCalc* worksheets to allocate some costs to this traffic in 2008. Traffic volumes from 2009 onwards are assumed – through the forecast market shares – to implicitly include national roaming volumes.

Software upgrades for HSDPA7.2/14.4

On the *NwDes* worksheet, we have amended the number of sites with *HSDPA3.6 upgraded to HSDPA7.2* and *HSDPA7.2 upgraded to HSDPA14.4* to only be driven by 2100MHz sites rather than UMTS 900MHz sites as well. This is to reflect the fact that these upgrades cannot be served by the single 900MHz carrier available to each operator in the model.

Third operator RNC mapping

The mapping of 3G sites to RNC locations has been revised. In the v5.1 model it was assumed that all NodeBs outside of Fylker with RNCs were hosted in Oslo. This mapping has been refined so that NodeB's in each Fylke are hosted on the nearest RNC.

3G traffic profile by Fylke for Telenor and NetCom

Current distributions of 3G traffic by Fylke for Telenor and NetCom appear to reflect short-term coverage and usage effects. Therefore, the 3G traffic distributions for these two operators have been calculated on sheet *CovDemIn* using each operator's mature 2G distribution.

HSUPA subscribers loading SGSN and GGSN

SGSN and GGSN units are now loaded with GPRS, R99 and HSDPA subscribers only (removing double-counted HSUPA subscribers).

F.2 Revised input parameters and other decisions

Market saturation

The mobile market saturation on the *M6* worksheet has been revised to 115% from 110%. This adjustment has been applied because NPT market information for end-2008 did not separate out mobile broadband subscribers, and therefore gave rise to an erroneous projection of a constant penetration rate around 110%. The penetration rate of 115% is the same as the final v4 cost model.

High-speed data subscriber market shares

Based on NPT market data, the high-speed data subscriber market share of Nordisk/ICE has been reduced from 25% in the long term to 5% in the long term, and the other operators have had their market share profiles revised accordingly.

Data usage

Based on NPT market data and operator data, the usage per subscriber per month of both low-speed and high-speed data has been adjusted for Telenor from 2006 onwards, for NetCom from 2006 onwards, and for the third operator from 2008 onwards.

Cell radii

The UMTS 2100MHz cell radius for Rogaland for the third operator has been reduced to better reflect those of the other two operators.

Proportion of NodeBs with HSDPA7.2 activated

For the six Fylker to which HSDPA 7.2 is deployed, the proportion of 33% of NodeBs upgraded to HSDPA7.2 is now scaled by the same multipliers used to derive the traffic distribution, to reflect the modelled concentration of traffic in the four main cities in Norway. Therefore, the proportions 2100MHz sites now upgraded with HSPA7.2 are now:

- 99% for Oslo
- 66% for Hordaland, Rogaland and Sør-Trøndelag
- 33% for Akershus and Vestfold (i.e. unchanged from the draft model).

Third operator network

We have made the following changes to the third operator network:

- [*NtwDesBase*] The GSM in-fill radius as a proportion of the wide-area radius has been revised to be 50% in all years, in order to be consistent with the inputs of the other operators
- [*NtwDesBase*] The 2G wide-area coverage in the six most urban Fylker has been revised to be completed in 2008. However, the extent of coverage has been reduced to be 80% of that calculated for the 2100MHz network, in order to correctly reflect the 80:20 proportion for GSM wide-area and GSM in-fill coverage
- [*NtwDesBase*] The 2G in-fill coverage has been revised to extend to 25% of the wide-area coverage, in order to correctly reflect the 80:20 proportion for GSM wide-area and GSM in-fill coverage
- [*M6*] The inputs to the migration profile (in 2009, 2012, 2016 and 2020) have been changed to 75%, 60%, 30% and 0% respectively.

As a result, the 2G coverage and 2100MHz coverage are the same in the six main Fylker. With 900MHz 3G coverage used elsewhere, this means that the 2×5MHz spectrum allocation of 900MHz is never used for both the 2G and 3G networks in the same place.

Pure LRIC calculation

In addition to the existing calculation of pure LRIC, an alternative methodology has been implemented (as suggested by one operator), which calculates the difference of the economic costs with and without terminated traffic. The results of this alternative calculation are displayed below the existing methodology on the *Ctrl* worksheet as "Pure LRIC – difference of Economic Depreciation of cashflows".

Blended LRIC

On the *Ctrl* worksheet, the model now outputs a blended LRIC as well as a blended LRIC+ and LRIC+++.

