SPECIFICATION REPORT FOR THE AUSTRALIAN COMPETITION AND CONSUMER COMMISSION

SPECIFICATION OF THE COST MODULE OF THE WIK MOBILE NETWORK AND COST MODEL VERSION 1.1

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List of Abbreviations and Terms

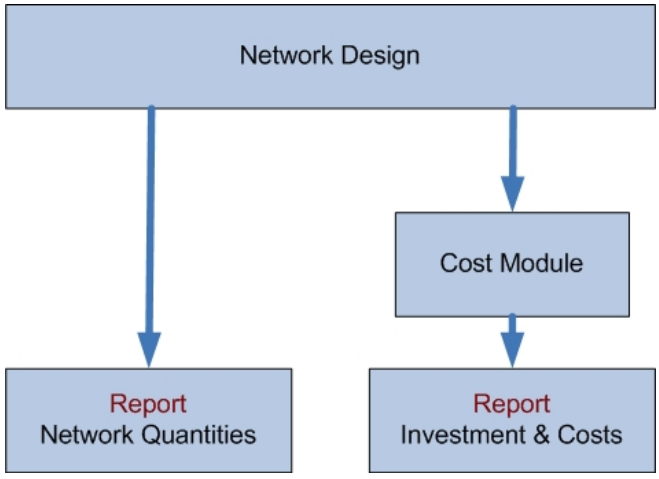
BHCA	Busy Hour Call Attempts
BSC	Base Station Controller
BSCTREE	Base Station Controller Tree
BSC-MSC link	Link between a BSC and a MSC
BSS	Base Station Subsystem
BTS	Base Transmission Station
BTS hub	Centrally located BTS in a District with the largest traffic flow
BTS-BSC link	Link between a BTS and a BSC
BTS hub-BSC link	Link between a BTS hub and a BSC
BTS-BTS hub link	Link between a BTS and a BTS hub
Busy Hour	The period in a day experiencing peak network traffic volume
CAPEX	Capital Expenditure
CP	Central Processor
CPU	Central Processing Unit
District	Aggregated postal areas based on population and physical size. Districts are the basic geographical unit used for calculating cell deployment.
DP	Debt Premium
DWDM	Dense Wave Division Multiplex
E1	ETSI framing specification for the transmission of 32 64 Kbps data streams
ETSI	European Telecommunications Standards Institute
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HLR	Home Location Register
Hw	Hardware
IC	Indirect Costs
IT	Information Technology
Kbps	Kilobits Per Second
Mbps	Megabits Per Second
MHz	Megahertz
MMS	Multimedia Message Service
MSC	Mobile Switching Centre
MTAS	Mobile Terminating Access Service
NSS	Network Switching Subsystem
OC	Operating Cost
OPEX	Operating Expenditure
PTP	Point to point

PTPRAL	Point to Point Radio Links
RL	Radio Link
SDH	Synchronous Digital Hierarchy
SMS	Short Message Service
SMSC	Short Message Service Centre
SNPT	Strategic Network Planning Tool
SP	Signalling Processor
STM-1	Synchronous Transport Module -1
Sw	Software
TRAU	Transcoder and Rate Adaptation Unit
TRX	Transceivers
VLR	Visitor Location Register
WACC	Weighted Average Cost of Capital
WDM	Wavelength Division Multiplexing
WIK	WIK-Consult
WIK-MNCM	WIK Mobile Network and Cost Model

1 Objective of the Cost Module

This document sets out the cost modelling module of the WIK Mobile Network and Cost Model (WIK-MNCM) as well as the description of output reports for volumes of assets, investment values and costs. These three components of the Cost Module are derived from the Network Design Module or the Strategic Network Planning Tool (SNPT). Figure 1-1 shows the corresponding relationships between the SNPT and the Cost Module.

Figure 1-1: Relationships between the WIK-MNCM modules



2 Investment calculation

The calculation of the investment values is based on the reference model for a GSM network as outlined in section 4.2 of the report titled '*Mobile Termination Cost Model for Australia*, January 2007' (the Report). A GSM network comprises the following productive network elements:

- Radio access provided by Base Transceiver Stations (BTSs), composed of one or several cells (sectors).
- Control functions (radio resource management, BTS control and intra-BSC handover) provided by Base Station Controllers (BSCs).
- Call and mobility management provided by Mobile Switching Centres (MSCs) and bandwidth adaptation from 16 Kbps to standard 64 Kbps circuits (DS0) performed by the Transcoder and Rate Adaptation Unit (TRAU).
- Other elements of the mobile network such as the Home Location Register (HLR) and the Visitor Location Register (VLR).

Mobile traffic is originated and terminated at a user terminal (refered to as a 'mobile station'). Mobile stations are not considered to be network elements in the WIK-MNCM because from the technical point of view they do not form part of the network and from the cost modelling point of view the cost of mobile stations are part of the subscriber sphere of mobile services.

The elements that provide these network functions are connected by a transmission network which is comprised of three parts:

- The aggregation network which is provided by two types of links:
    - BTS-BTS hub links
    - BTS hub-BSC links,
- The backhaul network provided by BSC-MSC links, and
- The core network provided by MSC-MSC links.

Network support functions and assets that are provided by the network management system, network planning and support, field service etc. are not modelled directly but are treated as a proportion to investment values of the productive network assets.

2.1 Productive network asset investment (investment for explicitly modelled network elements)

The productive network asset investment includes investment for BTSs, BSCs, MSCs as well as for the transmission facilities within the Base Station Subsystem (BSS) and Network Switching Subsystem (NSS).

2.1.1 BTS investment

The BTS investment comprises:

- Site construction which is required once for each BTS location,
- BTS equipment required for each type of BTS (Macrocell, Microcell, Picocell and in different sectorisations), and
- Equipment for providing the transceiver in each sector (TRX).

2.1.1.1 Site construction investment

Description: Fixed investment for site construction includes land, buildings and the construction of BTS sites (buildings and tower facilities). Investment also includes services such as planning, management and construction for different BTS types: i) Macrocell BTS, ii) Microcell BTS and iii) Picocell BTS.

Parameters:

Parameter	Value	Description	Source
p_bts_site_ma	>=0	Average investment for site construction per BTS Macrocell	Input
p_bts_site_mi	>=0	Average investment for site construction per BTS Microcell	Input
p_bts_site_pi	>=0	Average investment for site construction per BTS Picocell	Input
sf_bts_site_ma	[0,1]	Sharing factor reflecting the average impact on investment due to sharing of a BTS Macrocell site with other operators	Input
sf_bts_site_mi	[0,1]	Sharing factor reflecting the average impact on investment due to sharing of a BTS Microcell site with other operators	Input
sf_bts_site_pi	[0,1]	Sharing factor reflecting the average impact on investment due to sharing of a BTS Picocell site with other operators	Input
nBTS_site_ma	>=0	Number of base stations Macrocell sites	Output
nBTS_site_mi	>=0	Number of base stations Microcell sites	Output
nBTS_site_pi	>=0	Number of base stations Picocell sites	Output

Total investment for site construction is calculated by the following:

```
di_bts_site_ma      = nBTS_site_ma * p_bts_site_ma * sf_bts_site_ma
di_bts_site_mi      = nBTS_site_mi * p_bts_site_mi * sf_bts_site_mi
di_bts_site_pi      = nBTS_site_pi * p_bts_site_pi * sf_bts_site_pi

di_bts_site =       di_bts_site_ma
                +   di_bts_site_mi
                +   di_bts_site_pi
```

2.1.1.2 BTS equipment investment

Description: Fixed investment for BTS electronic GSM 900/1,800 equipment includes cables, amplifiers, combiner, power supply etc. Investment figures include associated services such as installation associated with each BTS type: i) Macrocell BTS, ii) Microcell BTS and iii) Picocell BTS.

Proposed parameters:

Parameter	Value	Description	Source
p_bts_ma_1	>=0	Average investment for 1-sector base stations Macrocell in 900 or 1800 MHz	Input
p_bts_ma_2	>=0	Average investment for 2-sectors base stations Macrocell in 900 or 1800 MHz	Input
p_bts_ma_3	>=0	Average investment for 3-sectors base stations Macrocell in 900 or 1800 MHz	Input
p_bts_mi_3	>=0	Average investment for 3-sectors base stations Microcell in 900 or 1800 MHz	Input
p_bts_pi_3	>=0	Average investment for 3-sectors base stations Picocell in 900 or 1800 MHz	Input
nBTS_ma_1	>=0	Number of base stations Macrocell (1-sector) in 900 or 1800 MHz	Output
nBTS_ma_2	>=0	Number of base stations Macrocell (2-sectors) in 900 or 1800 MHz	Output
nBTS_ma_3	>=0	Number of base stations Macrocell (3-sectors) in 900 or 1800 MHz	Output
nBTS_mi_3	>=0	Number of base stations Microcell (3-sectors) in 900 or 1800 MHz	Output
nBTS_pi_3	>=0	Number of base stations Picocell (3-sectors) in 900 or 1800 MHz	Output

Total investment for BTS equipment is calculated on the basis:

```
di_bts_eq    = nBTS_ma_1 * p_bts_ma_1
             + nBTS_ma_2 * p_bts_ma_2
             + nBTS_ma_3 * p_bts_ma_3
             + nBTS_mi_3 * p_bts_mi_3
             + nBTS_pi_3 * p_bts_pi_3
```

2.1.1.3 TRX investment

Description: Investment per TRX unit includes the value of equipment and installation services. Since TRX prices do not differ for GSM 900 and GSM 1,800 equipment, the investment value for TRXs is assumed to be the same for both 900 and 1,800 MHz equipment.

Parameter	Value	Description	Source
p_TRX	>=0	Average investment for TRX in 900 or 1800 MHz	Input
nTRX_ma	>=0	Number of TRXs in Macrocell BTS in 900 or 1800 MHz	Output
nTRX_mi	>=0	Number of TRXs in Microcell BTS in 900 or 1800 MHz	Output
nTRX_pi	>=0	Number of TRXs in Picocell BTS in 900 or 1800 MHz	Output

Total investment for TRXs is calculated by the following:

```
di_trx = (ntrx_ma + ntrx_mi + ntrx_pi)* p_trx
```

2.1.1.4 Total BTS investment

```
di_bts       = di_bts_site
             + di_bts_eq
             + di_trx
```

2.1.2 BSC investment

The main function of the BSC is to control the BTS (call maintenance), which means monitoring the signal level of the radio channels between the mobile station and the relevant BTS. While the capacity of the BSC depends on the quality of the equipment (dependent on the supplier), generally BSCs will control a large number of BTSs. For example, an Ericsson CME 201 BSC can control a maximum of 256 BTS locations with a maximum of 512 cells (noting that due to sectoring a BTS location can have up to three cells).

2.1.2.1 BSC site construction investment

Description: Fixed investment in relation to BSC site construction relates to construction of a BSC site and any building requirements. Site construction investment also includes planning, management and construction services.

Parameter	Value	Description	Source
p_bsc_site	>=0	Average investment for site construction per BSC	Input
sf_bsc_site	[0,1]	Sharing factor reflecting the average impact on investment due to sharing of a BSC site with other operators	Input
nBSC	>=0	Number of BSC sites	Output

Total investment for BSC site construction is calculated by the following:

```
di_bsc_site =    nBSC * p_bsc_site * sf_bsc_site
```

2.1.2.2 BSC equipment investment

Description: Investment in BSC equipment. Investment in BSC equipment can be hardware and/or software. While the BSC equipment is different for GSM 900 or GSM 1,800 systems, there is no difference in equipment prices.

The number of BSC units required is derived from i) the total number of BTSs assigned to a particular BSC, ii) a capacity limit in terms of number of TRXs and iii) an average utilisation ratio.

Several BSC units can be located at one BSC location and a predetermined maximum number of BTSs can be assigned to a single 'controlling' BSC unit.

Parameter	Value	Description	Source
p_bsc_unit_hw	>=0	Hardware investment per BSC unit	Input
p_bsc_unit_sw		Software investment per BSC unit	Input
cap_bsc_unit	>=0	Maximum number of TRXs which can be controlled by one BSC unit	Input
n_bsc_unit	>=0	Number of BSC units at one BSC site	Output

The number of BSC units is derived as follows:

$$n\_BSC\_Unit = \sum_{BSC.Sites.i} \left\lceil \frac{No.of.TRX\_at.BSC.Site.i}{cap\_bsc\_unit} \right\rceil$$

The total investment for BSC equipment is then given by:

```
di_bsc_unit_hw   =  n_bsc_unit * p_bsc_unit_hw
di_bsc_unit_sw   =  n_bsc_unit * p_bsc_unit_sw
di_bsc_unit      = di_bsc_unit_hw + di_bsc_unit_sw
```

2.1.2.3 Total investment for BSCs

Total investment for BSCs is given by:

```
di_bsc           = di_bsc_site
                 + di_bsc_unit_hw
                 + di_bsc_unit_sw
```

2.1.3 TRAU investment

Description: The BSC traffic is routed through a TRAU before it is forwarded to the MSC. TRAU equipment can be integrated within a MSC.

Total investment for the TRAU is calculated by the following:

```
ntrau = Number of TRX / (Maximum_Number_TRX_per_TRAU)
di_trau =        ntrau * p_trau
```

Parameter	Value	Description	Source
p_trau	>=0	Investment per TRAU	Input
ntrau	>=0	Total number of TRAUs	Output

2.1.4 MSC investment

This section details the MSC investment calculation. The MSC investment includes site construction and any building requirements, basic MSC equipment, the TRAU (which the WIK-MNCM assumes is operated at the MSC) and the 2 Mbps ports.

2.1.4.1 Site construction investment

Description: Fixed investment for construction of a MSC site and any building requirements. Investment also includes associated planning, management and construction services. Regional site price variations are not explicitly modelled in the site construction investment value. In this respect an average investment value is used.

Parameter	Value	Description	Source
p_msc_site	>=0	Average investment per MSC site	Input
sf_msc_site	[0,1]	Sharing factor reflecting the average impact on investment due to sharing of a MSC site with other operators	Input
nMSC	>=0	Total number of MSC sites	Output

Total investment for MSC site construction is calculated on the following basis:

```
di_msc_site =    nMSC * p_msc_site * sf_msc_site
```

2.1.4.2 MSC hardware and software equipment investment

Description: Investment for MSC equipment includes switching matrix, central processing unit (CPU), cabinets, racks, VLR, signalling equipment as well as other assets like power supply equipment, battery and air-conditioning etc. The investment figure includes material and installation costs and the equipment comprises hardware and software components.

While most components of the MSC (such as the switching matrix and interfaces) are driven by traffic (and the number of ports) the MSC has to handle, some MSC equipment (such as the CPU) is driven by the number of busy hour call attempts.

To take account of the different cost drivers for the MSC equipment, the equipment is categorised as: a switching machine (switching matrix, ports etc.) and a CPU which controls the switching matrix and the corresponding path from inlets to outlets. A CPU contains one or more signalling processor units which handle the signalling messages and work in conjunction with the CPU for the set-up and termination of connections through the switching matrix.[1]

The total number of ports include the number of BSC-facing ports, backbone-facing ports and interconnection ports. The WIK-MNCM assumes that each switching unit is capable of dealing with a maximum number of ports. The required number of switching units is calculated on the basis of the total number of ports, a pre-defined capacity limit in terms of ports and a pre-defined maximum utilisation ratio for the switching matrix.

This capacity limit is given as an input parameter. The model algorithm ensures that once the limit is exceeded an additional machine is required. This may result in the situation where several units are deployed at one MSC site.

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1 The Telecommunication Network Handbook edited by J.E. Flood (IEE Telecommunications Series No. 36) contains in chapter 5 a good overview over the elements of modern digital switching machines.

Parameters:

Parameter	Value	Description	Source
p_msc_hw	>=0	Average hardware investment per switching machine	Input
p_msc_sw	>=0	Average software investment per switching machine	Input
p_cp	>=0	Average investment per CPU	Input
p_sp	>=0	Average investment per signalling processor	Input
max_ports	>=0	Maximum number of ports of one MSC base unit	Input
cp_bhca	>=0	Maximum number of BHCA per CPU	Input
sp_bhca	>=0	Maximum number of BHCA per signalling processor	Input
ur_sp	>=0	Average utilisation ratio of signalling processor	Input
ur_cp	>=0	Average utilisation ratio of central processor	Input
n_mach	>=0	Number of switching machines at a particular MSC site according to capacity limit in terms of ports.	Output
n_BHCA	>=0	Number of total (unsuccessful and successful) Busy Hour Call Attempts from circuit switched services	Output
n_BHCA_sms	>=0	Number of total (unsuccessful and successful) Busy Hour Call Attempts from SMS	Output

The required number of switching machines is calculated separately for each MSC site taking into account the total number of ports connected:

```
for each site i:
n_mach_i = Ceil(Number of Ports at Site i / max_ports) :integer

Total Number of Switching machines in the network:
n_mach = Sum(n_mach_i) for all i

Number of Central Processor Units required:
n_cpu = (n_BHCA) / (cp_bhca * ur_cp)

Number of Signalling Processor Units required:
n_sp = (n_BHCA + n_bhca_sms) / (sp_bhca * ur_sp)
```

Total investment for MSC equipment is calculated as follows:

```
di_msc_hw       =  n_mach * p_msc_hw
di_msc_sw       =  n_mach * p_msc_sw
di_msc_unit     = di_msc_hw + di_msc_sw
```

Processor investment (for CPU and signalling) is considered separately from MSC equipment which is driven by traffic volume. The number of CPUs and Signalling Processors (SPs) depends on the number of busy hour call attempts. Processor investment is given by:

```
di_sig =          n_cpu * p_cp+ n_sp * p_sp
```

2.1.4.3 Ports investment

The types of 2 Mbps ports can be categorised into i) BSC-facing ports, ii) MSC (or core network)-facing ports and iii) interconnection ports. Investment for ports is a function of the quantity of ports and their price. The same price is used for the different types of ports.

Parameter	Value	Description	Source
p_port	>=0	Investment in material and installation per 2 Mbps port.	Input
n_icports	>=0	Total number of interconnection-facing 2 Mbps ports	Output
n_bscports	>=0	Total number of BSC-facing 2 Mbps ports	Output
n_mscports	>=0	Total number of MSC-facing 2 Mbps ports	Output

```
di_msc_icports      =      n_icports * p_port
di_msc_bscports     =      n_bscports * p_port
di_msc_mscports     =      n_mscports * p_port

di_msc_ports        =      di_ msc_icports + di_msc_bscports + di_msc_mscports
```

2.1.4.4 Total investment MSC and processor investment

The model differentiates by (i) MSCs as well as (ii) by signaling and central processor.