Leased NodeB-RNC backhaul links (E1)

The v5.1 model assumed that multiple distinct E1s were deployed to the NodeBs as HSDPA upgrades were deployed. The costs of these assets were recovered across all traffic. In reality, the first E1 is typically deployed as backhaul for voice and R99 data traffic (in the first WCDMA carrier) and subsequent E1 capacity upgrades should only be recovered by HSDPA traffic. To reflect this, we have moved these backhaul upgrade costs to the HSDPA software upgrade assets, by:

- renaming "Leased NodeB-RNC backhaul links (E1)" to "Leased NodeB-RNC first E1 for voice+R99" on the *L* worksheet
- renaming the named range "Backhaul.LLE1.Total" on the *NwDes* worksheet to "nodeB.RNC.first.E1.voice.R99.Total.3G". The formulae in the cells in this named range now derive the number of NodeBs in the network, rather than the number of separate backhaul E1s required
- revising the routeing factors for "Leased NodeB-RNC first E1 for voice+R99" on the *RF* worksheet to exclude HSDPA
- renaming the three HSDPA software assets on the *L* worksheet to indicate that they include the additional backhaul upgrades required
- adding in additional connection costs (capex) and opex to these three HSDPA assets to reflect the costs of the backhaul upgrades required, based on Telenor's leased line price list.

Unit costs

We have standardised the costs of BTS, MSCs and MSC ports across all three modelled network operators on the *CostBase* worksheet. We have also increased the cost of the third operator's "2G-only owned tower site acquisition and civil works" asset to be more consistent with the equivalent costs of the other two operators.

Optional capex adjustment

An array of multipliers have been included for each operator on a new worksheet called *CapexAdj*. These inputs (between 0 and 1) scale the capex for a particular asset in a particular year. This adjustment can be completely ignored by selecting "Scenario 0: Remove no capex" in cell D13 on the *Ctrl* worksheet. The other options for this cell allow varying degrees of capex to be excluded from the cost base of the modelled operator.

These inputs have been populated for the third operator, allowing a certain amount of network coverage investments to be excluded from the network costs of the calculation and funded instead through another means (e.g. asymmetric termination rates).

Access price per minute On the *NtwDesBase* worksheet, there is a new table that allows an input of the direct access price per terminated minute over time. This price input can then be added to any of the output lines (in nominal NOK) on the *Ctrl* worksheet. This addition can be completely switched off by setting all cells C80:C90 on the *Ctrl* worksheet to zero.

Capex cost trends On the *CostTrends* worksheet, the "site_acquisition" capex cost trend has been revised to +2% for the period 2000–2013 and this trends is applied to the six radio site acquisition assets (owned tower acquisition/civil works and third-party civil works, split into 2G-only, 3G-only and 2G/3G subtypes). An "Ancillary_materials" capex cost trend has also been created which is 0% up to 2000, +4% up to 2013 and 0% thereafter. This trend is applied to the six corresponding radio site ancillary assets, as well as BSC and MSC sites.

Opex cost trends On the *CostTrends* worksheet, the opex cost trends for both radio site and radio ancillary assets has been revised to +2% for the period 2000–2013.

DXX network Inputs related to the dimensioning of the DXX network for one of the operators have been adjusted on the *NtwDesBase* worksheet.

TDC market share The TDC market share has been updated based on submitted data.

MVNO cost bases The cost bases of the MVNOs have been re-reconciled to include business overheads and exclude MVNO access fees. This has required the adjustment of unit opex costs for certain assets. These adjustments have then also been applied to the generic MVNO.

Annex G: Operator submissions to v6 and model adjustments in developing v7.1 (public)

After NPT's public consultation in early 2010, NPT received some comments on the v6 model, provided by CSMG on behalf of Tele2 and Network Norway. This report makes three separate claims:

- deployment costs for the third operator network are too low (due to a number of possible factors)
- a number of assumptions and projections (related to market share, voice usage and data traffic) should be revised
- some costs required to move from MVNO to MNO have been overlooked.

CSMG claims that for each of these points, addressing the issue in the model would increase the resulting total investment costs and/or the LRIC of voice termination. However, CSMG does not submit an overall cost result if all of its suggestions are applied simultaneously. We discuss CSMG's suggestions in detail in this annex; our conclusions may be summarised as follows:

- There may be a reasonable case for adjusting the deployment assumptions for the third operator's network to take account of **a 3G network of sufficient quality to provide indoor coverage for the initial population** covered by Mobile Norway.
- In conjunction with this, the operator should carry the majority of its traffic on its 3G network, and therefore **the third operator does not have a "classical" migration profile of traffic** from 2G to 3G.
- **Some relatively minor adjustments to the market projection** can be applied, improving accuracy in subscribers and market share at end-2009, incoming traffic volumes, and **reflecting a faster growth but more conservative long-term position on mobile data traffic**.
- **Two further modifications to the third operator network** would bring it closer into line with the current situation (moving the 3G rollout to 2010-2011, adjusting the market allocation of one network party).

NPT finds it reasonable to incorporate these modifications to version 6 of the model. This results in a revised calculation, which we refer to as version 7.1 of the model.