Total direct MSC investment:

```
di_msc        = di_msc_site
              + di_msc_hw
              + di_msc_sw
              + di_msc_ports
```

Total direct investment in signaling (including central processor and signaling)

```
di_sig        = di_sig
```

2.1.5 HLR investment

The HLR stores information about a mobile subscriber in particular the subscriber's mobile number as well as the subscriber's activated services. The investment in the HLR is driven by the number of subscribers. Hence, the required number of HLR components is a function of the total number of subscribers on the network, a pre-defined capacity limit (in terms of subscribers) and a pre-defined utilisation ratio.

Parameter	Value	Description	Source
p_hlr	>=0	Investment in material and installation per HLR functionality	Input
max_hlr	>=0	Maximum number of registered subscribers per HLR component	Input
ur_hlr	>=0	Average utilisation ratio of a HLR component	Input
n_hlr	>=0	Number of HLRs in the network	Output

The total number of HLR components is calculated as follows:

```
n_hlr = Max (2, Ceil( (Total Number of Subscribers) / max_hlr * ur_hlr ))
```

Total investment in the HLR is given by:

```
di_HLR = n_hlr * p_hlr
```

2.1.6 SMSC investment

SMS demand is routed over the SMSC. Investment in the SMSC is a function of the required number of SMSCs in the network. The required number of SMSCs is determined by the SMS demand in terms of SMS, a pre-defined capacity limit and a pre-defined utilisation ratio.

Parameter	Value	Description	Source
p_smsc	>=0	Investment in material and installation per SMSC unit	Input
max_smsc	>=0	Maximum capacity in terms of number of SMS per SMSC unit	Input
ur_smsc	>=0	Average utilisation ratio of a SMSC	Input
n_smsc	>=0	Number of SMSC units in the network	Output

To account for network resilience the model has a minimum two SMSCs. The total number of SMSC units is calculated as follows:

```
n_smsc = Max (2, Ceil( (Number of SMS in the Busy Hour) / max_smsc * ur_smsc))
```

Total investment in SMSC components is given by:

```
di_smsc = n_smsc * p_smsc
```

2.1.7 BTS-BSC links investment

2.1.7.1 BTS-BTS hub investment

The BTS-BTS hub links are usually point-to-point (PTP) radio mini-links. The capacity is 2 Mbps. Due to the short distance of these links, the investment is independent of the length of the link.[2]

Note: Leased lines are not considered in this network segment as the links between the BTS and the BTS hub are modelled as radio links.

Parameter	Value	Description	Source
p_RL2	>=0	Investment per 2 Mbps radio mini-link	Input
n_RL2	>=0	Number of 2 Mbps radio links	Output
p_RL_fee	>=0	Licence charge per point-to-point	Input

The total BTS-BTS hub link investment is calculated as follows:

The total direct cost for radio mini-links and the licence charge for point-to-point connection is outlined separately:

Total direct investment in radio mini-links:

```
di_rl2_bts_btsh  = n_RL2 * p_RL2
```

Total direct investment in licence charges for radio links:

```
di_RL_fee = n_RL2 * p_RL_fee
```

2 Note that the equipment requirement is estimated by a star structure assuming that the lengths of star links will not be larger than the maximum values bridged by the PTP mini links. In reality the network structure will have the same number of links in a tree formation but a higher traffic flow when the E1 demand from the TRX is routed over more than one link. In most cases it is assumed that this will not increase the system requirements because the TRX demand between the BTS and BSC does not fully utilise the capacity of an E1 connection. For example, a 3 sectors BTS with 3 TRXs per sector requires 9 TRXs while an E1 can capture a traffic capacity of 15 TRXs.

2.1.7.2 BTS hub-BSC investment

The connections between the BTS hub and the BSC are different from those between the BTS-BTS hub due to longer link lengths and higher capacity E1 link flows. Hence, the corresponding algorithm calculates a tree structure which allows the WIK-MNCM to generate a corresponding link set which can be implemented by a cost-minimising combination of i) PTP radio links and ii) leased lines. The BTS hub-BSC segments are either PTP radio links or leased lines.

For each link the costs of both PTP radio links and leased lines are calculated and the lowest cost solution is adopted in the WIK-MNCM.

- Radio link investment

  The possible capacities of the radio link are assumed to be between E1 and E4 (2, 8, 34 or 140 Mbps). In the case of 8, 34 or 140 Mbps a corresponding multiplexer is required to aggregate n x 2 Mbps.

  In the case that the lengths of the radio links exceed a pre-defined distance a repeater is necessary. Repeaters are considered for 8, 34 or 140 Mbps systems.

Parameter	Value	Description	Source
p_RL2	>=0	Investment per 2 Mbps radio link system	Input
p_RL8	>=0	Investment per 8 Mbps radio link system	Input
p_RL34	>=0	Investment per 34 Mbps radio link system	Input
p_RL140	>=0	Investment per 140 Mbps radio link system	Input
p_rep_site	>=0	Investment per repeater site	Input
p_RL2_rep	>=0	Investment per repeater for a 2 Mbps radio link system	Input
p_RL8_rep	>=0	Investment per repeater for a 8 Mbps radio link system	Input
p_RL34_rep	>=0	Investment per repeater for a 34 Mbps radio link system	Input
p_RL140_rep	>=0	Investment per repeater for a 140 Mbps radio link system	Input
sf_rep	[0,1]	Sharing factor for repeater sites	
Dist_rl		Maximum distance for radio transmission in Km for which a repeater is not needed	Input
N_RL2_btsh_bsc	>=0	Number of 2 Mbps radio links	Output
N_RL8_btsh_bsc	>=0	Number of 8 Mbps radio links	Output
N_RL34_btsh_bsc	>=0	Number of 34 Mbps radio links	Output
N_RL140_btsh_bsc	>=0	Number of 140 Mbps radio links	Output
n_rep_sites	>=0	Number of repeater sites	Output
n_RL2_rep	>=0	Number of repeaters for 2 Mbps radio link system	Input
n_RL8_rep	>=0	Number of repeaters for 8 Mbps radio link system	Input
n_RL34_rep	>=0	Number of repeaters for 34 Mbps radio link system	Input
n_RL140_rep	>=0	Number of repeaters for 140 Mbps radio link system	Input

```
Direct investment in radio links:
di_RL2_btsh_bsc           =      p_RL2 * N_RL2_btsh_bsc
di_RL8_btsh_bsc           =      p_RL8 * N_RL8_btsh_bsc
di_RL34_btsh_bsc          =      p_RL34 * N_RL34_btsh_bsc
di_RL140_btsh_bsc         =      p_RL140 * N_RL140_btsh_bsc

Direct investment in licence charges:

di_rl_fee_btsh_bsc        = p_RL_fee * (N_RL2_btsh_bsc+ N_RL8_btsh_bsc
                          + N_RL34_btsh_bsc + N_RL140_btsh_bsc)

Direct investment in repeater sites:

di_rep_site               =      n_rep_sites * p_rep_site * sf_rep

n_RL2_rep = Link_length / dist_rl
n_RL8_rep = Link_length / dist_rl
n_RL34_rep = Link_length / dist_rl
n_RL140_rep = Link_length / dist_rl

di_RL2_rep = n_RL2_rep * p_RL2_rep
di_RL8_rep = n_RL8_rep * p_RL8_rep
di_RL34_rep = n_RL34_rep * p_RL34_rep
di_RL140_rep = n_RL140_rep * p_RL140_rep
```

Total investment for radio links (after finalisation of the algorithm) is:

```
Total direct investment in radio links:

di_rlx_btsh_bsc           = di_RL2_btsh_bsc
                          + di_RL8_btsh_bsc
                          + di_RL34_btsh_bsc
                          + di_RL140_btsh_bsc
                          + di_RL2_rep
                          + di_RL8_rep
                          + di_RL34_rep
                          + di_RL140_rep
                          + di_rep_site
```

- Leased lines costs

  The possible capacities of leased lines are assumed to be 2 Mbps.[3]

  2 Mbps and STM-1 leased line prices typically vary depending on their length. The leased lines prices are therefore categorised as[4]:

  - ‘Local’: for lengths between 0 Km and 10 Km,
  - ‘Regional’: for lengths between 10 Km and 150 Km, and
  - ‘Long Distance’: for lengths over 150 Km.

  The price scheme for leased lines is assumed to be categorised into i) prices which are given on a per Km basis and ii) an upfront payment for the provision of leased lines. Note that leased line prices per Km are defined as (recurring) annual costs. The distribution of the investment value over the economic lifetime of the relevant asset (in this case the provision of a service) is therefore only required for the upfront payments.

Parameter	Value	Description	Source
p_LL2_loc	>=0	Annual leased line price per Km (0-10 Km)	Input
p_LL2f_loc	>=0	Investment (one-off) for the provision of a local leased line	Input
p_LL2_reg	>=0	Annual leased line price per Km (10-150 Km)	Input
p_LL2f_reg	>=0	Investment (one-off) for the provision of a regional leased line	Input
p_LL2_ld	>=0	Annual leased line price per Km (over 150 Km)	Input
p_LL2f_ld	>=0	Investment (one-off) for the provision of a long distance leased line	Input
N_LL2_loc	>=0	Number of Km for local leased lines (0-10 Km)	Output
N_LL2f_loc	>=0	Number of local leased lines (0-10 Km)	Output
N_LL2_reg	>=0	Number of Km for regional leased lines (10-150 Km)	Output
N_LL2f_reg	>=0	Number of regional leased line per Km (10-150 Km)	Output
N_LL2_ld	>=0	Number of Km for long distance leased lines (over 150 Km)	Output
N_LL2f_ld	>=0	Number of long distance leased line (over 150 Km)	Output

3 Note that digital leased lines are implemented by SDH equipment where E2 is not relevant any more and even E3 insertion into a STM-1 frame is not an optimal solution (only 3 E3s per STM-1).

4 Here it is assumed that the operator offering digital leased lines implements a transmission infrastructure with high capacities (e.g. a cable with 16 fibre pairs and 10Gbit/s WDM until 40 Gbit/s DWDM systems with a maximum value of the total capacity per cable link of 64*16 up to 256*16 STM-1 groups). Hence the civil engineering costs are dependent on the length of the leased line while multiplexer and cross-connection functions provided in the end nodes increase with the number of STM-1.

```
Direct costs for leased lines by type:

dc_LL2_loc_btsh_bsc       =     p_LL2_loc * N_LL2_loc
dc_LL2_reg_btsh_bsc       =     p_LL2_reg * N_LL2_reg
dc_LL2_ld_btsh_bsc        =     p_LL2_ld * N_LL2_ld

Total direct cost for leased lines:

dc_LL2_btsh_bsc           = dc_LL2_loc_btsh_bsc
                          + dc_LL2_reg_btsh_bsc
                          + dc_LL2_ld_btsh_bsc

Direct investment by type of leased line:

di_LL2f_loc_btsh_bsc      =     p_LL2f_loc * N_LL2f_loc
di_LL2f_reg_btsh_bsc      =     p_LL2f_reg * N_LL2f_reg
di_LL2f_ld_btsh_bsc       =     p_LL2f_ld * N_LL2f_ld

Total direct investment of leased linesdi_ll2f_btsh_bsc          =
di_LL2f_loc_btsh_bsc
                          + di_LL2f_reg_btsh_bsc
                          + di_LL2f_ld_btsh_bsc
```

2.1.8 BSC-MSC links investment

BSC-MSC links are delivered by leased lines and based on a star structure for the network. The possible capacity of leased lines is assumed to be STM-1 (155 Mbps).

STM-1 leased line prices typically vary according to their length. The leased line prices are therefore categorised as:

- ‘Local’: for lengths between 0 Km and 10 Km,
- ‘Regional’: for lengths between 10 Km and 150 Km, and
- ‘Long Distance’: for lengths over 150 Km.

The price scheme for leased lines is assumed to be categorised into i) prices which are given on a per kilometre basis and ii) an upfront payment for the provision of leased lines. Note that leased line prices per kilometre are defined as a (recurring) annual cost. A distribution of an investment value over the economic lifetime of the relevant asset (in this case the provision of a service) is therefore only required for the upfront payments.

Parameter	Value	Description	Source
p_LL155_loc	>=0	Annual STM-1 leased line price per Km (0-10 Km)	Input
p_LL155f_loc	>=0	Investment (one-off) for the provision of a local STM-1 leased line	Input
p_LL155_reg	>=0	Annual STM-1 leased line price per Km (10-150 Km)	Input
p_LL155f_reg	>=0	Investment (one-off) for the provision of a regional STM-1 leased line	Input
p_LL155_ld	>=0	Annual STM-1 leased line price per Km (over 150 Km)	Input
p_LL155f_ld	>=0	Investment (one-off) for the provision of a long distance STM-1 leased line	Input
N_LL155_loc	>=0	Number of Km for local leased lines (0-10 Km)	Output
N_LL155f_loc	>=0	Number of local leased lines (0-10 Km)	Output
N_LL155_reg	>=0	Number of Km for regional leased lines (10-150 Km)	Output
N_LL155f_reg	>=0	Number of regional leased line per Km (10-150 Km)	Output
N_LL155_ld	>=0	Number of Km for long distance leased lines (over 150 Km)	Output
N_LL155f_ld	>=0	Number of long distance leased line (over 150 Km)	Output

Annual costs for leased lines are calculated as follows:

```
dc_LL155_loc_bsc_msc      =     p_LL155_loc * N_LL155_loc
dc_LL155_reg_bsc_msc      =     p_LL155_reg * N_LL155_reg
dc_LL155_ld_bsc_msc       =     p_LL155_ld * N_LL155_ld
```

Total costs:

```
dc_LL155_bsc_msc          = dc_LL155_loc_bsc_msc
                          + dc_LL155_reg_bsc_msc
                          + dc_LL155_ld_bsc_msc
```

The one-off upfront payment for leased line is treated as an investment value. The investment for the upfront payment for leased lines is calculated as follows:

```
di_LL155f_loc_bsc_msc     =     p_LL155f_loc * N_LL155f_loc
di_LL155f_reg_bsc_msc     =     p_LL155f_reg * N_LL155f_reg
di_LL155f_ld_bsc_msc      =     p_LL155f_ld * N_LL155f_ld
```

Total investment for (the upfront payment for) leased lines is as follows:

```
di_ll155f_bsc_msc         = di_LL155f_loc_bsc_msc
                          + di_LL155f_reg_bsc_msc
                          + di_LL155f_ld_bsc_msc
```

2.1.9 MSC-MSC links

MSC-MSC links use STM-1 leased lines based on a meshed core network.[5]

The leased lines capacity in the WIK-MNCM is assumed to be STM-1 (155 Mbps). Leased line prices typically vary according to their length. Transmission links between MSCs are typically realised on high capacity backbone routes in Australia. This results in lower unit prices compared to leased lines which are built alongside the backbone routes.

The price structure for these types of leased lines is also assumed to be categorised into i) prices which are given on a per kilometre basis and ii) an upfront payment for the provision of a single leased line. Note that leased line prices per kilometre are defined as a (recurring) annual cost. The distribution of the investment value over the economic lifetime of the relevant asset is therefore only required for the upfront payments. For the detailed structure of leased line prices and their description refer to Table 5-8 of the Report.

Parameter	Value	Description	Source
p_LL155_core	>=0	Annual STM-1 leased line price per Km for core network links	Input
p_LL155f_core	>=0	Investment (one-off) for the provision of a core STM-1 leased line	Input
N_LL155_core	>=0	Number of Km for local leased lines	Output
N_LL155f_core	>=0	Number of local leased lines	Output

```
dc_LL155_core=      p_LL155_core * N_LL155_core

di_LL155f_core =    p_LL155f_core * N_LL155f_core
```

5 The core network design algorithm of the WIK-MNCM incorporates a function which provides a routing of the E1 demand between two MSC locations over an intermediate MSC to optimise the used capacities of the STM-1 links. WIK-Consult assumes a STM-1 capacity of 50 E1s, hence a rerouting takes place only for a direct E1 demand of lower than 25 E1 groups assuming that the both other STM-1 groups have sufficient free capacity.

2.2 Investment in network support assets

Investment for the network support assets includes assets to be used for network management, operation and maintenance. These investments are not explicitly modelled. This approach is explained in section 4.3 of the Report. Assets in this category would generally include:

- Motor vehicles ('mv'),
- Office equipment ('of'),
- Workshop, tools and small item equipment ('wo'),
- IT / general purpose computer ('it'),
- Network management ('nm'), and
- Land and buildings ('lb').

Network support assets investment is calculated on the basis of a percentage mark-up on the investment of the particular productive network asset.