A public version of CSMG's report is available on NPT's website. The sections below provide a public response to CSMG's paper, including a summary of adjustments made in developing the v7.1 model, as follows:

- Annex G.1 discusses the deployment costs for the third operator
- Annex G.2 investigates the input assumptions
- Annex G.3 considers migration costs
- Annex G.4 lists the small number of changes applied to the v6 model to arrive at v7.1.

Some figures are not for public disclosure and marked with [X].

G.1 Deployment costs for the third operator

In this section we discuss the issues raised by CSMG, undertake some investigations in the v6 model, and outline possible solutions.

G.1.1 Issues raised

The third operator network calculated in the model reflects:

- 1209 radio sites at mid 2009 for 75% population coverage
- NOK1.44 billion in capital investment for non-MVNO investments.

CSMG submits that this network differs significantly from that of the Mobile Norway network plan, which has a higher radio site deployment for a similar level of population coverage, and greater capital investment. CSMG suggests the following possible reasons.

► *Wide-area coverage parameters in the cost model are determined by outdoor signal strength simulations, whereas for an operator deploying a coverage network today, good indoor coverage is required.*

Today's indoor coverage levels achieved by Telenor and NetCom – based on an initial deployment intended for outdoor coverage – have in effect developed over many years of increasing GSM traffic. Therefore applying the same outdoor coverage requirements may not reflect the network which Mobile Norway is intending to deploy. Also, it seems reasonable that (as suggested by CSMG) that reliance (or preferably from a commercial perspective, partial reliance) on national roaming complicates the network requirements of the third operator. This is because it must balance its own coverage extent and quality investments (in 2G and/or 3G equipment) and corresponding traffic against factors including:

- the availability of national roaming (2G and/or 3G) charged on a per-minute basis
- technical and service implications of national roaming handovers.

► *The coverage algorithm uses a continuous table of area to population by Fylke, and it is not clear whether the model accounts for the scattered pockets of population over various locations*

The model uses a continuous parameterised distribution of population by area to identify the relationship between the measures of area and population covered; this distribution has been obtained from actual Norwegian population data by Fylke. The cell radii used to determine GSM and UMTS coverage by Fylke have been derived using NPT's coverage simulations. These simulations take a detailed radio planning view of network coverage (performed for GSM and UMTS networks for Telenor, NetCom and Mobile Norway) and include the number of radio sites used in the simulation. However, the simulation data used in the setting up of the model was based primarily on the existing operators' mature networks (e.g. over 75% population coverage).

Figure G.1 shows the population-to-area relationship in the model, plus a number of points obtained from operator data (obscured for reasons of confidentiality).

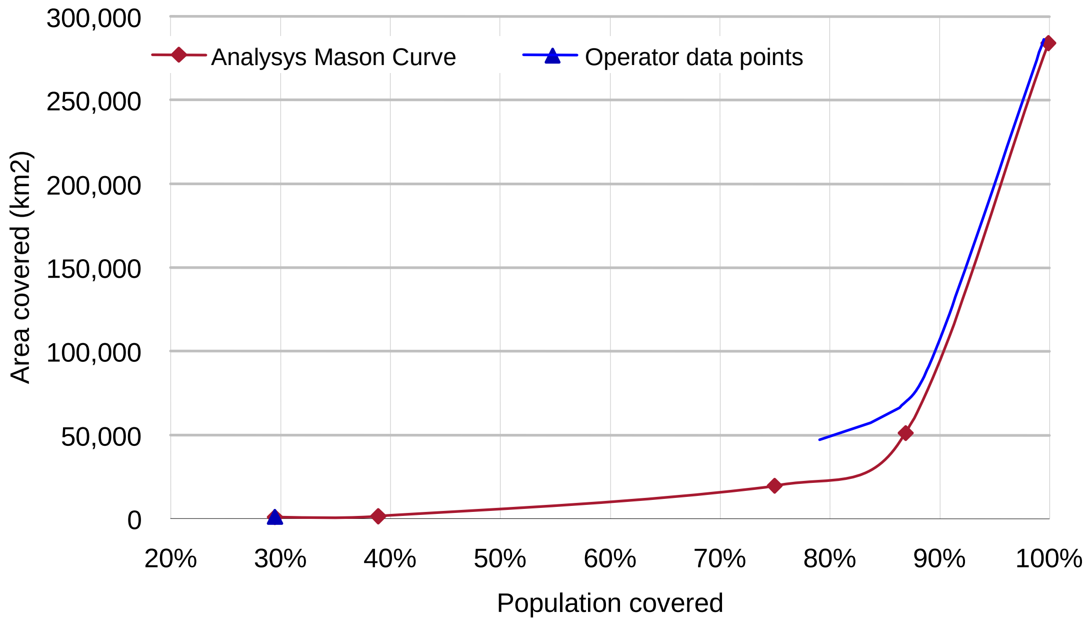


Figure G.1: Population and area coverage [Source: Analysys Mason, operator data]

This chart suggests that:

- the model is reasonably accurate in determining the relationship between population and coverage above around 90% population
- the model is reasonably accurate in determining the relationship between population and coverage below around 40% population
- there may be some discrepancy in the continuity of populations between 40% and 90% coverage, possibly due to the effect of disparate population areas (as suggested by CSMG).

Given the importance of the 75% population coverage figure for Mobile Norway's network, highlighted in Figure G.1 above, it appears that the model may not fully reflect the disparateness in population distribution between around 50% and 90% population coverage. However, in reality this will be a complex factor which varies by Fylke (some Fylker such as Oslo being more contiguous than others), and therefore only an approximate adaptation may be practical in the cost model.

► *The traffic distribution is the same for 2G and 3G, and no 3G capacity sites are required in the model. It is expected that 3G traffic concentration will be higher in the cities, particularly in the early years, and therefore additional 3G capacity sites should be deployed.*

We consider that it is reasonable, from a pragmatic modelling perspective, to assume the same *Fylke distribution* for 2G and 3G traffic, subject to overall network coverage by Fylke (i.e. the proportion of traffic which is generated on the 3G network spreads out into the Fylker as coverage by Fylke increases). Norway is characterised by a highly technological, highly mobile population distributed across both urban and rural parts of the country (e.g. in mountainous regions, coastal waters, holiday home areas). Therefore, in our view handset variations, usage variations and propensity to use 2G or 3G will be a broad mixture across all user types across all areas, rather than being polarised significantly between areas of the country. As such, the same underlying traffic distribution would seem reasonable.

However, the modelled third operator network (in the v6 model) carries its traffic in a similar way to the rest of the market – migrating traffic from 2G to 3G following the "classical" market migration profile. This means that the third operator model initially deploys capacity sites in its 2G layer (assumed to accommodate an initial 75% of its traffic from 2G handsets).

We recognised at the draft stage of the cost model (v5.1) that the third operator network had a different balance of capacity in its 2G and 3G networks compared to the incumbent operators, however we decided to use a "classical" migration profile in the model finalisation.

The submission of CSMG suggest that Mobile Norway is intending to follow a 3G-dominated network deployment (with the potential for capacity driven 3G sites) in which migration from 2G to 3G on its own network is not a strong trend.

G.1.2 Investigations

Reviewing CSMG's comments, we consider that:

- It is possible to adapt the model so that 3G coverage for the third entrant provides indoor quality from launch.
- The population-to-area coverage curve in the region of 40% to 90% population coverage could be increased by an approximate factor.
- The migration profile for the third entrant may not follow a "classical" 2G to 3G migration, but the operator may instead focus on carrying the majority of traffic on 3G.

► *Indoor coverage quality from launch*

Providing indoor coverage quality implies a smaller cell radius for site deployments. This can most simply be reflected in the model with a lower UMTS2100 cell radius, which determines how densely sites are deployed in urban areas. Setting the *UMTS 2100 cell radius* to 0.61 of its original value results in approximately [X] UMTS sites for 75% population coverage. This factor (0.61) is broadly consistent with the radius multiplier we have applied for indoor coverage in other similar cost models.[13]

However, having a lower UMTS cell radius for 2100MHz coverage applies in the model beyond 75% population coverage. As can be seen in Figure G.1, above around 80% population coverage, there is a dramatic increase in population spread. Whilst we accept that there may be valid arguments for increasing the level of coverage to provide indoor signals for the densest 75% of population, it would be highly uneconomic to apply an indoor coverage quality to up to 96% population as covered by 2100MHz UMTS in the model. This is due to the vast increase in Fylke areas to be covered. Therefore, we have made a further modification to the model so that the reduction in cell radius applies for initial coverage only, and over time this is balanced out by much larger "rural" cells which do not provide ubiquitous indoor coverage.

► *Adapting the population-to-area curve*

Based on Figure G.1 and the discussion above, an approximate adjustment to the population-to-area curve might be reasonable. We have tested the following adjustment to all Fylker except Svalbard:

- no change below 30% population
- twice the area to be covered from 40% to 85% population
- no change to area to be covered from 90% population and above.

13 See for example, Analysys Mason's bottom-up LRIC model for OPTA, April 2010.

This adjustment results in site deployment calculations of approximately:

- 900 UMTS sites for 73% population coverage *without* the indoor adjustment to cell radius
- 1900 UMTS sites for 66% population coverage *with* the indoor adjustment to cell radius
- 2500 UMTS sites for 73% population coverage *with* the indoor adjustment to cell radius.