2.2.1 Network support assets investment for BTSs

The network support assets investment relating to BTSs is calculated as follows:

Parameter	Value	Description	Source
iif_mv_bts	[0,1]	Investment for motor vehicles (allocated to BTS(BTS sites, equipment, TRX)) as a percentage of direct investment in BTS	Input
iif_of_bts	[0,1]	Investment for office equipment (allocated to BTS(BTS sites, equipment, TRX)) as a percentage of direct investment in BTS	Input
iif_wo_bts	[0,1]	Investment for workshop equipment (allocated to BTS(BTS sites, equipment, TRX)) as a percentage of direct investment in BTS	Input
iif_it_bts	[0,1]	Investment for IT network support equipment (allocated to BTS(BTS sites, equipment, TRX)) as a percentage of direct investment in BTS	Input
iif_nm_bts	[0,1]	Investment for network management equipment (allocated to BTS(BTS sites, equipment, TRX)) as a percentage of direct investment in BTS	Input
iif_lb_bts	[0,1]	Investment for land and buildings equipment (allocated to BTS(BTS sites, equipment, TRX)) as a percentage of direct investment in BTS	Input

2.2.1.1 Indirect Investment for BTS sites

```
ii_bts_site_mv      =      iif_mv_bts * di_bts_site
ii_bts_site_of      =      iif_of_bts * di_bts_site
ii_bts_site_wo      =      iif_wo_bts * di_bts_site
ii_bts_site_it      =      iif_it_bts * di_bts_site
ii_bts_site_nm      =      iif_nm_bts * di_bts_site
ii_bts_site_lb      =      iif_lb_bts * di_bts_site
```

Total network support assets investment relating to BTS sites is:

```
ii_bts_site         =      ii_bts_site_mv
                    +      ii_bts_site_of
                    +      ii_bts_site_wo
                    +      ii_bts_site_it
                    +      ii_bts_site_nm
                    +      ii_bts_site_lb
```

2.2.1.2 Indirect Investment for BTS equipment

```
ii_bts_eq_mv =      iif_mv_bts * di_bts_eq
ii_bts_eq_of =      iif_of_bts * di_bts_eq
ii_bts_eq_wo =      iif_wo_bts * di_bts_eq
ii_bts_eq_it =      iif_it_bts * di_bts_eq
ii_bts_eq_nm =      iif_nm_bts * di_bts_eq
ii_bts_eq_lb =      iif_lb_bts * di_bts_eq
```

Total network support assets investment relating to BTS sites is:

```
ii_bts_eq           =      ii_bts_eq_mv
                    +      ii_bts_eq_of
                    +      ii_bts_eq_wo
                    +      ii_bts_eq_it
                    +      ii_bts_eq_nm
                    +      ii_bts_eq_lb
```

2.2.1.3 Indirect Investment for TRX

```
ii_trx_mv    =     iif_mv_bts * di_trx
ii_trx_of    =     iif_of_bts * di_trx
ii_trx_wo    =     iif_wo_bts * di_trx
ii_trx_it    =     iif_it_bts * di_trx
ii_trx_nm    =     iif_nm_bts * di_trx
ii_trx_lb    =     iif_lb_bts * di_trx
```

Total network support assets investment relating to TRX is:

```
ii_trx             =     ii_trx_mv
                   +     ii_trx_of
                   +     ii_trx_wo
                   +     ii_trx_it
                   +     ii_trx_nm
                   +     ii_trx_lb
```

2.2.1.4 Total indirect Investment for BTSs

```
ii_bts_mv    =     iif_mv_bts * di_bts
ii_bts_of    =     iif_of_bts * di_bts
ii_bts_wo    =     iif_wo_bts * di_bts
ii_bts_it    =     iif_it_bts * di_bts
ii_bts_nm    =     iif_nm_bts * di_bts
ii_bts_lb    =     iif_lb_bts * di_bts
```

Total network support assets investment relating to BTSs is:

```
ii_bts       =     ii_bts_mv
             +     ii_bts_of
             +     ii_bts_wo
             +     ii_bts_it
             +     ii_bts_nm
             +     ii_bts_lb
```

2.2.2 Network support assets investment for BSCs

The network support assets investment relating to BSCs is calculated as follows:

Parameter	Value	Description	Source
iif_mv_bsc	[0,1]	Investment for motor vehicles (allocated to BSC(sites and equipment)) as a percentage of direct investment in BSC	Input
iif_of_bsc	[0,1]	Investment for office equipment (allocated to BSC(sites and equipment)) as a percentage of direct investment in BSC	Input
iif_wo_bsc	[0,1]	Investment for workshop equipment (allocated to BSC(sites and equipment)) as a percentage of direct investment in BSC	Input
iif_it_bsc	[0,1]	Investment for IT network support equipment (allocated to BSC(sites and equipment)) as a percentage of direct investment in BSC	Input
iif_nm_bsc	[0,1]	Investment for network management equipment (allocated to BSC(sites and equipment)) as a percentage of direct investment in BSC	Input
iif_lb_bsc	[0,1]	Investment for land and buildings equipment (allocated to BSC(sites and equipment)) as a percentage of direct investment in BSC	Input

2.2.2.1 Indirect Investment for BSC sites

```
ii_bsc_site_mv      =     iif_mv_bsc * di_bsc_site
ii_bsc_site_of      =     iif_of_bsc * di_bsc_site
ii_bsc_site_wo      =     iif_wo_bsc * di_bsc_site
ii_bsc_site_it      =     iif_it_bsc * di_bsc_site
ii_bsc_site_nm      =     iif_nm_bsc * di_bsc_site
ii_bsc_site_lb      =     iif_lb_bsc * di_bsc_site
```

Total network support assets investment relating to BSC sites is:

```
ii_bsc_site         =     ii_bsc_site_mv
                    +     ii_bsc_site_of
                    +     ii_bsc_site_wo
                    +     ii_bsc_site_it
                    +     ii_bsc_site_nm
                    +     ii_bsc_site_lb
```

2.2.2.2 Indirect Investment for BSC equipment (hardware and software)

```
ii_bsc_unit        =     iif_mv_bsc * di_bsc_unit
ii_bsc_unit_of     =     iif_of_bsc * di_bsc_unit
ii_bsc_unit_wo     =     iif_wo_bsc * di_bsc_unit
ii_bsc_unit_it     =     iif_it_bsc * di_bsc_unit
ii_bsc_unit_nm     =     iif_nm_bsc * di_bsc_unit
ii_bsc_unit_lb     =     iif_lb_bsc * di_bsc_unit
```

Total network support assets investment relating to BSC equipment is:

```
ii_bsc_unit        =     ii_bsc_unit_mv
                   +     ii_bsc_unit_of
                   +     ii_bsc_unit_wo
                   +     ii_bsc_unit_it
                   +     ii_bsc_unit_nm
                   +     ii_bsc_unit_lb
```

2.2.2.3 Total indirect Investment for BSCs

```
ii_bsc_mv =  iif_mv_bsc * di_bsc
ii_bsc_of =  iif_of_bsc * di_bsc
ii_bsc_wo =  iif_wo_bsc * di_bsc
ii_bsc_it =  iif_it_bsc * di_bsc
ii_bsc_nm =  iif_nm_bsc * di_bsc
ii_bsc_lb =  iif_lb_bsc * di_bsc
```

Total network support assets investment relating to BSCs is:

```
ii_bsc = ii_bsc_mv
       + ii_bsc_of
       + ii_bsc_wo
       + ii_bsc_it
       + ii_bsc_nm
       + ii_bsc_lb
```

2.2.3 Network support assets investment for TRAUs

The network support assets investment for TRAUs is calculated as follows:

Parameter	Value	Description	Source
iif_mv_trau	[0,1]	Investment for motor vehicles (allocated to TRAU) as a percentage of direct investment in TRAU	Input
iif_of_trau	[0,1]	Investment for office equipment (allocated to TRAU) as a percentage of direct investment in TRAU	Input
iif_wo_trau	[0,1]	Investment for workshop equipment (allocated to TRAU) as a percentage of direct investment in TRAU	Input
iif_it_trau	[0,1]	Investment for IT network support equipment (allocated to TRAU) as a percentage of direct investment in TRAU	Input
iif_nm_trau	[0,1]	Investment for network management equipment (allocated to TRAU) as a percentage of direct investment in TRAU	Input
iif_lb_trau	[0,1]	Investment for land and buildings equipment (allocated to TRAU) as a percentage of direct investment in TRAU	Input

```
ii_trau_mv          = iif_mv_trau * di_trau
ii_trau_of          = iif_of_trau * di_trau
ii_trau_wo          = iif_wo_trau * di_trau
ii_trau_it          = iif_it_trau * di_trau
ii_trau_nm          = iif_nm_trau * di_trau
ii_trau_lb          = iif_lb_trau * di_trau
```

Total network support assets investment relating to TRAUs is:

```
ii_trau      = ii_trau_mv
             + ii_trau_of
             + ii_trau_wo
             + ii_trau_it
             + ii_trau_nm
             + ii_trau_lb
```

2.2.4 Network support assets investment for MSCs

Network support assets investment relating to MSCs is calculated as follows:

Parameter	Value	Description	Source
iif_mv_msc	[0,1]	Investment for motor vehicles (allocated to MSC (sites, units, ports, signaling)) as a percentage of direct investment in MSC	Input
iif_of_msc	[0,1]	Investment for office equipment (allocated to MSC (sites, units, ports, signaling)) as a percentage of direct investment in MSC	Input
iif_wo_msc	[0,1]	Investment for workshop equipment (allocated to MSC (sites, units, ports, signaling)) as a percentage of direct investment in MSC	Input
iif_it_msc	[0,1]	Investment for IT network support equipment (allocated to MSC (sites, units, ports, signaling)) as a percentage of direct investment in MSC	Input
iif_nm_msc	[0,1]	Investment for network management equipment (allocated to MSC (sites, units, ports, signaling)) as a percentage of direct investment in MSC	Input
iif_lb_msc	[0,1]	Investment for land and buildings equipment (allocated to MSC (sites, units, ports, signaling)) as a percentage of direct investment in MSC	Input

2.2.4.1 Indirect Investment for MSC sites

```
ii_msc_site_mv      =     iif_mv_msc * di_msc_site
ii_msc_site_of      =     iif_of_msc * di_msc_site
ii_msc_site_wo      =     iif_wo_msc * di_msc_site
ii_msc_site_it      =     iif_it_msc * di_msc_site
ii_msc_site_nm      =     iif_nm_msc * di_msc_site
ii_msc_site_lb      =     iif_lb_msc * di_msc_site
```

Total network support assets investment relating to MSC sites is:

```
ii_msc_site         =     ii_msc_site_mv
                    +     ii_msc_site_of
                    +     ii_msc_site_wo
                    +     ii_msc_site_it
                    +     ii_msc_site_nm
                    +     ii_msc_site_lb
```

2.2.4.2 Indirect Investment for MSC units (hardware and software)

```
ii_msc_unit_mv      =     iif_mv_msc * di_msc_unit
ii_msc_unit_of      =     iif_of_msc * di_msc_unit
ii_msc_unit_wo      =     iif_wo_msc * di_msc_unit
ii_msc_unit_it      =     iif_it_msc * di_msc_unit
ii_msc_unit_nm      =     iif_nm_msc * di_msc_unit
ii_msc_unit_lb      =     iif_lb_msc * di_msc_unit
```

Total network support assets investment relating to MSC units is:

```
ii_msc_unit         =     ii_msc_unit_mv
                    +     ii_msc_unit_of
                    +     ii_msc_unit_wo
                    +     ii_msc_unit_it
                    +     ii_msc_unit_nm
                    +     ii_msc_unit_lb
```

2.2.4.3 Indirect Investment for MSC ports

```
ii_msc_ports_mv     =     iif_mv_msc * di_msc_ports
ii_msc_ports_of     =     iif_of_msc * di_msc_ports
ii_msc_ports_wo     =     iif_wo_msc * di_msc_ports
ii_msc_ports_it     =     iif_it_msc * di_msc_ports
ii_msc_ports_nm     =     iif_nm_msc * di_msc_ports
ii_msc_ports_lb     =     iif_lb_msc * di_msc_ports
```

Total network support assets investment relating to MSC ports is:

```
ii_msc_ports        =     ii_msc_ports_mv
                    +     ii_msc_ports_of
                    +     ii_msc_ports_wo
                    +     ii_msc_ports_it
                    +     ii_msc_ports_nm
                    +     ii_msc_ports_lb
```

2.2.4.4 Indirect Investment for MSC interconnection ports

```
ii_msc_icports_mv   =     iif_mv_msc * di_msc_icports
ii_msc_icports_of   =     iif_of_msc * di_msc_icports
ii_msc_icports_wo   =     iif_wo_msc * di_msc_icports
ii_msc_icports_it   =     iif_it_msc * di_msc_icports
ii_msc_icports_nm   =     iif_nm_msc * di_msc_icports
ii_msc_icports_lb   =     iif_lb_msc * di_msc_icports
```

Total network support assets investment relating to MSC interconnection ports is:

```
ii_msc_icports      =     ii_msc_icports_mv
                    +     ii_msc_icports_of
                    +     ii_msc_icports_wo
                    +     ii_msc_icports_it
                    +     ii_msc_icports_nm
                    +     ii_msc_icports_lb
```

2.2.4.5 Network support assets investment for BSC faced ports:

```
ii_msc_bscports_mv  =     iif_mv_msc * di_msc_bscports
ii_msc_bscports_of  =     iif_of_msc * di_msc_bscports
ii_msc_bscports_wo  =     iif_wo_msc * di_msc_bscports
ii_msc_bscports_it  =     iif_it_msc * di_msc_bscports
ii_msc_bscports_nm  =     iif_nm_msc * di_msc_bscports
ii_msc_bscports_lb  =     iif_lb_msc * di_msc_bscports
```

Total network support assets investment relating to BSC faced ports is:

```
ii_msc_bscports     =     ii_msc_bscports_mv
                    +     ii_msc_bscports_of
                    +     ii_msc_bscports_wo
                    +     ii_msc_bscports_it
                    +     ii_msc_bscports_nm
                    +     ii_msc_bscports_lb
```

2.2.4.6 Network support assets investment for MSC faced ports:

```
ii_msc_mscports_mv  =     iif_mv_msc * di_msc_mscports
ii_msc_mscports_of  =     iif_of_msc * di_msc_mscports
ii_msc_mscports_wo  =     iif_wo_msc * di_msc_mscports
ii_msc_mscports_it  =     iif_it_msc * di_msc_mscports
ii_msc_mscports_nm  =     iif_nm_msc * di_msc_mscports
ii_msc_mscports_lb  =     iif_lb_msc * di_msc_mscports
```

Total network support assets investment relating to MSC faced ports is:

```
ii_msc_mscports     =     ii_msc_mscports_mv
                    +     ii_msc_mscports_of
                    +     ii_msc_mscports_wo
                    +     ii_msc_mscports_it
                    +     ii_msc_mscports_nm
                    +     ii_msc_mscports_lb
```

Network support assets investment for MSCs (excluding processor investment) is:

```
ii_msc_mv =         iif_mv_msc * di_msc
ii_msc_of =         iif_of_msc * di_msc
ii_msc_wo =         iif_wo_msc * di_msc
ii_msc_it =         iif_it_msc * di_msc
ii_msc_nm =         iif_nm_msc * di_msc
ii_msc_lb =         iif_lb_msc * di_msc
```

Network support assets investment for processor investment is:

```
Same iif_xxx used as for MSC.
ii_sig_mv =         iif_mv_msc * di_sig
ii_sig_of =         iif_of_msc * di_sig
ii_sig_wo =         iif_wo_msc * di_sig
ii_sig_it =         iif_it_msc * di_sig
ii_sig_nm =         iif_nm_msc * di_sig
ii_sig_lb =         iif_lb_msc * di_sig
```

Total network support assets investment for MSCs (excluding processor investment) is:

```
ii_msc = ii_msc_mv
       + ii_msc_of
       + ii_msc_wo
       + ii_msc_it
       + ii_msc_nm
       + ii_msc_lb
```

Total network support assets investment for processor investment:

```
ii_sig = ii_sig_mv
       + ii_sig_of
       + ii_sig_wo
       + ii_sig_it
       + ii_sig_nm
       + ii_sig_lb
```

2.2.5 Network support assets investment for the HLR

Network support assets investment relating to the HLR is calculated as follows:

Parameter	Value	Description	Source
iif_mv_hlr	[0,1]	Investment for motor vehicles (allocated to HLR) as a percentage of direct investment in HLR	Input
iif_of_hlr	[0,1]	Investment for office equipment (allocated to HLR) as a percentage of direct investment in HLR	Input
iif_wo_hlr	[0,1]	Investment for workshop equipment (allocated to HLR) as a percentage of direct investment in HLR	Input
iif_it_hlr	[0,1]	Investment for IT network support equipment (allocated to HLR) as a percentage of direct investment in HLR	Input
iif_nm_hlr	[0,1]	Investment for network management equipment (allocated to HLR) as a percentage of direct investment in HLR	Input
iif_lb_hlr	[0,1]	Investment for land and buildings equipment (allocated to HLR) as a percentage of direct investment in HLR	Input

```
ii_hlr_mv =         iif_mv_hlr * di_hlr
ii_hlr_of =         iif_of_hlr * di_hlr
ii_hlr_wo =         iif_wo_hlr * di_hlr
ii_hlr_it =         iif_it_hlr * di_hlr
ii_hlr_nm =         iif_nm_hlr * di_hlr
ii_hlr_lb =         iif_lb_hlr * di_hlr
```

Total network support assets investment for the HLR is:

```
ii_hlr       = ii_hlr_mv
             + ii_hlr_of
             + ii_hlr_wo
             + ii_hlr_it
             + ii_hlr_nm
             + ii_hlr_lb
```

2.2.6 Network support assets investment for SMSCs

Network support assets investment for the SMSCs is calculated as follows:

Parameter	Value	Description	Source
iif_mv_smsc	[0,1]	Investment for motor vehicles (allocated to SMSC) as a percentage of direct investment in SMSC	Input
iif_of_smsc	[0,1]	Investment for office equipment (allocated to SMSC) as a percentage of direct investment in SMSC	Input
iif_wo_smsc	[0,1]	Investment for workshop equipment (allocated to SMSC) as a percentage of direct investment in SMSC	Input
iif_it_smsc	[0,1]	Investment for IT network support equipment (allocated to SMSC) as a percentage of direct investment in SMSC	Input
iif_nm_smsc	[0,1]	Investment for network management equipment (allocated to SMSC) as a percentage of direct investment in SMSC	Input
iif_lb_smsc	[0,1]	Investment for land and buildings equipment (allocated to SMSC) as a percentage of direct investment in SMSC	Input

```
ii_smsc_mv =        iif_mv_smsc * di_smsc
ii_smsc_of =        iif_of_smsc * di_smsc
ii_smsc_wo =        iif_wo_smsc * di_smsc
ii_smsc_it =        iif_it_smsc * di_smsc
ii_smsc_nm =        iif_nm_smsc * di_smsc
ii_smsc_lb =        iif_lb_smsc * di_smsc
```

Total network support assets investment relating to SMSCs:

```
ii_smsc      = ii_smsc_mv
             + ii_smsc_of
             + ii_smsc_wo
             + ii_smsc_it
             + ii_smsc_nm
             + ii_smsc_lb
```

2.2.7 Network support assets investment for BTS-BSC links

2.2.7.1 Network support assets investment for the BTS-BTS hub links

Network support assets investment for the BTS-BTS hub links is calculated as follows:

Parameter	Value	Description	Source
iif_mv_rl2_bts_btsh	[0,1]	Investment for motor vehicles (allocated to radio link system) as a percentage of direct investment in radio link system	Input
iif_of_rl2_bts_btsh	[0,1]	Investment for office equipment (allocated to radio link system) as a percentage of direct investment in radio link system	Input
iif_wo_rl2_bts_btsh	[0,1]	Investment for workshop equipment (allocated to radio link system) as a percentage of direct investment in radio link system	Input
iif_it_rl2_bts_btsh	[0,1]	Investment for IT network support equipment (allocated to radio link system) as a percentage of direct investment in radio link system	Input
iif_nm_rl2_bts_btsh	[0,1]	Investment for network management equipment (allocated to radio link system) as a percentage of direct investment in radio link system	Input
iif_lb_rl2_bts_btsh	[0,1]	Investment for land and buildings equipment (allocated to radio link system) as a percentage of direct investment in radio link system	Input

```
ii_rl2_bts_btsh_mv      =     iif_mv_rl2_bts_btsh * di_rl2_bts_btsh
ii_rl2_bts_btsh_of      =     iif_of_rl2_bts_btsh * di_rl2_bts_btsh
ii_rl2_bts_btsh_wo      =     iif_wo_rl2_bts_btsh * di_rl2_bts_btsh
ii_rl2_bts_btsh_it      =     iif_it_rl2_bts_btsh * di_rl2_bts_btsh
ii_rl2_bts_btsh_nm      =     iif_nm_rl2_bts_btsh * di_rl2_bts_btsh
ii_rl2_bts_btsh_lb      =     iif_lb_rl2_bts_btsh * di_rl2_bts_btsh
```

Total network support assets investment relating to BTS-BTS hub:

```
ii_bts_btsh              = ii_rl2_bts_btsh_mv
                         + ii_rl2_bts_btsh_of
                         + ii_rl2_bts_btsh_wo
                         + ii_rl2_bts_btsh_it
                         + ii_rl2_bts_btsh_nm
                         + ii_rl2_bts_btsh_lb
```

RL fees not considered.

2.2.7.2 Network support assets investment for the BTS hub-BSC links

Network support assets investment relating to BTS hub-BSC links is calculated as follows:

- Radio link

Parameter	Value	Description	Source
iif_mv_rlx_btsh_bsc	[0,1]	Investment for motor vehicles (allocated to radio link system) as a percentage of direct investment in radio link system	Input
iif_of_rlx_btsh_bsc	[0,1]	Investment for office equipment (allocated to radio link system) as a percentage of direct investment in radio link system	Input
iif_wo_rlx_btsh_bsc	[0,1]	Investment for workshop equipment (allocated to radio link system) as a percentage of direct investment in radio link system	Input
iif_it_rlx_btsh_bsc	[0,1]	Investment for IT network support equipment (allocated to radio link system) as a percentage of direct investment in radio link system	Input
iif_nm_rlx_btsh_bsc	[0,1]	Investment for network management equipment (allocated to radio link system) as a percentage of direct investment in radio link system	Input
iif_lb_rlx_btsh_bsc	[0,1]	Investment for land and buildings equipment (allocated to radio link system) as a percentage of direct investment in radio link system	Input

```
ii_rlx_btsh_bsc_mv       =     iif_mv_rlx_btsh_bsc * di_rlx_btsh_bsc
ii_rlx_btsh_bsc_of       =     iif_of_rlx_btsh_bsc * di_rlx_btsh_bsc
ii_rlx_btsh_bsc_wo       =     iif_wo_rlx_btsh_bsc * di_rlx_btsh_bsc
ii_rlx_btsh_bsc_it       =     iif_it_rlx_btsh_bsc * di_rlx_btsh_bsc
ii_rlx_btsh_bsc_nm       =     iif_nm_rlx_btsh_bsc * di_rlx_btsh_bsc
ii_rlx_btsh_bsc_lb       =     iif_lb_rlx_btsh_bsc * di_rlx_btsh_bsc
```

Total network support assets investment relating to BTS hub-BSC radio links:

```
ii_rlx_btsh_bsc          = ii_rlx_btsh_bsc_mv
                         + ii_rlx_btsh_bsc_of
                         + ii_rlx_btsh_bsc_wo
                         + ii_rlx_btsh_bsc_it
                         + ii_rlx_btsh_bsc_nm
                         + ii_rlx_btsh_bsc_lb
RL fees not considered.
```

- Leased lines

Parameter	Value	Description	Source
iif_mv_ll2f_btsh_bsc	[0,1]	Mark-up for motor vehicles (allocated to leased lines) as a percentage of an upfront investment for leased lines	Input
iif_of_ll2f_btsh_bsc	[0,1]	Mark-up for office equipment (allocated to leased lines) as a percentage of an upfront investment for leased lines	Input
iif_wo_ll2f_btsh_bsc	[0,1]	Mark-up for workshop equipment (allocated to leased lines) as a percentage of an upfront investment for leased lines	Input
iif_it_ll2f_btsh_bsc	[0,1]	Mark-up for IT network support equipment (allocated to leased lines) as a percentage of an upfront investment for leased lines	Input
iif_nm_ll2f_btsh_bsc	[0,1]	Mark-up for network management equipment (allocated to leased lines) as a percentage of an upfront investment for leased lines	Input
iif_lb_ll2f_btsh_bsc	[0,1]	Mark-up for land and buildings equipment (allocated to leased lines) as a percentage of an upfront investment for leased lines	Input

Network support assets investment for the upfront payment (for provisioning):

```
ii_ll2f_btsh_bsc_mv      = iif_mv_ll2f_btsh_bsc * di_LL2f_btsh_bsc
ii_ll2f_btsh_bsc_of      = iif_of_ll2f_btsh_bsc * di_LL2f_btsh_bsc
ii_ll2f_btsh_bsc_wo      = iif_wo_ll2f_btsh_bsc * di_LL2f_btsh_bsc
ii_ll2f_btsh_bsc_it      = iif_it_ll2f_btsh_bsc * di_LL2f_btsh_bsc
ii_ll2f_btsh_bsc_nm      = iif_nm_ll2f_btsh_bsc * di_LL2f_btsh_bsc
ii_ll2f_btsh_bsc_lb      = iif_lb_ll2f_btsh_bsc * di_LL2f_btsh_bsc
```

Total network support assets investment relating to BTS hub - BSC links:

```
ii_ll2f_btsh_bsc         = ii_ll2f_btsh_bsc_mv
                         + ii_ll2f_btsh_bsc_of
                         + ii_ll2f_btsh_bsc_wo
                         + ii_ll2f_btsh_bsc_it
                         + ii_ll2f_btsh_bsc_nm
                         + ii_ll2f_btsh_bsc_lb
```

2.2.8 Network support assets investment for BSC-MSC links

Network support assets investment relating to BSC-MSC links is calculated as follows:

Parameter	Value	Description	Source
iif_mv_ll155f_bsc_msc	[0,1]	Mark-up for motor vehicles (allocated to STM-1 leased lines) as a percentage of an upfront investment for STM-1 leased lines	Input
iif_of_ll155f_bsc_msc	[0,1]	Mark-up for office equipment (allocated to STM-1 leased lines) as a percentage of an upfront investment for STM-1 leased lines	Input
iif_wo_ll155f_bsc_msc	[0,1]	Mark-up for workshop equipment (allocated to STM-1 leased lines) as a percentage of an upfront investment for STM-1 leased lines	Input
iif_it_ll155f_bsc_msc	[0,1]	Mark-up for IT network support equipment (allocated to STM-1 leased lines) as a percentage of an upfront investment for STM-1 leased lines	Input
iif_nm_ll155f_bsc_msc	[0,1]	Mark-up for network management equipment (allocated to STM-1 leased lines) as a percentage of an upfront investment for STM-1 leased lines	Input
iif_lb_ll155f_bsc_msc	[0,1]	Mark-up for land and buildings equipment (allocated to STM-1 leased lines) as a percentage of an upfront investment in STM-1 leased lines	Input

```
ii_ll155f_bsc_msc_mv      = iif_mv_ll155f_bsc_msc * di_LL155f_bsc_msc
ii_ll155f_bsc_msc_of      = iif_of_ll155f_bsc_msc * di_LL155f_bsc_msc
ii_ll155f_bsc_msc_wo      = iif_wo_ll155f_bsc_msc * di_LL155f_bsc_msc
ii_ll155f_bsc_msc_it      = iif_it_ll155f_bsc_msc * di_LL155f_bsc_msc
ii_ll155f_bsc_msc_nm      = iif_nm_ll155f_bsc_msc * di_LL155f_bsc_msc
ii_ll155f_bsc_msc_lb      = iif_lb_ll155f_bsc_msc * di_LL155f_bsc_msc
```

Total network support assets investment relating to BSC-MSC links:

```
ii_ll155f_bsc_msc         = ii_ll155f_bsc_msc_mv
                          + ii_ll155f_bsc_msc_of
                          + ii_ll155f_bsc_msc_wo
                          + ii_ll155f_bsc_msc_it
                          + ii_ll155f_bsc_msc_nm
                          + ii_ll155f_bsc_msc_lb
```

2.2.9 Network support assets investment for MSC-MSC links

Network support assets investment relating to MSC-MSC links is calculated as follows:

Parameter	Value	Description	Source
iif_mv_ll155f_core	[0,1]	Mark-up for motor vehicles (allocated to STM-1 core leased lines) as a percentage of an upfront investment for STM-1 core leased lines	Input
iif_of_ll155f_core	[0,1]	Mark-up for office equipment (allocated to STM-1 core leased lines) as a percentage an upfront investment for STM-1 core leased lines	Input
iif_wo_ll155f_core	[0,1]	Mark-up for workshop equipment (allocated to STM-1 core leased lines) as a percentage of an upfront investment for STM-1 core leased lines	Input
iif_it_ll155f_core	[0,1]	Mark-up for IT network support equipment (allocated to STM-1 core leased lines) as a percentage of an upfront investment for STM-1 core leased lines	Input
iif_nm_ll155f_core	[0,1]	Mark-up for network management equipment (allocated to STM-1 core leased lines) as a percentage of an upfront investment for core STM-1 leased lines	Input
iif_lb_ll155f_core	[0,1]	Mark-up for land and buildings equipment (allocated to STM-1 core leased lines) as a percentage of an upfront investment for core STM-1 leased lines	Input

Network support assets investment is calculated as follows:

```
ii_ll155f_core_mv        = iif_mv_ll155f_core * di_LL155f_core
ii_ll155f_core_of        = iif_of_ll155f_core * di_LL155f_core
ii_ll155f_core_wo        = iif_wo_ll155f_core * di_LL155f_core
ii_ll155f_core_it        = iif_it_ll155f_core * di_LL155f_core
ii_ll155f_core_nm        = iif_nm_ll155f_core * di_LL155f_core
ii_ll155f_core_lb        = iif_lb_ll155f_core * di_LL155f_core
```

Total network support assets investment relating to MSC-MSC links:

```
ii_ll155f_core           = ii_ll155f_core_mv
                         + ii_ll155f_core_of
                         + ii_ll155f_core_wo
                         + ii_ll155f_core_it
                         + ii_ll155f_core_nm
                         + ii_ll155f_core_lb
```

2.3 Output of the investment calculation

The investment calculation as shown above generates the following investment values.

Total productive network assets investment:

```
di          = di_bts
            + di_bsc
            + di_trau
            + di_msc
            + di_sig
            + di_HLR
            + di_smsc
            + di_rl2_bts_btsh
            + di_RL_fee
            + di_rlx_btsh_bsc
            + di_rl_fee_btsh_bsc
            + di_ll2f_btsh_bsc
            + di_ll155f_bsc_msc
            + di_LL155f_core
```

whereby

```
      di_bts
            di_bts_site
            di_bts_eq
            di_trx
      di_bsc
            di_bsc_site
            di_bsc_unit_hw
            di_bsc_unit_sw
      di_trau
      di_msc
            di_msc_site
            di_msc_hw
            di_msc_sw
            di_msc_ports
                  di_msc_icports
                  di_msc_bscports
                  di_msc_mscports
      di_sig
      di_HLR
      di_smsc
      di_rl2_bts_btsh
```

```
di_RL_fee
di_rlx_btsh_bsc
di_rl_fee_btsh_bsc
di_ll2f_btsh_bsc
       di_LL2f_loc_btsh_bsc
       di_LL2f_reg_btsh_bsc
       di_LL2f_ld_btsh_bsc
di_ll155f_bsc_msc
       di_LL155f_loc_bsc_msc
       di_LL155f_reg_bsc_msc
       di_LL155f_ld_bsc_msc
di_LL155f_core
```

Total network support assets investment:

```
ii         = ii_bts
           + ii_bsc
           + ii_trau
           + ii_msc
           + ii_sig
           + ii_hlr
           + ii_smsc
           + ii_bts_btsh
           + ii_rlx_btsh_bsc
           + ii_ll2f_btsh_bsc
           + ii_ll155f_bsc_msc
           + ii_LL155f_core
```

3 Cost calculation

This section outlines how investment values are converted into annual costs. Investment classified as ‘productive network assets’ and ‘network support assets’ become annualised ‘direct’ and ‘indirect’ costs respectively to represent annualised capital expenditure or CAPEX. Furthermore, this section outlines how annual operating expenses (OPEX) and common organisational-level costs are derived.

3.1 Direct costs of the productive network assets

3.1.1 Direct costs of the BTSs

3.1.1.1 Direct costs of the BTS sites

The annuity factor for the investment value of the BTS site construction is calculated on the basis of the WACC, the expected annual rate of price change (‘dp_x’), the economic lifetime (‘el_x’) as well as the growth rate for mobile services (‘g_x’).

```
af_bts_site = (WACC - dp_bts_site - g_bts_site - dp_bts_site * g_bts_site)
              / (1-((1 + dp_bts_site) * (1+ g_bts_site)
              / (1 + WACC))^el_bts_site)
```

Annual direct costs for the BTS sites are then calculated by:

```
dc_bts_site = di_bts_site * af_bts_site
```

3.1.1.2 Direct costs of the BTS equipment

The annuity factor for the investment value of the BTS equipment is calculated on the basis of the WACC, the expected annual rate of price change (‘dp_x’) , the economic lifetime (‘el_x’) as well as the growth rate for mobile services (‘g_x’).

```
af_bts_eq =   (WACC - dp_bts_eq - g_bts_eq - dp_bts_eq * g_bts_eq)
              / (1-((1 + dp_bts_eq)*(1 + g_bts_eq)
              / (1 + WACC))^el_bts_eq)
```

Annual direct costs for the BTS equipment are then calculated by:

```
dc_bts_eq =  af_bts_eq * di_bts_eq
```

3.1.1.3 Direct costs of the TRXs

The annuity factor for the investment value of the TRX equipment is calculated on the basis of the WACC, the expected annual rate of price change (‘dp_x’), the economic lifetime (‘el_x’) as well as the growth rate for mobile services (‘g_x’).

```
af_trx =      (WACC - dp_trx - g_trx - dp_trx * g_trx)
              / (1-((1 + dp_trx)*(1+ g_trx)
              / (1 + WACC))^el_trx)
```

Annual direct costs are then calculated by:

```
dc_trx =  af_trx * di_trx
```

3.1.1.4 Total direct costs for the BTSs

Total direct costs for the BTSs are: *)

```
dc_bts       = dc_bts_site
             + dc_bts_eq
             + dc_trx
             + lic_GSM900
             + lic_GSM1800
             + gsm1800freq

whereby
gsm1800freq   =    di_gsm1800freq * [(WACC - dp_gsm1800freq - g_gsm1800freq
              - dp_ gsm1800freq * g_ gsm1800freq)
              / (1-((1 + dp_ gsm1800freq)*(1+ g_ gsm1800freq)
              / (1 + WACC))^el_ gsm1800freq)]
```

*) *Note, that the annual licence fee costs for GSM 900 frequencies are added at this point to the BTS direct costs as annual costs. The investment figure for the GSM 1,800 licence fee is outlined in section 3.5 of the Report and converted to annual cost on the basis of the annuity formula.*

3.1.2 Direct costs of the BSC

3.1.2.1 Direct costs of the BSC sites

The annuity factor for the investment value of the BSC sites is calculated on the basis of the WACC, the expected annual rate of price change (‘dp_x’), the economic lifetime (‘el_x’) as well as the growth rate for mobile services (‘g_x’).

```
af_bsc_site =  (WACC - dp_bsc_site - g_bsc_site - dp_bsc_site * g_bsc_site)
               / (1-((1 + dp_bsc_site)*(1+ g_bsc_site)
               / (1 + WACC))^ el_bsc_site)
```

Annual direct costs for the BSC sites are then calculated by:

```
dc_bsc_site = af_bsc_site * di_bsc_site
```

3.1.2.2 Direct costs of the BSC equipment

The annuity factor for the investment value of the BSC equipment is calculated on the basis of the WACC, the expected annual rate of price change (‘dp_x’), the economic lifetime (‘el_x’) as well as the growth rate for mobile services (‘g_x’).

```
af_bsc_unit_hw =    (WACC - dp_bsc_unit_hw - g_bsc_unit_hw - dp_bsc_unit_hw *
                    g_bsc_unit_hw)
                    /(1-((1 + dp_bsc_unit_hw)*(1+ g_bsc_unit_hw)
                    / (1 + WACC))^ el_bsc_unit_hw)
af_bsc_unit_sw =    (WACC - dp_bsc_unit_sw - g_bsc_unit_sw - dp_bsc_unit_sw *
                    g_bsc_unit_sw)
                    /(1-((1 + dp_bsc_unit_sw)*(1+ g_bsc_unit_sw)
                    / (1 + WACC))^ el_bsc_unit_sw)
```

Annual direct costs for the BSC equipment are then calculated by:

```
dc_bsc_unit = af_bsc_unit_hw * di_bsc_unit_hw + af_bsc_unit_sw * di_bsc_unit_sw
```

3.1.2.3 Total direct costs for the BSCs

Total direct costs for the BSCs are:

```
dc_bsc              =      dc_bsc_site
                    +      dc_bsc_unit
```

3.1.3 Direct costs of the TRAUs

The annuity factor for the investment value of the TRAU equipment is calculated on the basis of the WACC, the expected annual rate of price change (‘dp_x’), the economic lifetime (‘el_x’) as well as the growth rate for mobile services (‘g_x’).

```
af_trau =      (WACC - dp_trau - g_trau - dp_trau * g_trau)
               /(1-((1 + dp_trau)*(1+ g_trau)
               / (1 + WACC))^el_trau)
```

Annual direct costs for the TRAUs are calculated by:

```
dc_trau =     af_trau * di_trau
```

3.1.4 Direct costs of the MSCs

3.1.4.1 Direct costs of the MSC sites

The annuity factor for the investment value of the MSC sites is calculated on the basis of the WACC, the expected annual rate of price change (‘dp_x’), the economic lifetime (‘el_x’) as well as the growth rate for mobile services (‘g_x’).

```
af_msc_site  = (WACC - dp_msc_site - g_msc_site - dp_msc_site * g_msc_site)
             /(1-((1 + dp_msc_site)*(1 + g_msc_site)
             / (1 + WACC))^el_msc_site)
```

Annual direct costs for the MSC sites are calculated by:

```
dc_msc_site  = af_msc_site * di_msc_site
```