► *Carrying the majority of traffic on 3G*

It may be reasonable to adjust the model so that the third operator has a 'migration profile' dominated by 3G traffic. As the amount of capacity in the 2G coverage layer of this operator (from around [X] sites with 5MHz of paired 900MHz spectrum) is much less than the amount of capacity in the 3G layer (from [X] sites with 15MHz of paired 2100MHz spectrum), we have applied a migration profile in which only 15% of the third operator's network traffic is on 2G at the outset.

The effect of applying this adjustment to the model is to move traffic from the 2G to the 3G layer, altering the traffic-dimensioning calculations of the 2G BTS and 3G NodeBs, subject to the coverage adjustments discussed above.

G.1.3 Solutions

Based on the above analysis, we have explored a number of solutions which could be applied in the cost model. We compare these solutions with the v6 model in the following table, and also show the ultimate result from the final v7.1 model. The investment costs for the MVNO-to-MNO step are shown with and without the *planning period input* to the model. Applying the calculation of investment costs for the MNO step *without* the planning period input means that the calculated investment costs reflect only those assets activated in the network at the time of achieving 75% population coverage, rather than also including those investments which are in the course of construction (e.g. for more than 75% population coverage).

	v6	*Mobile Norway plan*	*1.Apply indoor coverage quality*	*2. Apply indoor coverage quality with 3G traffic load*	*3. Apply indoor coverage quality, adjusted population-area curve and 3G traffic load*	*v7.1 Apply indoor coverage quality with 3G traffic load, market adjustments and specific adjustments to third operator network*
3G Population coverage	75% mid 09/10	75%	75% mid 09/10	75% mid 09/10	73% in 2010	approx 75% mid 2011/12
Sites for 75% coverage	1209	[X]	[X]	[X]	[X]	[X]
Investment cost for MVNO to MNO step (with planning period), NOK billions	1.44		[X]	[X]	[X]	[X]
Investment cost for MNVO to MNO step (without planning period), NOK billions		[X]	[X]	[X]	[X]	[X]
LRIC of termination in 2013, real 2009 NOK	[X]		[X]	[X]	[X]	[X]
LRIC+++ of termination in 2013, real 2009 NOK	[X]		[X]	[X]	[X]	[X]

Figure G.2: Comparison of cases [Source: Analysys Mason, CSMG, v6 model, v7.1 model]

Solution 2 and v7.1 are reasonably consistent with the Mobile Norway network plan in terms of sites and investments. This indicates a higher investment cost but at least a [X]% lower LRIC of termination in 2013. The lower LRIC arises because the larger 3G coverage network has more capacity and is more heavily loaded with traffic (thus, less traffic sensitive). Solution 2 and v7.1 imply two potential changes to NPT's regulation: possibly more asymmetry (e.g. in the second half of 2012) and possibly a lower symmetrical target charge by 2013.

Furthermore, we note that all the modelled cases have approximately similar LRIC+++s within a range of NOK0.04 per minute, meaning that they are broadly efficient to the same extent, just with different balances of coverage costs and traffic-sensitive costs. No solutions stand out as highly efficient (on a LRIC+++ of voice basis) compared to the other cases.

Whilst Solution 2 and v7.1 might appear similar to Mobile Norway's suggested network investment plan, we have not compared the operating expenditure forecasts of Solution 2 with Mobile Norway's proposed operating expenditures. In particular, because the levels of operating expenditures in the cost model are "incumbent-like", it is possible that Mobile Norway plans to incur fewer operating expenditures than forecast in the model. As such, although investment costs are the (current) focus of the model calculation, part of the long-term costs of termination come from expected operating expenditures.

G.2 Input assumptions

In this section we discuss the issues raised by CSMG, consider up-to-date market information, undertake some investigations in the v6 model, and outline possible solutions.

G.2.1 Issues and investigations

CSMG has raised a number of queries on the model inputs.

► *Third operator market share should start around 19% rather than 15%*

The model uses the market share forecast for the third entrant (as forecast in 2006), time-shifted to 15% at launch, as a reasonable basis on which to calculate the costs of a national third entrant network operator. Tele2 submitted in its response[14] to the draft model that NPT is too optimistic in predicting three operators each with 33% market share by 2020; a more conservative approach should be applied. Conservatism was recognised in setting up the draft (and final) model: not all of the Tele2-plus-Network Norway retail share was applied immediately to the third operator network in 2009 onwards (e.g. reflecting the time taken to issue new SIM cards where necessary, or the activities needed to switch customers from the MVNO customer systems to the national roaming systems). CSMG is arguing that the market share of the third entrant should be higher than modelled, since Tele2 and Network Norway reached a combined market share of 19% at year-end 2009 in the model.

It is possible to advance the third operator market share forecast in the model to start at 19% at end-2009. However, at the end of 2009, Tele2 and Network Norway achieved a combined market share of [X] (based on full-year market information), and therefore advancing the third operator market share to start at 17% is more reasonable.