3.1.4.2 Direct costs of the MSC (hardware and software) equipment

The annuity factor for the investment value of the MSC is calculated on the basis of the WACC, the expected annual rate of price change ('dp_x'), the economic lifetime ('el_x') as well as the growth rate for mobile services ('g_x').

```
af_msc_hw      = (WACC - dp_msc_hw - g_msc_hw - dp_msc_hw * g_msc_hw)
               / (1-((1 + dp_msc_hw)(1 + g_msc_hw)
               / (1 + WACC))^el_msc_hw)
af_msc_sw      = (WACC - dp_msc_sw - g_msc_sw - dp_msc_sw * g_msc_sw)
               / (1-((1 + dp_msc_sw)(1 + g_msc_sw)
               / (1 + WACC))^el_msc_sw)
```

Annual direct costs for the MSC equipment are calculated by:

```
dc_msc_unit  = af_msc_hw * di_msc_hw + af_msc_sw * di_msc_sw
```

Processor and signalling annual direct costs are calculated by using the same annuity factor used for the MSC equipment:

```
dc_sig       = af_msc_hw * di_sig
```

3.1.4.3 Direct costs of the MSC ports

The annuity factor for the investment value of the MSC ports is calculated on the basis of the WACC, the expected annual rate of price change ('dp_x'), the economic lifetime ('el_x') as well as the growth rate for mobile services ('g_x').

```
af_ports           = (WACC - dp_ports - g_ports - dp_ports * g_ports)
                   / (1-((1 + dp_ports)(1 + g_ports)
                   / (1 + WACC))^el_ports)
```

Annual direct costs for the MSC ports are then calculated by:

```
dc_msc_icports     = af_ports * di_msc_icports
dc_msc_bscports    = af_ports * di_msc_bscports
dc_msc_mscports    = af_ports * di_msc_mscports

dc_msc_ports       =     dc_msc_icports
                   +     dc_msc_bscports
                   +     dc_msc_mscports
```

3.1.4.4 Total direct costs for the MSC

```
Total direct costs for the MSC (excluding processor and signalling)

dc_msc       = dc_msc_site
             + dc_msc_unit
             + dc_msc_ports

Total direct cost for processor and signalling

dc_sig       = dc_sig
```

3.1.5 Direct costs of the HLR

The annuity factor for the investment value of the HLR is calculated on the basis of the WACC, the expected annual rate of price change (‘dp_x’), the economic lifetime (‘el_x’) as well as the growth rate for mobile services (‘g_x’).

```
af_hlr             = (WACC - dp_hlr - g_hlr - dp_hlr * g_hlr)
                   / (1-((1 + dp_hlr)(1 + g_hlr)
                   / (1 + WACC))^el_hlr)
```

Annual direct costs for the HLR are calculated by:

```
dc_hlr = af_hlr * di_hlr
```

3.1.6 Direct costs of the SMSC

The annuity factor for the investment value of the SMSC is calculated on the basis of the WACC, the expected annual rate of price change (‘dp_x’), the economic lifetime (‘el_x’) as well as the growth rate for mobile services (‘g_x’).

```
af_smsc            = (WACC - dp_smsc - g_smsc - dp_smsc * g_smsc)
                   / (1-((1 + dp_smsc)*(1 + g_smsc)
                   / (1 + WACC))^el_smsc)
```

Annual direct costs for the SMSCs are calculated by:

```
dc_smsc      = af_smsc * di_smsc
```

3.1.7 Direct costs of the BTS-BSC links

3.1.7.1 Direct costs of the BTS-BTS hub links

The annuity factor for the investment value of the BTS-BTS hub links is calculated on the basis of the WACC, the expected annual rate of price change ('dp_x'), the economic lifetime ('el_x') as well as the growth rate for mobile services ('g_x').

```
af_rl2        = (WACC - dp_rl2 - g_rl2 - dp_rl2 * g_rl2)
              / (1-((1 + dp_rl2)*(1 + g_rl2)
              / (1 + WACC))^el_rl2)
```

Annual direct costs of the BTS-BTS hub radio links are calculated by:

```
dc_rl2_bts_btsh          = af_rl2 * di_rl2_bts_btsh
                         + n_khz_bts_btsh * p_khz_bts_btsh
                         + di_RL_fee * af_rl2
```

where n_khz_bts_btsh is the kHz frequency required by the BTS-BTS hub including the maximum number of radio links.

Note: The fee is annualised under the conservative assumption that dp, g and el are the same as for the equipment.

3.1.7.2 BTS hub-BSC links

The annuity factor for the investment value of the BTS hub - BSC links is calculated on the basis of the WACC, the expected annual rate of price change ('dp_x'), the economic lifetime ('el_x') as well as the growth rate for mobile services ('g_x').

- Direct costs of the radio links

```
af_rlx_btsh_bsc     = (WACC - dp_rlx_btsh_bsc - g_rlx_btsh_bsc -
                    dp_rlx_btsh_bsc * g_rlx_btsh_bsc)
                    /(1-((1 + dp_rlx_btsh_bsc)*(1 + g_rlx_btsh_bsc)
                    / (1 + WACC))^el_rlx_btsh_bsc)
af_rep_btsh_bsc     = (WACC - dp_rep_btsh_bsc - g_rep_btsh_bsc -
                    dp_rep_btsh_bsc * g_rep_btsh_bsc)
                    / (1-((1 + dp_rep_btsh_bsc)*(1 + g_rep_btsh_bsc)
                    / (1 + WACC))^el_rep_btsh_bsc)
af_rep_site         = (WACC – dp_rep_site – g_rep_site – dp_rep_site *
                    g_rep_site)
                    / (1-((1 + dp_rep_site)*(1 + g_rep_site)
                    / (1 + WACC))^ el_rep_site)
```

Annual direct costs of the radio links are calculated by:

Direct costs for the radio link systems are calculated by:

```
dc_rlx_btsh_bsc     = af_rlx_btsh_bsc * di_rl2_btsh_bsc
                    + af_rlx_btsh_bsc * di_rl8_btsh_bsc
                    + af_rlx_btsh_bsc * di_rl34_btsh_bsc
                    + af_rlx_btsh_bsc * di_rl140_btsh_bsc
                    + n_khz_btsh_bsc * p_khz_btsh_bsc
                    + af_rlx_btsh_bsc * di_rl_fee_btsh_bsc
```

where n_khz_btsh_bsc is the kHz frequency required by the BTS-BTS hub including the maximum number of radio links.
Note: The fee is annualised under the conservative assumption that dp, g and el are the same as for the equipment.

Direct costs for the repeater are calculated by:

```
dc_rep_btsh_bsc     = af_rep_btsh_bsc * di_rl2_rep
                    + af_rep_btsh_bsc * di_rl8_rep
                    + af_rep_btsh_bsc * di_rl34_rep
                    + af_rep_btsh_bsc * di_r140_rep
                    + af_rep_site * di_rep_site
```

Total direct cost for the radio links are:

```
dc_rl_btsh_bsc      = dc_rlx_btsh_bsc + dc_rep_btsh_bsc
```

- Direct costs of the leased lines

```
af_LL2f_btsh_bsc    = (WACC - dp_LL2f_btsh_bsc - g_LL2f_btsh_bsc
                    - dp_LL2f_btsh_bsc * g_LL2f_btsh_bsc)
                    /(1-((1 + dp_LL2f_btsh_bsc)*(1 + g_LL2f_btsh_bsc)
                    /(1 + WACC))^el_LL2f_btsh_bsc)
```

Annual direct costs for the leased lines are calculated by:

Direct costs for the upfront investment in leased lines:

```
dc_LL2f_btsh_bsc    = af_LL2f_btsh_bsc * di_LL2f_btsh_bsc
```

Direct costs for the leased lines (based on distance):

```
dc_LL2_btsh_bsc     = dc_LL2_loc_btsh_bsc
                    + dc_LL2_reg_btsh_bsc
                    + dc_LL2_ld_btsh_bsc
```

3.1.8 Direct costs of the BSC-MSC links

```
af_LL155f_bsc_msc   = (WACC - dp_LL155f_bsc_msc - g_LL155f_bsc_msc
                    - dp_LL155f_bsc_msc * g_LL155f_bsc_msc)
                    / (1-((1 + dp_LL155f_bsc_msc)(1 + g_LL155f_bsc_msc)
                    / (1 + WACC))^el_LL155f_bsc_msc)
```

Annual direct costs for the leased lines are calculated by:

Direct costs for the upfront investment in leased lines:

```
dc_LL155f_bsc_msc   = af_LL155f_bsc_msc * di_LL155f_bsc_msc
```

Direct costs for the leased lines (based on distance):

```
dc_LL155_bsc_msc    = dc_LL155_loc_bsc_msc
                    + dc_LL155_reg_bsc_msc
                    + dc_LL155_ld_bsc_msc
```

3.1.9 Direct costs of the MSC-MSC links

```
af_LL155f_core = (WACC - dp_LL155f_core - g_LL155f_core
               - dp_LL155f_core * g_LL155f_core)
               / (1-((1 + dp_LL155f_core)(1 + g_LL155f_core)
               / (1 + WACC))^el_LL155f_core)
```

Annual direct costs are then calculated by:

Direct cost for the upfront investment in leased lines:

```
dc_LL155f_core      = af_LL155f_core * di_LL155f_core
```

Direct costs for the leased lines (based on distance):

```
dc_ll155_core       = dc_LL155_core
```

3.2 Indirect costs (related to the network support assets)

The annuity factor for the investment value of the network support assets is calculated on the basis of the WACC, the expected annual rate of price change ('dp_x'), the economic lifetime ('el_x') as well as the growth rate for mobile services ('g_x').

Indirect costs relating to the network support assets are categorised as either

- Motor vehicles,
- Office equipment,
- Workshop facilities,
- IT / general purpose computer,
- Network management, or
- Land and buildings.

The annuity factors, which are defined for each category of network support assets, are given by the following formula:

```
Motor vehicles:
af_mv          = (WACC - dp_mv - g_mv - dp_mv * g_mv)
               / (1-((1 + dp_mv)(1 + g_mv)
               / (1 + WACC))^el_mv)
Office equipment:
af_of          = (WACC - dp_of - g_of - dp_of * g_of)
               / (1-((1 + dp_of)(1 + g_of)
               / (1 + WACC))^el_of)
Workshop facilities:
af_wo          = (WACC - dp_wo - g_wo - dp_wo * g_wo)
               / (1-((1 + dp_wo)(1 + g_wo)
               / (1 + WACC))^el_wo)
General IT:
af_it          = (WACC - dp_it - g_it - dp_it * g_it)
               / (1-((1 + dp_it)(1 + g_it)
               / (1 + WACC))^el_it)
Network management:
af_nm          = (WACC - dp_nm - g_nm - dp_nm * g_nm)
               / (1-((1 + dp_nm)(1 + g_nm)
               / (1 + WACC))^el_nm)
Land and buildings:
af_lb          = (WACC - dp_lb - g_lb - dp_lb * g_lb)
               / (1-((1 + dp_lb)(1 + g_lb)
               / (1 + WACC))^el_lb)
```

Indirect annual costs are calculated for each group of productive network assets by the following formulae:

3.2.1 Indirect costs of the BTSs

3.2.1.1 Indirect costs of the BTS sites

```
ic_bts_site_mv      = ii_bts_site_mv * af_mv
ic_bts_site_of      = ii_bts_site_of * af_of
ic_bts_site_wo      = ii_bts_site_wo * af_wo
ic_bts_site_it      = ii_bts_site_it * af_it
ic_bts_site_nm      = ii_bts_site_nm * af_nm
ic_bts_site_lb      = ii_bts_site_lb * af_lb

ic_bts_site         = ic_bts_site mv
                    + ic_bts_site_of
                    + ic_bts_site_wo
                    + ic_bts_site_it
                    + ic_bts_site_nm
                    + ic_bts_site_lb
```

3.2.1.2 Indirect costs of the BTS equipment

```
ic_bts_eq_mv = ii_bts_eq_mv * af_mv
ic_bts_eq_of = ii_bts_eq_of * af_of
ic_bts_eq_wo = ii_bts_eq_wo * af_wo
ic_bts_eq_it = ii_bts_eq_it * af_it
ic_bts_eq_nm = ii_bts_eq_nm * af_nm
ic_bts_eq_lb = ii_bts_eq_lb * af_lb

ic_bts_eq           = ic_bts_eq mv
                    + ic_bts_eq_of
                    + ic_bts_eq_wo
                    + ic_bts_eq_it
                    + ic_bts_eq_nm
                    + ic_bts_eq_lb
```

3.2.1.3 Indirect costs of the TRX

```
ic_trx_mv    = ii_trx_mv * af_mv
ic_trx_of    = ii_trx_of * af_of
ic_trx_wo    = ii_trx_wo * af_wo
ic_trx_it    = ii_trx_it * af_it
ic_trx_nm    = ii_trx_nm * af_nm
ic_trx_lb    = ii_trx_lb * af_lb

ic_trx              = ic_trx mv
                    + ic_trx_of
                    + ic_trx_wo
                    + ic_trx_it
                    + ic_trx_nm
                    + ic_trx_lb
```

3.2.1.4 Total indirect costs of the BTSs

```
ic_bts_mv    = ii_bts_mv * af_mv
ic_bts_of    = ii_bts_of * af_of
ic_bts_wo    = ii_bts_wo * af_wo
ic_bts_it    = ii_bts_it * af_it
ic_bts_nm    = ii_bts_nm * af_nm
ic_bts_lb    = ii_bts_lb * af_lb

ic_bts       = ic_bts mv
             + ic_bts_of
             + ic_bts_wo
             + ic_bts_it
             + ic_bts_nm
             + ic_bts_lb
```

3.2.2 Indirect costs of the BSCs

3.2.2.1 Indirect costs of the BSC sites

```
ic_bsc_site_mv      = ii_bsc_site_mv * af_mv
ic_bsc_site_of      = ii_bsc_site_of * af_of
ic_bsc_site_wo      = ii_bsc_site_wo * af_wo
```

```
ic_bsc_site_it      = ii_bsc_site_it * af_it
ic_bsc_site_nm      = ii_bsc_site_nm * af_nm
ic_bsc_site_lb      = ii_bsc_site_lb * af_lb

ic_bsc_site         = ic_bsc_site mv
                    + ic_bsc_site_of
                    + ic_bsc_site_wo
                    + ic_bsc_site_it
                    + ic_bsc_site_nm
                    + ic_bsc_site_lb
```

3.2.2.2 Indirect costs of the BSC equipment (hardware and software)

```
ic_bsc_unit_mv      = ii_bsc_unit_mv * af_mv
ic_bsc_unit_of      = ii_bsc_unit_of * af_of
ic_bsc_unit_wo      = ii_bsc_unit_wo * af_wo
ic_bsc_unit_it      = ii_bsc_unit_it * af_it
ic_bsc_unit_nm      = ii_bsc_unit_nm * af_nm
ic_bsc_unit_lb      = ii_bsc_unit_lb * af_lb

ic_bsc_unit         = ic_bsc_unit_mv
                    + ic_bsc_unit_of
                    + ic_bsc_unit_wo
                    + ic_bsc_unit_it
                    + ic_bsc_unit_nm
                    + ic_bsc_unit_lb
```

3.2.2.3 Total indirect costs of the BSCs

```
     ic_bsc_mv =    ii_bsc_mv * af_mv
     ic_bsc_of =    ii_bsc_of * af_of
     ic_bsc_wo =    ii_bsc_wo * af_wo
     ic_bsc_it =    ii_bsc_it * af_it
     ic_bsc_nm =    ii_bsc_nm * af_nm
     ic_bsc_lb =    ii_bsc_lb * af_lb
```

Total indirect costs associated with the BSCs:

```
ic_bsc  =     ic_bsc_mv
        +     ic_bsc_of
        +     ic_bsc_wo
        +     ic_bsc_it
        +     ic_bsc_nm
        +     ic_bsc_lb
```

3.2.3 Indirect costs of the TRAUs

```
ic_trau_mv =  ii_trau_mv * af_mv
ic_trau_of =  ii_trau_of * af_of
ic_trau_wo =  ii_trau_wo * af_wo
ic_trau_it =  ii_trau_it * af_it
ic_trau_nm =  ii_trau_nm * af_nm
ic_trau_lb =  ii_trau_lb * af_lb
```

Total indirect costs associated with the TRAUs:

```
 ic_trau      =     ic_trau_mv
              +     ic_trau_of
              +     ic_trau_wo
              +     ic_trau_it
              +     ic_trau_nm
              +     ic_trau_lb
```

3.2.4 Indirect costs of the MSCs

3.2.4.1 Indirect costs of the MSC sites

```
ic_msc_site_mv     = ii_msc_site_mv * af_mv
ic_msc_site_of     = ii_msc_site_of * af_of
ic_msc_site_wo     = ii_msc_site_wo * af_wo
ic_msc_site_it     = ii_msc_site_it * af_it
ic_msc_site_nm     = ii_msc_site_nm * af_nm
ic_msc_site_lb     = ii_msc_site_lb * af_lb
```

```
ic_msc_site         = ic_msc_site mv
                    + ic_msc_site_of
                    + ic_msc_site_wo
                    + ic_msc_site_it
                    + ic_msc_site_nm
                    + ic_msc_site_lb
```

3.2.4.2 Indirect costs of the MSC units (hardware and software)

```
ic_msc_unit_mv      = ii_msc_unit_mv * af_mv
ic_msc_unit_of      = ii_msc_unit_of * af_of
ic_msc_unit_wo      = ii_msc_unit_wo * af_wo
ic_msc_unit_it      = ii_msc_unit_it * af_it
ic_msc_unit_nm      = ii_msc_unit_nm * af_nm
ic_msc_unit_lb      = ii_msc_unit_lb * af_lb

ic_msc_unit         = ic_msc_unit mv
                    + ic_msc_unit_of
                    + ic_msc_unit_wo
                    + ic_msc_unit_it
                    + ic_msc_unit_nm
                    + ic_msc_unit_lb
```

3.2.4.3 Indirect costs of the MSC ports

```
ic_msc_ports_mv     = ii_msc_ports_mv * af_mv
ic_msc_ports_of     = ii_msc_ports_of * af_of
ic_msc_ports_wo     = ii_msc_ports_wo * af_wo
ic_msc_ports_it     = ii_msc_ports_it * af_it
ic_msc_ports_nm     = ii_msc_ports_nm * af_nm
ic_msc_ports_lb     = ii_msc_ports_lb * af_lb

ic_msc_ports        = ic_msc_ports mv
                    + ic_msc_ports_of
                    + ic_msc_ports_wo
                    + ic_msc_ports_it
                    + ic_msc_ports_nm
                    + ic_msc_ports_lb
```

3.2.4.4 Indirect costs of the MSC interconnection ports

```
ic_msc_icports_mv   = ii_msc_icports_mv * af_mv
ic_msc_icports_of   = ii_msc_icports_of * af_of
ic_msc_icports_wo   = ii_msc_icports_wo * af_wo
ic_msc_icports_it   = ii_msc_icports_it * af_it
ic_msc_icports_nm   = ii_msc_icports_nm * af_nm
ic_msc_icports_lb   = ii_msc_icports_lb * af_lb

ic_msc_icports      = ic_msc_icports mv
                    + ic_msc_icports_of
                    + ic_msc_icports_wo
                    + ic_msc_icports_it
                    + ic_msc_icports_nm
                    + ic_msc_icports_lb
```

3.2.4.5 Indirect costs of the BSC faced ports

```
ic_msc_bscports_mv  = ii_msc_bscports_mv * af_mv
ic_msc_bscports_of  = ii_msc_bscports_of * af_of
ic_msc_bscports_wo  = ii_msc_bscports_wo * af_wo
ic_msc_bscports_it  = ii_msc_bscports_it * af_it
ic_msc_bscports_nm  = ii_msc_bscports_nm * af_nm
ic_msc_bscports_lb  = ii_msc_bscports_lb * af_lb

ic_msc_bscports     = ic_msc_bscports mv
                    + ic_msc_bscports_of
                    + ic_msc_bscports_wo
                    + ic_msc_bscports_it
                    + ic_msc_bscports_nm
                    + ic_msc_bscports_lb
```

3.2.4.6 Indirect costs of the MSC faced ports

```
ic_msc_mscports_mv  = ii_msc_mscports_mv * af_mv
ic_msc_mscports_of  = ii_msc_mscports_of * af_of
ic_msc_mscports_wo  = ii_msc_mscports_wo * af_wo
ic_msc_mscports_it  = ii_msc_mscports_it * af_it
ic_msc_mscports_nm  = ii_msc_mscports_nm * af_nm
ic_msc_mscports_lb  = ii_msc_mscports_lb * af_lb
```

```
ic_msc_mscports     = ic_msc_mscports mv
                    + ic_msc_mscports_of
                    + ic_msc_mscports_wo
                    + ic_msc_mscports_it
                    + ic_msc_mscports_nm
                    + ic_msc_mscports_lb
```

3.2.4.7 Total indirect cost of the MSCs

```
ic_msc_mv =  ii_msc_mv * af_mv
ic_msc_of =  ii_msc_of * af_of
ic_msc_wo =  ii_msc_wo * af_wo
ic_msc_it =  ii_msc_it * af_it
ic_msc_nm =  ii_msc_nm * af_nm
ic_msc_lb =  ii_msc_lb * af_lb
```

Indirect costs for the processor:

```
ic_sig_mv =  ii_sig_mv * af_mv
ic_sig_of =  ii_sig_of * af_of
ic_sig_wo =  ii_sig_wo * af_wo
ic_sig_it =  ii_sig_it * af_it
ic_sig_nm =  ii_sig_nm * af_nm
ic_sig_lb =  ii_sig_lb * af_lb
```

Total indirect costs associated with the MSCs (excluding processor and signalling):

```
      ic_msc        = ic_msc_mv
                    + ic_msc_of
                    + ic_msc_wo
                    + ic_msc_it
                    + ic_msc_nm
                    + ic_msc_lb
```

Total indirect costs associated with the processor investment:

```
     ic_sig         = ic_sig_mv
                    + ic_sig_of
                    + ic_sig_wo
                    + ic_sig_it
                    + ic_sig_nm
                    + ic_sig_lb
```

3.2.5 Indirect costs of the HLR

```
ic_hlr_mv =  ii_hlr_mv * af_mv
ic_hlr_of =  ii_hlr_of * af_of
ic_hlr_wo =  ii_hlr_wo * af_wo
ic_hlr_it =  ii_hlr_it * af_it
ic_hlr_nm =  ii_hlr_nm * af_nm
ic_hlr_lb =  ii_hlr_lb * af_lb
```

Total indirect costs associated with the HLR:

```
ic_hlr = ic_hlr_mv
       + ic_hlr_of
       + ic_hlr_wo
       + ic_hlr_it
       + ic_hlr_nm
       + ic_hlr_lb
```

3.2.6 Indirect costs of the SMSCs

```
ic_smsc_mv = ii_smsc_mv * af_mv
ic_smsc_of = ii_smsc_of * af_of
ic_smsc_wo = ii_smsc_wo * af_wo
ic_smsc_it = ii_smsc_it * af_it
ic_smsc_nm = ii_smsc_nm * af_nm
ic_smsc_lb = ii_smsc_lb * af_lb
```

Total indirect costs associated with the SMSCs:

```
ic_smsc      = ic_smsc_mv
             + ic_smsc_of
             + ic_smsc_wo
             + ic_smsc_it
             + ic_smsc_nm
             + ic_smsc_lb
```

3.2.7 Indirect costs of the BTS-BSC links

3.2.7.1 Indirect costs of the BTS-BTS hub links

```
ic_rl2_bts_btsh_mv  =     ii_rl2_bts_btsh_mv * af_mv
ic_rl2_bts_btsh_of  =     ii_rl2_bts_btsh_of * af_of
ic_rl2_bts_btsh_wo  =     ii_rl2_bts_btsh_wo * af_wo
ic_rl2_bts_btsh_it  =     ii_rl2_bts_btsh_it * af_it
ic_rl2_bts_btsh_nm  =     ii_rl2_bts_btsh_nm * af_nm
ic_rl2_bts_btsh_lb  =     ii_rl2_bts_btsh_lb * af_lb
```

Total indirect costs associated with the BTS – BTS hub links:

```
ic_rl2_bts_btsh     = ic_rl2_bts_btsh_mv
                    + ic_rl2_bts_btsh_of
                    + ic_rl2_bts_btsh_wo
                    + ic_rl2_bts_btsh_it
                    + ic_rl2_bts_btsh_nm
                    + ic_rl2_bts_btsh_lb
Note: RL Fees not considered.
```

3.2.7.2 Indirect costs of the BTS hub-BSC links

- Indirect costs of the radio link

Indirect costs for the radio link systems:

```
ic_rlx_btsh_bsc_mv  =     ii_rlx_btsh_bsc_mv * af_mv
ic_rlx_btsh_bsc_of  =     ii_rlx_btsh_bsc_of * af_of
ic_rlx_btsh_bsc_wo  =     ii_rlx_btsh_bsc_wo * af_wo
ic_rlx_btsh_bsc_it  =     ii_rlx_btsh_bsc_it * af_it
ic_rlx_btsh_bsc_nm  =     ii_rlx_btsh_bsc_nm * af_nm
ic_rlx_btsh_bsc_lb  =     ii_rlx_btsh_bsc_lb * af_lb
```

Total indirect costs for the BTS hub-BSC radio links:

```
ic_rl_btsh_bsc            = ic_rlx_btsh_bsc_mv
                          + ic_rlx_btsh_bsc_of
                          + ic_rlx_btsh_bsc_wo
                          + ic_rlx_btsh_bsc_it
                          + ic_rlx_btsh_bsc_nm
                          + ic_rlx_btsh_bsc_lb
```

Note: RL fees not considered.

- Indirect costs of the leased lines:

```
ic_ll2f_btsh_bsc_mv = ii_ll2f_btsh_bsc_mv * af_mv
ic_ll2f_btsh_bsc_of = ii_ll2f_btsh_bsc_of * af_of
ic_ll2f_btsh_bsc_wo = ii_ll2f_btsh_bsc_wo * af_wo
ic_ll2f_btsh_bsc_it = ii_ll2f_btsh_bsc_it * af_it
ic_ll2f_btsh_bsc_nm = ii_ll2f_btsh_bsc_nm * af_nm
ic_ll2f_btsh_bsc_lb = ii_ll2f_btsh_bsc_lb * af_lb

ic_ll2f_btsh_bsc    = ic_ll2f_btsh_bsc_mv
                    + ic_ll2f_btsh_bsc_of
                    + ic_ll2f_btsh_bsc_wo
                    + ic_ll2f_btsh_bsc_it
                    + ic_ll2f_btsh_bsc_nm
                    + ic_ll2f_btsh_bsc_lb
```

Total indirect costs relating to the BTS hub-BSC links:

```
ic_btsh_bsc         = ic_rl_btsh_bsc
                    + ic_ll2f_btsh_bsc
```

3.2.8 Indirect costs of the BSC-MSC links

```
ic_ll155f_bsc_msc_mv      = ii_ll155f_bsc_msc_mv * af_mv
ic_ll155f_bsc_msc_of      = ii_ll155f_bsc_msc_of * af_of
ic_ll155f_bsc_msc_wo      = ii_ll155f_bsc_msc_wo * af_wo
ic_ll155f_bsc_msc_it      = ii_ll155f_bsc_msc_it * af_it
ic_ll155f_bsc_msc_nm      = ii_ll155f_bsc_msc_nm * af_nm
ic_ll155f_bsc_msc_lb      = ii_ll155f_bsc_msc_lb * af_lb


ic_ll155f_bsc_msc         = ic_ll155f_bsc_msc_mv
                          + ic_ll155f_bsc_msc_of
                          + ic_ll155f_bsc_msc_wo
                          + ic_ll155f_bsc_msc_it
                          + ic_ll155f_bsc_msc_nm
                          + ic_ll155f_bsc_msc_lb
```

3.2.9 Indirect costs of the MSC-MSC links

```
ic_ll155f_core_mv   = ii_ll155f_core_mv * af_mv
ic_ll155f_core_of   = ii_ll155f_core_of * af_of
ic_ll155f_core_wo   = ii_ll155f_core_wo * af_wo
ic_ll155f_core_it   = ii_ll155f_core_it * af_it
ic_ll155f_core_nm   = ii_ll155f_core_nm * af_nm
ic_ll155f_core_lb   = ii_ll155f_core_lb * af_lb


ic_ll155f_core            = ic_ll155f_core_mv
                          + ic_ll155f_core_of
                          + ic_ll155f_core_wo
                          + ic_ll155f_core_it
                          + ic_ll155f_core_nm
                          + ic_ll155f_core_lb
```

3.3 OPEX

The calculation of OPEX is outlined in this section. It is a widely accepted approach to derive annual operating expenditures as percentage mark-ups on investment. Given that OPEX is typically varies between the different network assets (productive network assets and network support assets), different mark-ups are applied to each category of network asset as outlined below.

ocf_x	[0,1]	Annual OPEX for BTS sites, BTS equipment etc. as a percentage of investment	Input
ocf_mv	[0,1]	Annual OPEX for equipment (motor vehicles) as a percentage of investment	Input
ocf_of	[0,1]	Annual OPEX for equipment (office equipment) as a percentage of investment	Input
ocf_wo	[0,1]	Annual OPEX for equipment (workshop equipment) as a percentage of investment	Input
ocf_it	[0,1]	Annual OPEX for equipment (IT network support) as a percentage of investment	Input
ocf_nm	[0,1]	Annual OPEX for equipment (network management equipment) as a percentage of investment	Input
ocf_lb	[0,1]	Annual OPEX for equipment (land and buildings equipment) as a percentage of investment	Input

3.3.1 OPEX relating to the BTSs

OPEX related to BTSs is different for each of the BTS types: Macrocells, Microcells and Picocells. OPEX is derived for productive network assets as well as for network support assets relating to the BTSs.

The impact of BTS site sharing on OPEX: As long as BTS sites are shared between operators the model assumes that this also holds for site-related OPEX. For this purpose the OPEX calculation for BTS sites is based on the site investment adjusted for any site sharing cost savings that accrue.

OPEX relating to the BTS sites

```
oc_di_bts_site          = ocf_bts * di_bts_site
oc_ii_bts_site          = ocf_mv * ii_bts_site_mv
                        + ocf_of * ii_bts_site_of
                        + ocf_wo * ii_bts_site_wo
                        + ocf_it * ii_bts_site_it
                        + ocf_nm * ii_bts_site_nm
                        + ocf_lb * ii_bts_site_lb
```

```
oc_bts_site_              = oc_di_bts_site_
                          + oc_ii_bts_site_
```

OPEX relating to the BTS equipment

```
oc_di_bts_eq              = ocf_bts * di_bts_eq
oc_ii_bts_eq              = ocf_mv * ii_bts_eq_mv
                          + ocf_of * ii_bts_eq_of
                          + ocf_wo * ii_bts_eq_wo
                          + ocf_it * ii_bts_eq_it
                          + ocf_nm * ii_bts_eq_nm
                          + ocf_lb * ii_bts_eq_lb
oc_bts_eq_                = oc_di_eq_
                          + oc_ii_bts_eq
```

OPEX relating to TRXs

```
oc_di_trx                 = ocf_bts * di_trx
oc_ii_trx                 = ocf_mv * ii_trx_mv
                          + ocf_of * ii_trx_of
                          + ocf_wo * ii_trx_wo
                          + ocf_it * ii_trx_it
                          + ocf_nm * ii_trx_nm
                          + ocf_lb * ii_trx_lb

oc_trx_                   = oc_di_trx_
                          + oc_ii_trx
```

Total OPEX relating to the BTSs

```
oc_di_bts           = ocf_bts * di_bts
oc_ii_bts           = ocf_mv * ii_bts mv
                    + ocf_of * ii_bts_of
                    + ocf_wo * ii_bts_wo
                    + ocf_it * ii_bts_it
                    + ocf_nm * ii_bts_nm
                    + ocf_lb * ii_bts_lb
oc_bts              = oc_di_bts
                    + oc_ii_bts
```

3.3.2 OPEX relating to the BSCs

OPEX relating to the BSC sites

```
oc_di_bsc_site            = ocf_bsc * di_bsc_site
oc_ii_bsc_site            = ocf_mv * ii_bsc_site_mv
                          + ocf_of * ii_bsc_site_of
                          + ocf_wo * ii_bsc_site_wo
                          + ocf_it * ii_bsc_site_it
                          + ocf_nm * ii_bsc_site_nm
                          + ocf_lb * ii_bsc_site_lb

oc_bsc_site_              = oc_di_bsc_site_
                          + oc_ii_bsc_site_
```

OPEX relating to the BSC equiment (hardware and software)

```
oc_di_bsc_unit            = ocf_bsc * di_bsc_unit
oc_ii_bsc_unit            = ocf_mv * ii_bsc_unit_mv
                          + ocf_of * ii_bsc_unit_of
                          + ocf_wo * ii_bsc_unit_wo
                          + ocf_it * ii_bsc_unit_it
                          + ocf_nm * ii_bsc_unit_nm
                          + ocf_lb * ii_bsc_unit_lb

oc_bsc_unit_              = oc_di_bsc_unit_
                          + oc_ii_bsc_unit_
```

Total OPEX relating to the BSCs

```
oc_di_bsc          = ocf_bsc * di_bsc
oc_ii_bsc          = ocf_mv * ii_bsc_mv
                   + ocf_of * ii_bsc_of
                   + ocf_wo * ii_bsc_wo
                   + ocf_it * ii_bsc_it
                   + ocf_nm * ii_bsc_nm
                   + ocf_lb * ii_bsc_lb

oc_bsc             = oc_di_bsc
                   + oc_ii_bsc
```

3.3.3 OPEX relating to the TRAUs

```
oc_di_trau          = ocf_trau * di_trau
oc_ii_trau          = ocf_mv * ii_trau_mv
                    + ocf_of * ii_trau_of
                    + ocf_wo * ii_trau_wo
                    + ocf_it * ii_trau_it
                    + ocf_nm * ii_trau_nm
                    + ocf_lb * ii_trau_lb

oc_trau             = oc_di_trau
                    + oc_ii_trau
```

3.3.4 OPEX relating to the MSCs

OPEX relating to the MSC sites

```
oc_di_msc_site            = ocf_msc * di_msc_site
oc_ii_msc_site            = ocf_mv * ii_msc_site_mv
                          + ocf_of * ii_msc_site_of
                          + ocf_wo * ii_msc_site_wo
                          + ocf_it * ii_msc_site_it
                          + ocf_nm * ii_msc_site_nm
                          + ocf_lb * ii_msc_site_lb

oc_msc_site_              = oc_di_msc_site_
                          + oc_ii_msc_site_
```

OPEX relating to the MSC units

```
oc_di_msc_unit            = ocf_msc * di_msc_unit
oc_ii_msc_unit            = ocf_mv * ii_msc_unit_mv
                          + ocf_of * ii_msc_unit_of
                          + ocf_wo * ii_msc_unit_wo
                          + ocf_it * ii_msc_unit_it
                          + ocf_nm * ii_msc_unit_nm
                          + ocf_lb * ii_msc_unit_lb

oc_msc_unit_              = oc_di_msc_unit_
                          + oc_ii_msc_unit_
```

OPEX relating to the MSC ports

```
oc_di_msc_ports          = ocf_msc * di_msc_ports
oc_ii_msc_ports          = ocf_mv * ii_msc_ports_mv
                         + ocf_of * ii_msc_ports_of
                         + ocf_wo * ii_msc_ports_wo
                         + ocf_it * ii_msc_ports_it
                         + ocf_nm * ii_msc_ports_nm
                         + ocf_lb * ii_msc_ports_lb

oc_msc_ports_            = oc_di_msc_ports
                         + oc_ii_msc_ports
```

OPEX relating to the MSC interconnection ports

```
oc_di_msc_icports        = ocf_msc * di_msc_icports
oc_ii_msc_icports        = ocf_mv * ii_msc_icports_mv
                         + ocf_of * ii_msc_icports_of
                         + ocf_wo * ii_msc_icports_wo
                         + ocf_it * ii_msc_icports_it
                         + ocf_nm * ii_msc_icports_nm
                         + ocf_lb * ii_msc_icports_lb

oc_msc_icports           = oc_di_msc_icports
                         + oc_ii_msc_icports
```

OPEX relating to the BSC faced ports

```
oc_di_msc_bscports       = ocf_msc * di_msc_bscports
oc_ii_msc_bscports       = ocf_mv * ii_msc_bscports_mv
                         + ocf_of * ii_msc_bscports_of
                         + ocf_wo * ii_msc_bscports_wo
                         + ocf_it * ii_msc_bscports_it
                         + ocf_nm * ii_msc_bscports_nm
                         + ocf_lb * ii_msc_bscports_lb

oc_msc_bscports          = oc_di_msc_bscports
                         + oc_ii_msc_bscports
```