A further possible adjustment to the model, for consistency, is to then link the Tele2 and Network Norway market shares to the third operator share. This can be applied, for example, by setting the forecast market shares of Tele2 and Network Norway to half of the total share achieved by the third network operator.

► *The national roaming multiplier should use actual population coverage*

CSMG highlights that the calculation of the third operator's market share uses an approximate population coverage proportion, rather than the actual coverage proportion calculated later in the model (which is slightly higher). This approximation can be revised so that the model uses the actual population coverage in the calculation of the third operator's market share.

14 Tele2 letter 9 September 2010

► *Incoming voice traffic*

CSMG submits that the amount of incoming traffic per subscriber for the third operator appears low in 2009, compared to the amount of incoming traffic per subscriber which Tele2 and Network Norway achieved. We have examined the levels of incoming traffic (from other networks) that Tele2 and Network Norway carry, based on five months of actual data submitted to NPT. This data suggests the following full-year traffic volumes for Tele2 and Network Norway:

	Incoming traffic from other networks
Tele2	[X]
Network Norway	[X]
Total	[X]

Figure G.3: Extrapolated 2010 incoming traffic [Source: Operator data]

With a forecast 2010 year-average subscriber base of 972 000 subscribers, this level of usage equates to around [X] minutes per subscriber per month incoming from other networks. It is straightforward to increase the amount of usage per subscriber on the third operator network (e.g. by adjusting the 2012 forecast target). Our investigation of incoming traffic has also revealed an over-statement of 2007 incoming traffic volumes (due to a double counting of wholesale and end-user mobile-to-mobile termination traffic in our aggregation of operator information). This over-statement can be revised straightforwardly by reducing the amount of incoming traffic for Telenor and NetCom in 2007.

► *Forecast data usage*

CSMG submits that whilst the roll-out of LTE should not cause overall 3G data traffic to decline in the short term, 3G/HSPA and GPRS traffic should level off once LTE has been deployed. CSMG submits that this should happen from around 2011 onwards. We have investigated this suggestion by (a) observing current levels of mobile data usage, and (b) setting usage from 2011 to be constant.

NPT has recently supplied us with full-year 2009 market information. This shows that total data traffic from Norwegian users was 39% higher in 2009 than we forecast for 2009 in the model. Since our forecast was made only six months ago, this demonstrates how rapidly the mobile data market is evolving. This is illustrated in Figure G.4, which suggests that the 2011 forecast level of usage (12 billion Mbytes for the whole market) may well be reached one year earlier than we forecast (i.e. in 2010), and that the eventual level of traffic in 2011 (at which CSMG suggests usage should stabilise in the short term) is also likely to be higher than we forecast.

analysys mason

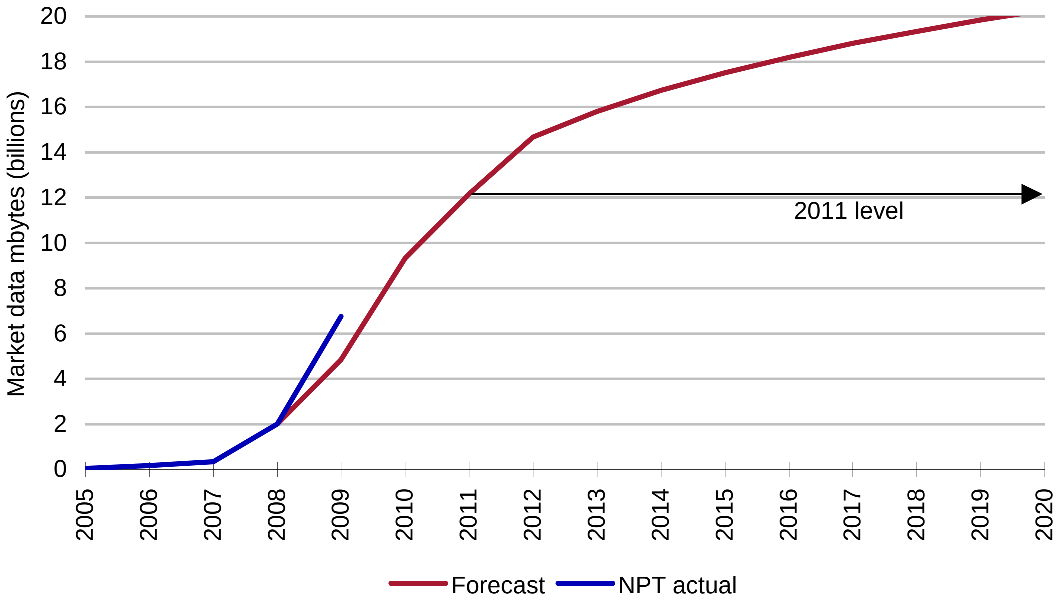


Figure G.4: Actual and forecast mobile data traffic [Source: NPT, v6 model]

It remains difficult to predict long-term mobile data traffic in order to calculate the long-run costs using economic depreciation (as the model does), and this uncertainty could be recognised by maintaining a conservative projection for the purposes of regulation. We have investigated a solution in which mobile broadband traffic volumes are higher in 2009 (according to actual data), higher in 2010, but constant in 2011 onwards at around 14 billion Mbytes per year (see Figure G.5).