OPEX relating to the MSC faced ports

```
oc_di_msc_mscports        = ocf_msc * di_msc_mscports
oc_ii_msc_mscports        = ocf_mv * ii_msc_mscports_mv
                          + ocf_of * ii_msc_mscports_of
                          + ocf_wo * ii_msc_mscports_wo
                          + ocf_it * ii_msc_mscports_it
                          + ocf_nm * ii_msc_mscports_nm
                          + ocf_lb * ii_msc_mscports_lb

oc_msc_mscports           = oc_di_msc_mscports
                          + oc_ii_msc_mscports
```

OPEX relating to the MSCs (excluding signalling):

```
oc_di_msc          = ocf_msc * di_msc
oc_ii_msc          = ocf_mv * ii_msc_mv
                   + ocf_of * ii_msc_of
                   + ocf_wo * ii_msc_wo
                   + ocf_it * ii_msc_it
                   + ocf_nm * ii_msc_nm
                   + ocf_lb * ii_msc_lb
```

OPEX relating to the processor:

```
Same OC factor (operating cost factor) as for MSC used.
oc_di_sig          = ocf_msc * di_sig
oc_ii_sig          = ocf_mv * ii_sig_mv
                   + ocf_of * ii_sig_of
                   + ocf_wo * ii_sig_wo
                   + ocf_it * ii_sig_it
                   + ocf_nm * ii_sig_nm
                   + ocf_lb * ii_sig_lb

oc_msc             = oc_di_msc
                   + oc_ii_msc

oc_sig             = oc_di_sig
                   + oc_ii_sig
```

3.3.5 OPEX relating to the HLR

Input parameters:

ocf_hlr	>0	Annual OPEX for HLR as a percentage of investment	Input

OPEX relating to the HLR:

```
oc_di_hlr          = di_hlr * ocf_hlr
oc_ii_hlr          = ocf_mv * ii_hlr_mv
                   + ocf_of * ii_hlr_of
                   + ocf_wo * ii_hlr_wo
                   + ocf_it * ii_hlr_it
                   + ocf_nm * ii_hlr_nm
                   + ocf_lb * ii_hlr_lb
```

Total OPEX relating to the HLR:

```
oc_hlr       = oc_di_hlr
             + oc_ii_hlr
```

3.3.6 OPEX relating to the SMSCs

Input parameters:

ocf_smsc	>0	Annual OPEX for SMSC as a percentage of investment	Input

OPEX relating to the SMSCs:

```
oc_di_smsc         = di_smsc * ocf_smsc
oc_ii_smsc         = ocf_mv * ii_smsc_mv
                   + ocf_of * ii_smsc_of
                   + ocf_wo * ii_smsc_wo
                   + ocf_it * ii_smsc_it
                   + ocf_nm * ii_smsc_nm
                   + ocf_lb * ii_smsc_lb
```

Total OPEX relating to the SMSCs:

```
oc_smsc            = oc_di_smsc
                   + oc_ii_smsc
```

3.3.7 OPEX relating to the BTS-BSC links

3.3.7.1 OPEX relating to the BTS-BTS hub links

```
oc_di_bts_btsh      = ocf_bts_btsh * di_rl2_bts_btsh
oc_ii_bts_btsh      = ocf_mv * ii_rl2_bts_btsh_mv
                    + ocf_of * ii_rl2_bts_btsh_of
                    + ocf_wo * ii_rl2_bts_btsh_wo
                    + ocf_it * ii_rl2_bts_btsh_it
                    + ocf_nm * ii_rl2_bts_btsh_nm
                    + ocf_lb * ii_rl2_bts_btsh_lb

oc_bts_btsh         = oc_di_bts_btsh
                    + oc_ii_bts_btsh
```

Note: RL Fees are not considered here.

3.3.7.2 OPEX relating to the BTS hub-BSC links

- OPEX relating to the radio links

```
OPEX for the radio links

oc_di_rl_btsh_bsc   = ocf_rl_btsh_bsc * di_rlx_btsh_bsc
oc_ii_rl_btsh_bsc   = ocf_mv * ii_rlx_btsh_bsc_mv
                    + ocf_of * ii_rlx_btsh_bsc_of
                    + ocf_wo * ii_rlx_btsh_bsc_wo
                    + ocf_it * ii_rlx_btsh_bsc_it
                    + ocf_nm * ii_rlx_btsh_bsc_nm
                    + ocf_lb * ii_rlx_btsh_bsc_lb

oc_rl_btsh_bsc      = oc_di_rl_btsh_bsc
                    + oc_ii_rl_btsh_bsc

Note: RL fees not considered.
```

- OPEX relating to the leased lines

```
oc_di_ll2f_btsh_bsc = ocf_ll2f_btsh_bsc * di_ll2f_btsh_bsc
oc_ii_ll2f_btsh_bsc = ocf_mv * ii_ll2f_btsh_bsc_mv
                    + ocf_of * ii_ll2f_btsh_bsc_of
                    + ocf_wo * ii_ll2f_btsh_bsc_wo
                    + ocf_it * ii_ll2f_btsh_bsc_it
                    + ocf_nm * ii_ll2f_btsh_bsc_nm
                    + ocf_lb * ii_ll2f_btsh_bsc_lb

oc_ll2f_btsh_bsc    = oc_di_ll2f_btsh_bsc
                    + oc_ii_ll2f_btsh_bsc
```

- Total OPEX relating to BTS hub-BSC links:

```
oc_btsh_bsc  = oc_rl_btsh_bsc
             + oc_ll2f_btsh_bsc
```

3.3.8 OPEX relating to the BSC-MSC links

```
oc_di_ll155f_bsc_msc      = ocf_ll155f_bsc_msc * di_ll155f_bsc_msc
oc_ii_ll155f_bsc_msc      = ocf_mv * ii_ll155f_bsc_msc_mv
                          + ocf_of * ii_ll155f_bsc_msc_of
                          + ocf_wo * ii_ll155f_bsc_msc_wo
                          + ocf_it * ii_ll155f_bsc_msc_it
                          + ocf_nm * ii_ll155f_bsc_msc_nm
                          + ocf_lb * ii_ll155f_bsc_msc_lb
```

Total OPEX relating to the BSC-MSC links:

```
oc_ll155f_bsc_msc         = oc_di_ll155f_bsc_msc
                          + oc_ii_ll155f_bsc_msc
```

3.3.9 OPEX relating to the MSC-MSC links

```
oc_di_ll155f_core         = ocf_llf155_core * di_LL155f_core
oc_ii_ll155f_core         = ocf_mv * ii_ll155f_core_mv
                          + ocf_of * ii_ll155f_core_of
                          + ocf_wo * ii_ll155f_core_wo
                          + ocf_it * ii_ll155f_core_it
                          + ocf_nm * ii_ll155f_core_nm
                          + ocf_lb * ii_ll155f_core_lb
```

Total OPEX relating to the MSC-MSC links:

```
oc_ll155f_core            = oc_di_ll155f_core
                          + oc_ii_ll155f_core
```

3.4 Total annual network costs

The total annual network costs include total direct costs, total indirect costs and total OPEX. Additionally, common organisational-level costs (overhead, administration, management etc.) that are calculated as a mark-up on total annual network costs are also factored in.

3.4.1 Total direct cost

Total direct costs are given by the sum of the direct costs for each group of productive network assets. These costs are calculated as follows:

```
totdc        = dc_bts
             + dc_bsc
             + dc_trau
             + dc_msc
             + dc_sig
             + dc_hlr
             + dc_smsc
             + dc_rl2_bts_btsh
             + dc_rl_btsh_bsc
             + dc_LL2_btsh_bsc
             + dc_LL2f_btsh_bsc
             + dc_ll155_bsc_msc
             + dc_ll155f_bsc_msc
             + dc_ll155_core
             + dc_ll155f_core
```

3.4.2 Total indirect cost

Similarly, total indirect costs are calculated by adding the corresponding indirect costs for each category of network support assets. These costs are calculated as follows:

```
totic        = ic_bts
             + ic_bsc
             + ic_trau
             + ic_msc
             + ic_sig
             + ic_hlr
             + ic_smsc
             + ic_rl2_bts_bths
             + ic_rl_btsh_bsc
```

```
            + ic_ll2f_btsh_bsc
            + ic_ll155f_bsc_msc
            + ic_ll155f_core
```

3.4.3 Total OPEX

The OPEX calculated for each category of network assets is added to obtain the total OPEX. These costs are calculated as follows:

```
totoc  = oc_bts
       + oc_bsc
       + oc_trau
       + oc_msc
       + oc_sig
       + oc_hlr
       + oc_smsc
       + oc_bts_btsh
       + oc_rl_btsh_bsc
       + oc_ll2f_btsh_bsc
       + oc_ll155f_bsc_msc
       + oc_ll155f_core
```

3.4.4 Common organisational-level costs

Common organisational-level costs are calculated as a percentage mark-up on total network costs (total direct costs, total indirect costs and total OPEX). This mark-up for common organisational-level costs is added to each network asset (productive network assets and network support assets).

Parameter	Value	Description	Source
Coco	[0;1]	Mark-up for common cost (in per cent)	Input
coco_fix	>= 0	(Additional) common cost as a fixed annual amount	Input

Common organisational-level cost mark-up on network assets

```
coco_bts_var              = (dc_bts + ic_bts + oc_bts) * coco
       coco_bts_site_var  = (dc_bts_site + ic_bts_site + oc_bts_site) * coco
       coco_bts_eq_var    = (dc_bts_eq + ic_bts_eq + oc_bts_eq) * coco
       coco_trx_var       = (dc_trx + ic_trx + oc_trx) * coco
       coco_lic_GSM900_var = (lic_GSM900) * coco
       coco_lic_GSM1800_var= (lic_GSM1800) * coco
       coco_GSM1800freq_var= (GSM1800freq) * coco
```

```
coco_bsc_var              = (dc_bsc + ic_bsc + oc_bsc) * coco
      coco_bsc_site_var   = (dc_bsc_site + ic_bsc_site + oc_bsc_site) * coco
      coco_bsc_unit_var   = (dc_bsc_unit + ic_bsc_unit + oc_bsc_unit) * coco

coco_trau_var             = (dc_trau + ic_trau + oc_trau) * coco

coco_msc_var              = (dc_msc + ic_msc + oc_msc) * coco

            coco_msc_site_var   = (dc_msc_site + ic_msc_site + oc_msc_site) *
            coco

            coco_msc_unit_var   = (dc_msc_unit + ic_msc_unit + oc_msc_unit) *
            coco

            coco_msc_ports_var  = (dc_msc_ports + ic_msc_ports + oc_msc_ports)
            * coco

            coco_msc_icports_var=   (dc_msc_icports   +   ic_msc_icports   +
            oc_msc_icports) * coco

            coco_msc_bscports_var=  (dc_msc_bscports  +  ic_msc_bscports  +
            oc_msc_bscports) * coco

            coco_msc_mscports_var=  (dc_msc_mscports  +  ic_msc_mscports  +
            oc_msc_mscports) * coco

coco_sig_var              = (dc_sig + ic_sig + oc_sig) * coco

coco_hlr_var              = (dc_hlr + ic_hlr + oc_hlr) * coco

coco_smsc_var             = (dc_smsc + ic_smsc + oc_smsc) * coco

coco_rl2_bts_btsh_var     = (dc_rl2_bts_btsh + ic_rl2_bts_btsh + oc_bts_btsh)
                          * coco

coco_rl_btsh_bsc_var      = (dc_rl_btsh_bsc + ic_rl_btsh_bsc + oc_rl_btsh_bsc)
                          * coco

coco_ll2f_btsh_bsc_var    = (dc_ll2f_btsh_bsc + ic_ll2f_btsh_bsc
                          + oc_ll2f_btsh_bsc) * coco
```

```
coco_ll155f_bsc_msc_var   = (dc_ll155f_bsc_msc + ic_ll155f_bsc_msc
                          + oc_ll155f_bsc_msc) * coco

coco_ll155f_core_var      = (dc_ll155f_core + ic_ll155f_core + oc_ll155f_core)
                           * coco
coco_ll2_btsh_bsc_var     = dc_ll2_btsh_bsc * coco

coco_ll155_bsc_msc_var    = dc_ll155_bsc_msc * coco

coco_ll155_core_var       = dc_ll155_core * coco
```

Fixed common organisational-level costs

```
div_fix = totdc + totic + totoc

coco_bts_fix              = coco_fix * (dc_bts + ic_bts + oc_bts)/div_fix
      coco_bts_site_fix   = coco_fix * (dc_bts_site + ic_bts_site
                          + oc_bts_site)/div_fix
      coco_bts_eq_fix     = coco_fix * (dc_bts_eq + ic_bts_eq
                           + oc_bts_eq)/div_fix
      coco_trx_fix        = coco_fix * (dc_trx + ic_trx
                           + oc_trx)/div_fix
      coco_lic_GSM900_fix = coco_fix * (lic_GSM900)/div_fix
      coco_lic_GSM1800_fix= coco_fix * (lic_GSM1800)/div_fix
      coco_GSM1800freq_fix= coco_fix * (GSM1800freq)/div_fix

coco_bsc_fix              = coco_fix * (dc_bsc + ic_bsc + oc_bsc)/div_fix
      coco_bsc_site_fix   = coco_fix * (dc_bsc_site + ic_bsc_site
                          + oc_bsc_site)/div_fix

      coco_bsc_unit_fix   = coco_fix * (dc_bsc_unit + ic_bsc_unit
                          + oc_bsc_unit)/div_fix

coco_trau_fix             = coco_fix * (dc_trau + ic_trau + oc_trau)/div_fix

coco_msc_fix              = coco_fix * (dc_msc + ic_msc + oc_msc)/div_fix

      coco_msc_site_fix   = coco_fix * (dc_msc_site + ic_msc_site
                          + oc_msc_site)/div_fix

      coco_msc_unit_fix   = coco_fix * (dc_msc_unit + ic_msc_unit
                          + oc_msc_unit)/div_fix

      coco_msc_ports_fix  = coco_fix * (dc_msc_ports + ic_msc_ports
                          + oc_msc_ports)/div_fix

      coco_msc_icports_fix= coco_fix * (dc_msc_icports + ic_msc_icports
                          + oc_msc_icports)/div_fix

      coco_msc_bscports_fix= coco_fix * (dc_msc_bscports + ic_msc_bscports
                          + oc_msc_bscports)/div_fix

      coco_msc_mscports_fix= coco_fix * (dc_msc_mscports + ic_msc_mscports
                          + oc_msc_mscports)/div_fix
```

```
coco_sig_fix              = coco_fix * (dc_sig + ic_sig + oc_sig)/div_fix

coco_hlr_fix              = coco_fix * (dc_hlr + ic_hlr + oc_hlr)/div_fix

coco_smsc_fix             = coco_fix * (dc_smsc + ic_smsc + oc_smsc)/div_fix

coco_rl2_bts_btsh_fix     = coco_fix * (dc_rl2_bts_btsh + ic_rl2_bts_btsh
                          + oc_bts_btsh)/div_fix

coco_rl_btsh_bsc_fix      = coco_fix * (dc_rl_btsh_bsc + ic_rl_btsh_bsc
                          + oc_rl_btsh_bsc)/div_fix

coco_LL2f_btsh_bsc_fix    = coco_fix * (dc_LL2f_btsh_bsc + ic_LL2f_btsh_bsc
                          + oc_LL2f_btsh_bsc)/div_fix

coco_LL155f_bsc_msc_fix   = coco_fix * (dc_LL155f_bsc_msc + ic_LL155f_bsc_msc
                          + oc_LL155f_bsc_msc)/div_fix

coco_LL155f_core_fix      = coco_fix * (dc_LL155f_core + ic_LL155f_core
                          + oc_LL155f_core)/div_fix

coco_LL2_btsh_bsc_fix     = coco_fix * dc_LL2_btsh_bsc/div_fix

coco_LL155_bsc_msc_fix    = coco_fix * dc_LL155_bsc_msc/div_fix

coco_LL155_core_fix       = coco_fix * dc_LL155_core/div_fix
```

Total value of common organisational-level costs applied to each network asset

```
coco_bts                  = coco_bts_var + coco_bts_fix
      coco_bts_site       = coco_bts_site_var + coco_bts_site_fix

      coco_bts_eq         = coco_bts_eq_var + coco_bts_eq_fix

      coco_trx            = coco_trx_var + coco_trx_fix

      coco_lic_GSM900     = coco_lic_GSM900_var + coco_lic_GSM900_fix

      coco_lic_GSM1800    = coco_lic_GSM1800_var + coco_lic_GSM1800_fix

      coco_GSM1800freq    = coco_GSM1800freq_var + coco_GSM1800freq_fix

coco_bsc                  = coco_bsc_var + coco_bsc_fix
      coco_bsc_site       = coco_bsc_site_var + coco_bsc_site_fix

      coco_bsc_unit       = coco_bsc_unit_var + coco_bsc_unit_fix

coco_trau                 = coco_trau_var + coco_trau_fix

coco_msc                  = coco_msc_var + coco_msc_fix
      coco_msc_site       = coco_msc_site_var + coco_msc_site_fix

      coco_msc_unit       = coco_msc_unit_var + coco_msc_unit_fix

      coco_msc_ports      = coco_msc_ports_var + coco_msc_ports_fix

      coco_msc_icports    = coco_msc_icports_var + coco_msc_icports_fix

      coco_msc_bscports   = coco_msc_bscports_var + coco_msc_bscports_fix

      coco_msc_mscports   = coco_msc_mscports_var + coco_msc_mscports_fix
```

```
coco_sig                  = coco_sig_var + coco_sig_fix

coco_hlr                  = coco_hlr_var + coco_hlr_fix

coco_smsc                 = coco_smsc_var + coco_smsc_fix

coco_rl2_bts_btsh         = coco_rl2_bts_btsh_var + coco_rl2_bts_btsh_fix

coco_rl_btsh_bsc          = coco_rl_btsh_bsc_var + coco_rl_btsh_bsc_fix

coco_LL2f_btsh_bsc        = coco_LL2f_btsh_bsc_var
                          + coco_LL2f_btsh_bsc_fix
coco_LL155f_bsc_msc       = coco_LL155f_bsc_msc_var + coco_LL155f_bsc_msc_fix

coco_LL155f_core          = coco_LL155f_core_var + coco_LL155f_core_fix

coco_LL2_btsh_bsc         = coco_LL2_btsh_bsc_var
                          + coco_LL2_btsh_bsc_fix

coco_LL155_bsc_msc        = coco_LL155_bsc_msc_var
                          + coco_LL155_bsc_msc_fix

coco_LL155_core           = coco_LL155_core_var + coco_LL155_core_fix



totcoco                   = coco_bts
                          + coco_bsc
                          + coco_trau
                          + coco_msc
                          + coco_sig
                          + coco_hlr
                          + coco_smsc
                          + coco_rl2_bts_btsh
                          + coco_rl_btsh_bsc
                          + coco_LL2f_btsh_bsc
                          + coco_LL155f_bsc_msc
                          + coco_LL155f_core
                          + coco_LL2_btsh_bsc
                          + coco_LL155_bsc_msc
                          + coco_LL155_core
```

Effective common organisational-level cost mark-up

```
coco_bts_eff              = coco_bts / (dc_bts + ic_bts + oc_bts)

coco_bsc_eff              = coco_bsc / (dc_bsc + ic_bsc + oc_bsc)

coco_trau_eff             = coco_trau / (dc_trau + ic_trau + oc_trau)

coco_msc_eff              = coco_msc / (dc_msc + ic_msc + oc_msc)

coco_sig_eff              = coco_sig / (dc_sig + ic_sig + oc_sig)

coco_hlr_eff              = coco_hlr / (dc_hlr + ic_hlr + oc_hlr)

coco_smsc_eff             = coco_smsc / (dc_smsc + ic_smsc + oc_smsc)

coco_rl2_bts_btsh_eff     = coco_rl2_bts_btsh
                          / (dc_rl2_bts_btsh + ic_rl2_bts_btsh
                          + oc_bts_btsh)

coco_rl_btsh_bsc_eff      = coco_rl_btsh_bsc
```

```
                          / (dc_rl_btsh_bsc + ic_rl_btsh_bsc
                          + oc_rl_btsh_bsc)

coco_LL2f_btsh_bsc_eff    = coco_LL2f_btsh_bsc
                          / (dc_LL2f_btsh_bsc + ic_LL2f_btsh_bsc
                          + oc_LL2f_btsh_bsc)

coco_LL155f_bsc_msc_eff   = coco_LL155f_bsc_msc
                          / (dc_LL155f_bsc_msc + ic_LL155f_bsc_msc
                          + oc_LL155f_bsc_msc)

coco_LL155f_core_eff      = coco_LL155f_core
                          / (dc_LL155f_core + ic_LL155f_core
                          + oc_LL155f_core)

coco_LL2_btsh_bsc_eff     = coco_LL2_btsh_bsc / dc_LL2_btsh_bsc

coco_LL155_bsc_msc_eff    = coco_LL155_bsc_msc / dc_LL155_bsc_msc

coco_LL155_core_eff       = coco_LL155_core / dc_LL155_core
```

3.4.5 Total annual network element costs

The total annual network element costs are derived using the following equations:

3.4.5.1 Total cost for the BTSs

```
Total cost for BTS sites

tot_bts_site       = dc_bts_site + ic_bts_site + oc_bts_site + coco_bts_site


Total cost for BTS equipment

tot_bts_eq                = dc_bts_eq + ic_bts_eq + oc_bts_eq + coco_bts_eq

Total cost for TRX

tot_trx                   = dc_trx + ic_trx + oc_trx + coco_trx


Total cost for annual license fee (GSM 900 frequency)

tot_lic_GSM900            = lic_GSM900 + coco_lic_GSM900


Total cost for annual license fee (GSM 1800 frequency)

tot_lic_GSM1800           = lic_GSM1800 + coco_lic_GSM1800
```

Total cost for license fee (Annualised investment in GSM 1800 frequency)

```
tot_GSM1800freq          = GSM1800freq + coco_GSM1800freq
```

Total cost for BTS

```
tot_bts            = dc_bts + ic_bts + oc_bts + coco_bts
```

3.4.5.2 Total cost for the BSCs

Total cost for BSC sites

```
tot_bsc_site       = dc_bsc_site + ic_bsc_site + oc_bsc_site + coco_bsc_site
```

Total cost for BSC equipment (hardware and software)

```
tot_bsc_unit       = dc_bsc_unit + ic_bsc_unit + oc_bsc_unit + coco_bsc_unit
```

Total cost for the BSCs

```
tot_bsc            = dc_bsc + ic_bsc + oc_bsc + coco_bsc
```

3.4.5.3 Total cost for TRAUs

```
tot_trau           = dc_trau + ic_trau + oc_trau + coco_trau
```

3.4.5.4 Total cost for MSCs

Total cost for MSC sites

```
tot_msc_site       = dc_msc_site + ic_msc_site + oc_msc_site + coco_msc_site
```

Total cost for MSC units (hardware and software)

```
tot_msc_unit       = dc_msc_unit + ic_msc_unit + oc_msc_unit + coco_msc_unit
```

Total cost for MSC ports

```
tot_msc_ports      =    dc_msc_ports    +    ic_msc_ports    +    oc_msc_ports
                   + coco_msc_ports
```

Total cost for MSC interconnection ports

```
tot_msc_icports     =   dc_msc_icports   +   ic_msc_icports   +   oc_msc_icports
                    + coco_msc_icports
```

Total cost for BSC faced ports

```
tot_msc_bscports    =  dc_msc_bscports  +  ic_msc_bscports  +  oc_msc_bscports
                    + coco_msc_bscports
```

Total cost for MSC faced ports

```
tot_msc_mscports    =  dc_msc_mscports  +  ic_msc_mscports  +  oc_msc_mscports
                    + coco_msc_mscports
```

Total cost for the MSCs (exluding processing)

```
tot_msc             = dc_msc + ic_msc + oc_msc + coco_msc
```

Total cost for the processor

```
tot_sig             = dc_sig + ic_sig + oc_sig + coco_sig

tot_hlr             = dc_hlr + ic_hlr + oc_hlr + coco_hlr

tot_smsc            = dc_smsc + ic_smsc + oc_smsc + coco_smsc

tot_rl2_bts_btsh    = dc_rl2_bts_btsh + ic_rl2_bts_btsh + oc_bts_btsh
                    + coco_rl2_bts_btsh

tot_rl_btsh_bsc     = dc_rl_btsh_bsc + ic_rl_btsh_bsc + oc_rl_btsh_bsc
                    + coco_rl_btsh_bsc

tot_ll2f_btsh_bsc   = dc_ll2f_btsh_bsc + ic_ll2f_btsh_bsc + oc_ll2f_btsh_bsc
                    + coco_ll2f_btsh_bsc

tot_ll155f_bsc_msc  = dc_ll155f_bsc_msc + ic_ll155f_bsc_msc
                    + oc_ll155f_bsc_msc + coco_ll155f_bsc_msc

tot_ll155f_core     = dc_ll155f_core + ic_ll155f_core + oc_ll155f_core
                    + coco_ll155f_core

tot_ll2_btsh_bsc    = dc_ll2_btsh_bsc + coco_LL2_btsh_bsc
```

```
tot_ll155_bsc_msc   = dc_ll155_bsc_msc + coco_LL155_bsc_msc

tot_ll155_core      = dc_ll155_core + coco_LL155_core

total_cost          = tot_bts
                    + tot_bsc
                    + tot_trau
                    + tot_msc
                    + tot_sig
                    + tot_hlr
                    + tot_smsc
                    + tot_rl2_bts_btsh
                    + tot_rl_btsh_bsc
                    + tot_ll2f_btsh_bsc
                    + tot_ll155f_bsc_msc
                    + tot_ll155f_core
                    + tot_ll2_btsh_bsc
                    + tot_ll155_bsc_msc
                    + tot_ll155_core
```

3.5 Costs per minute

The WIK-MNCM's overall objective is to derive the average cost per minute for the MTAS. The underlying investment values and associated cost calculations for the mobile network derived above are used to estimate the cost per minute of the MTAS.

3.5.1 Relevant services

To derive the cost per minute of the MTAS the following need to be identified: The network elements required for the provision of the MTAS, as well as other services also using these network elements. The cost calculations identify the cost of the network elements used to produce the MTAS:

Figure 3-1: Relevant Services

Service	
1	Voice Origination Off-Net
2	Voice Termination Off-Net
3	Voice On-Net
4	SMS
5	Basic Data Service with 9.6 Kbps
6	MMS
7	GPRS
8	High Speed Circuit Switched Data Service

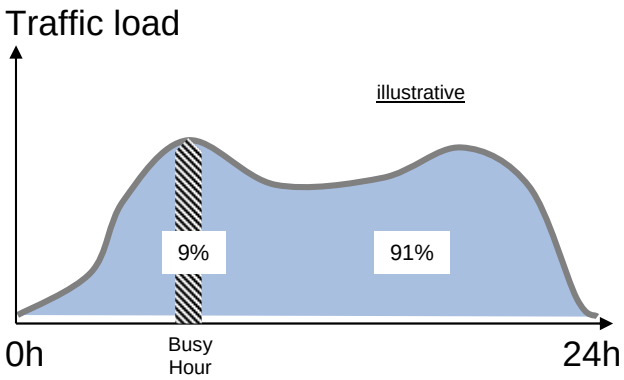
Figure 3-1 identifies the mix of services that are typically demanded by mobile users. The traffic volume for each service is calculated by using the input parameters shown in the 'Voice and Data Service Parameters' window. Once the traffic is calculated, an output file is written to derive the relative values of traffic for each service.

3.5.2 Annual traffic volumes

The costs calculated for the network elements relate to busy hour traffic volumes. Annual traffic volumes are then calculated for each network element to derive average (network element) costs per minute.

The network dimensioning is undertaken for traffic loads during the busy hour. These volumes need to be converted to annual traffic volumes. Annual traffic figures can be converted using the assumption that the busy hour traffic is a typical share of the daily traffic. A typical traffic load curve can take the following form as shown in Figure 3-2:

Figure 3-2: Traffic load curve and busy hour



Shape and percentages are examples only.

The share of the traffic volume in the busy hour in the daily traffic volume is an input parameter for the model. The traffic load curve is typically not valid for 365 days in a year, for example traffic loads differ between business days and over the weekend. To account for this a further input parameter defines the relevant number of days relevant for the busy hour pattern.

Using the ratio of busy hour traffic to total day traffic in a typical day and the number of typical days in a year, the model converts busy hour traffic into annual traffic. The typical day is defined as the day in the working week with the highest busy hour traffic. The number of typical days is that number which, if multiplied with the volume of traffic in a typical day, would generate the total volume of traffic in a year. The number of busy days derived in the model is an estimate, which can be verified by empirical data. A figure for annual traffic is required because (i) total costs are expressed as an annual figure, and (ii) an aggregation over any shorter period within the year would be influenced by seasonal variations.

The model uses annual minutes of traffic for calculating the per minute cost per service. The number of network elements is generally driven by the total minutes of successful calls (billable minutes) as well as by the number of busy hour call attempts, independent of whether they are successful or unsuccessful. However, the cost of unsuccessful calls are in the end also borne by billable minutes.

There are two different calculations to be made, (i) to derive the total annual minutes of actual billable traffic, and (ii) to derive the total number of busy hour call attempts (successful and unsuccessful call attempts), which are as outlined borne by total annual billable traffic. The relevant volumes are determined as follows:

$$\text{Annual traffic} = \left(\frac{\text{Busy hour traffic} \cdot (1 - \text{Ratio\_unbillable\_minutes})}{\text{Percentage busy hour of the day}} \right) \cdot \text{Number of days}$$

$$\text{Annual number of successful call attempts} = \left(\frac{\text{Successful busy hour call attempts}}{\text{Percentage busy hour day}} \right) \cdot \text{Number of days}$$

The model sums the total traffic routed on each network element, by each type of relevant service i.

	Total traffic per year for service i routed over network element j				**Note**
Network Element	i=1	…	i		
BTS	at1_bts	…	ati_bts	at_bts	
BSC	at1_bsc	…	ati_bsc	at_bsc	
TRAU	at1_trau		ati_trau	at_trau	
MSC	at1_msc	…	ati_msc	at_msc	
SP and CP	at1_sig	…	ati_sig	at_...	Measured in terms of call attempts
HLR	at1_HLR	…	ati_hlr	at_...	
SMSC	at1_smsc	…	ati_...	at_...	
BTS-BTS hub	at1_...	…	ati_...	at_...	
BTS hub – BSC	at1_...	…	ati_...	at_...	
BSC-MSC	at1_...	…	ati_...	at_...	
MSC-MSC	at1_...	…	ati_...	at_...	
Sum		..			

3.5.3 Unit network element costs

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

$$\text{Unit\_costs}_{\text{Network\_element\_j}} = \frac{\text{Total annual network element costs\_j}}{\text{at\_j}}$$

The network elements signal processing (SP), central processing (CP) and HLR are driven by the number of call attempts of the relevant services. For the purpose of deriving network elements' costs per minute the following equation is applied:

$$Unit\_costs_{Sig} = \left[\frac{\text{tot\_sig}}{\text{Annual number of call attempts}} \right] * \text{Average number of call attempts per min.}$$

By setting the HLR usage factor to 1 for terminating services, the total annual costs of the HLR are distributed over the total calls generated by subscribers of voice-Off-Net incoming and voice On-Net services which means that all the traffic for these services uses the HLR once, see also usage factors below.

3.5.4 Usage factors

One important step in the modelling process is to derive the usage factors which identify the amount of each element's output required to provide each service. In order to calculate incremental service costs, incremental unit output costs are multiplied by the usage factors according to the equations below.

For the calculation of the usage factors it is necessary to know the total traffic generated:

	By subscriber generated ('outgoing') total traffic demand per year for service i			
	i=1	…	i	
Subscriber	gt1	…	gti	gt

With these values the usage factors are calculated as follows:

$$uf^{\text{Service\_i}}_{\text{Network element group j}} = \frac{\text{Annual traffic of service i routed over network element group j}}{\text{Generated annual traffic of service i}}$$

Network element	**Network element usage factors for service i**		
	i=1		i
BTS	uf1_bts = at1_bts / gt1	…	ufi_bts = ati_bts / gti
BSC	uf1_bsc = at1_bsc / gt1	…	ufi_bsc = ati_bsc / gti
MSC	uf1_msc = at1_msc / gt1	…	ufi_msc = ati_msc / gti
Signalling			
HLR	**		
SMSC			
BTS-BTS hub	uf1_... = at1_... / gt1	…	ufi_... = ati_... / gti

Network element	Network element usage factors for service i		
BTS hub – BSC	uf1_... = at1_... / gt1	…	ufi_... = ati_... / gti
BSC-MSC	uf1_... = at1_... / gt1	…	ufi_... = ati_... / gti
MSC-MSC	uf1_... = at1_... / gt1	…	ufi_... = ati_... / gti

3.5.5 Cost per service minute

The costs per minute of service i are calculated by:

$$\text{Costs\_per\_minute}_{\text{Service\_i}} = \sum_{\textit{Network elements\_ j}} \text{Unit\_costs}_{\text{Network element\_j}} * \text{uf}^{\text{Service\_i}}_{\text{Network element\_j}}$$

3.6 Output of the cost calculation

The model calculates the network element cost figures in the following way:

Direct costs per network element:

```
dc_bts
       dc_bts_site
       dc_bts_eq
       dc_trx
       lic_GSM900
       lic_gsm1800
       gsm1800freq

              dc_bsc
       dc_bsc_site
       dc_bsc_unit
dc_trau
dc_msc
       dc_msc_site
       dc_msc_unit
       dc_msc_ports
              dc_msc_icports
              dc_msc_bscports
              dc_msc_mscports
dc_sig
dc_hlr
dc_smsc
dc_rl2_bts_btsh
```

```
dc_rl_btsh_bsc
dc_ll2f_btsh_bsc
dc_ll2_btsh_bsc
dc_ll155f_bsc_msc
dc_ll155_bsc_msc
dc_l1155f_core
dc_ll155_core
```

Indirect costs per network element:

```
ic_bts
ic_bsc
ic_trau
ic_msc
ic_sig
ic_hlr
ic_smsc
ic_rl2_bts_btsh
ic_rl_btsh_bsc
ic_ll2f_btsh_bsc
ic_ll155f_bsc_msc
ic_ll155f_core
```

OPEX per network element:

```
oc_bts
oc_bsc
oc_trau
oc_msc
oc_sig
oc_hlr
oc_smsc
oc_bts_btsh
oc_btsh_bsc
       oc_rl_btsh_bsc
       oc_ll2f_btsh_bsc
oc_ll155f_bsc_msc
oc_ll155f_core
```

Common organisational-level costs per network element:

```
coco_bts
coco_bsc
```

```
coco_trau
coco_msc
coco_sig
coco_hlr
coco_smsc
coco_rl2_bts_btsh
coco_rl_btsh_bsc
coco_ll2f_btsh_bsc
coco_ll155f_bsc_msc
coco_ll155f_core
coco_LL2_btsh_bsc
coco_LL155_bsc_msc
coco_LL155_core
```

Effective common organisational-level costs:

```
coco_bts_eff
coco_bsc_eff
coco_trau_eff
coco_msc_eff
coco_sig_eff
coco_hlr_eff
coco_smsc_eff
coco_rl2_bts_btsh_eff
coco_rl_btsh_bsc_eff
coco_LL2f_btsh_bsc_eff
coco_LL155f_bsc_msc_eff
coco_LL155f_core_eff
coco_LL2_btsh_bsc_eff
coco_LL155_bsc_msc_eff
coco_LL155_core_eff
```

Total annual network element costs:

```
total_cost
       tot_bts
              tot_bts_site
              tot_bts_eq
              tot_trx
              tot_lic_GSM900
              tot_lic_GSM1800
              tot_GSM1800freq
```

```
tot_bsc
      tot_bsc_site
      tot_bsc_unit
tot_trau
tot_msc
      tot_msc_site
      tot_msc_unit
      tot_msc_ports
            tot_msc_icports
            tot_msc_bscports
            tot_msc_mscports
tot_sig
tot_hlr
tot_smsc
tot_rl2_bts_btsh
tot_rl_btsh_bsc
tot_ll2f_btsh_bsc
tot_ll155f_bsc_msc
tot_ll155f_core
tot_ll2_btsh_bsc
tot_ll155_bsc_msc
tot_ll155_core
```

Total cost:

```
total_cost
      totdc
      totic
      totoc
      totcoco
```

3.7 Output of the network element quantities

The model calculates the network element quantities in the following way:

The model provides information about the total number of HLR units:

```
n_hlr              Total number of HLR units in the network
```

For each network site i the model includes information about the following quantities:

```
n_BSC_unit_i       Number of BSC units in site i
n_mach_i           Number of switching units in site i
n_cpu_i            Number of switching units in site i
n_sp_i             Number of signalling processor units in site i
n_smsc_i           Number of SMS center units in site i
```