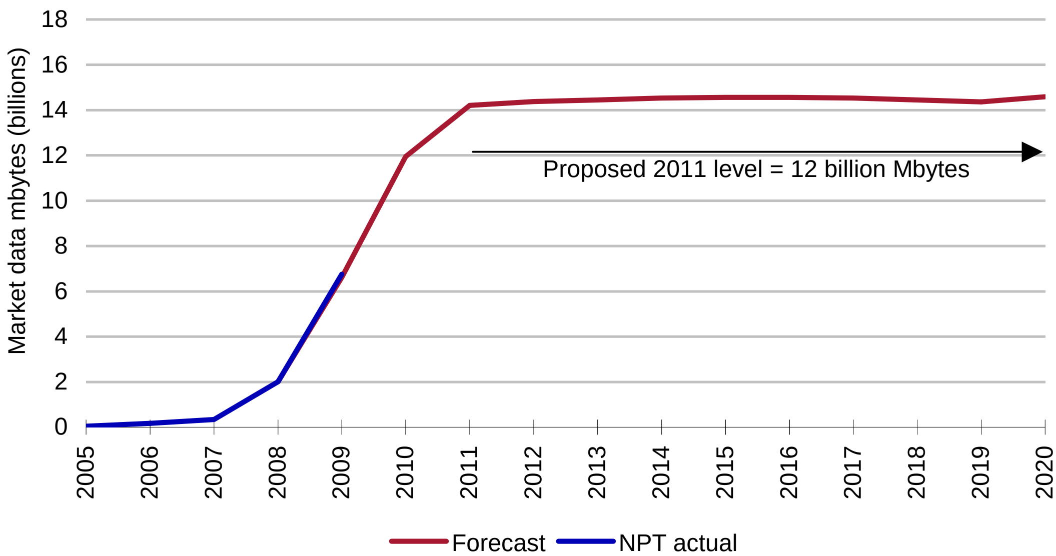


Figure G.5: Adjusted mobile data traffic forecast [Source: NPT, Analysys Mason]

G.2.2 Solutions

Based on the above investigations, we have developed a number of additional solutions.

	v6	*(From Section G.1) 2. Indoor coverage quality with 3G traffic load*	*4. Indoor coverage quality, 3G traffic load, 17% market share*	*5. Indoor coverage quality, 3G traffic load, actual population coverage*	*6. Indoor coverage quality, 3G traffic load, revised incoming traffic*	*7. Indoor coverage quality, 3G traffic load, adjusted mobile data traffic*	*v7.1 Apply indoor coverage quality with 3G traffic load, market adjustments and specific adjustments to third operator network*
Investment cost for MNVO to MNO step (without planning period), NOK billions		[X]	These market adjustments have no material impact on the amount of investment cost				[X]
LRIC of termination in 2013, real 2009 NOK	[X]	[X]	[X]	[X]	[X]	[X]	[X]
LRIC+++ of termination in 2013, real 2009 NOK	[X]	[X]	[X]	[X]	[X]	[X]	[X]

Figure G.6: Comparison of cases [Source: Analysys Mason, v6 model, v7.1 model]

The various possible solutions developed to address the comments by CSMG on the input assumptions to the final model consistently give rise to the following conclusions:

- Using our adjusted model (Solution 2), the investment cost to provide 75% coverage is similar to that submitted by CSMG.
- Once Solution 2 has been applied, the LRIC of termination decreases significantly from [X] to [X] per minute, and the suggested input revisions affect this value by ± NOK0.005.

G.3 Migration costs

CSMG has identified further areas where it considers that investment costs *might* have been overlooked in the calculation assessing the level of investment needed to develop the third entrant operator (or in reality, Mobile Norway's network).

► *New systems and their integration costs*

CSMG suggests that some systems purchased by the MVNO prior to MNO operation would need to be upgraded in order to be functional for the Mobile Norway situation, incurring additional costs. However, CSMG has not demonstrated that the **core network** investments and expenditures (i.e. not considering the 75% coverage network investments discussed earlier in this report) modelled for either the third entrant operator, or for the Tele2 and Network Norway MVNO models, are insufficient compared to these parties' actual and expected investments. Furthermore, CSMG has not explained why the current situation (with Tele2 and Network Norway acting as MVNOs on Telenor and NetCom) is any different from the future situation where Tele2 and Network Norway effectively act as MVNOs on the Mobile Norway network. Considering the above, we believe that there are likely to be no material additional investments for the situation where Tele2 and Network Norway move from the incumbents to the new host network, that can be considered reasonable investment costs required to establish the third national radio network.

► *Operational costs*

CSMG states that the rationale for excluding network operating costs from the investments required to establish the third entrant's network is unclear, and that opex for renting sites and transmission should be considered in NPT's 'Option 2' as investment costs.

The model and the calculated amount of investment for Option 2 already include a reasonable amount of capitalised opex in the unit costs of equipment. This capitalised opex is normally treated under standard accounting procedures as being relevant to the establishment of the assets, as distinct from their ongoing running costs. The level of capitalised opex in the model is consistent with similar investments incurred by Telenor and NetCom over time, and also consistent with the investments including capitalised opex as stated by Mobile Norway in its 2009 capex budget.

In our experience, it is *not* normal practice to capitalise the expected ongoing costs of assets (e.g. site rents, leased line rentals) – and in fact such a practice may be prohibited in prevailing accounting rules. Consistent with our view (rather than the submission of CSMG), the Mobile Norway April 2009 opex budget submitted during the model development states site rents and transmission fees as opex.

In our opinion, we do not consider that ongoing operating expenditures can be characterised or treated as allowable investment costs:

- Some rentals and transmission leases typically commence when the equipment is active (and therefore likely to be carrying load); these costs can be terminated after establishment with the intention to cease incurring the rental opex.

- Invested capital is required before service can be launched, and cannot be terminated in the same way as rental contracts.

G.4 List of changes in version 7.1

Version 7.1 of the cost model applies the changes investigated in a number of the solutions in this report, specifically:

- **Solution 2** for indoor coverage quality and the majority of third operator network traffic on 3G
- **Solutions 4, 5, 6 and 7** for revisions to the market calculations.

Version 7.1 also applies further changes to the third operator's network, noted below.

Changes in version 7.1 of the model are highlighted in light pink cells

► *Updates based on full-year 2009 market information and minor corrections to market calculations*

- Increase of year-end 2009 mobile subscriber penetration to 112.3% (see S-curve input cells on sheet *M6* rows 12 and 14)

- Mobile broadband population penetration at year-end 2009 increased to 14.5% (see *M6* row 19)

- Market share of third operator moved forwards one year to start at 17% (see sheet *M6* row 59)

- Market shares of Tele2 and Network Norway set equal at half of the third operator's share (17% and onwards) for 2009 and beyond (see sheet *M6* row 53 and 54)

- Calculation of traffic carried on third operator network adjusted to use actual (calculated) population coverage (see sheet *M6* row 71).

- Adjustment to the number of incoming minutes per year-end subscriber (see sheet *M6,* various rows 229 to 262)

- Reduction to mobile broadband Mbytes usage per subscriber per month from 2009/2010 onwards (see sheet *M6* rows 446 to 455)

► *Updates based on information submitted during the public consultation*

- Revision of the 2G-to-3G migration profile for the third entrant so that it predominantly uses its high-capacity UMTS network, and only a limited amount of traffic is carried on the low-capacity GSM network (see sheet *M6* row 113)

- Reduction of the third operator's 2100MHz cell radius so that it is based on providing indoor coverage (rather than outdoor coverage) to the initial population roll-out (see sheet *NwDesBase* rows 386 to 396, and *NwDes row 955*). Note, this adjustment is not present in the MVNO-only models provided to TDC and Ventelo.

► *Updates to the third operator's network*

Note, these adjustments are not present in the MVNO-only models provided to TDC and Ventelo.

- [X] As such, the third operator deploys 3G in 2010, activates it in 2011 and achieves approximately 75% coverage during 2011/12. The changes to implement this are applied in the model at:
  - sheet *NtwDesBase*, line 894, cell AB921 and cell AC946
  - sheet *3rdOpCov*, cells X130 to X172
  - sheet *NtwDesSlct*, cells X196 to X238

- [X] As such, a 50% multiplier is applied to the third operator's market share in 2009 and 2010. This change is applied in sheet *M6*, rows 59 and 61. The balance of traffic is approximately added back to [X] in row 51.

- As a result of the coverage network of the third operator being put back two years, the inputs used to estimate the amount of capex required for its investment to 75% population coverage have also been extended by two years. These changes have been applied in sheet *CapexAdj*, lines 1288 to 1412. The extension of the *capex adjustment* has **not** been applied to **all** assets in the model. For example, any GSM investments in 2010 and 2011 are not included in the capex investment figure; neither is the subsequent replacement of initial MSS software which has a three-year lifetime.