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

AUTHORS:

MICHAEL BRINKMANN
PROF. DR. KLAUS D. HACKBARTH
DRAGAN ILIC
DR. WERNER NEU
DR. KARL-HEINZ NEUMANN
PROF. DR. ANTONIO PORTILLA FIGUERAS

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Contents

List of Abbreviations and Terms  VI

1  Objective of the Cost Module  1

2  Investment calculation  2

   2.1  Productive network asset investment (investment for explicitly modelled network elements)  3

       2.1.1  BTS investment  3

           2.1.1.1  Site construction investment  3

           2.1.1.2  BTS equipment investment  4

           2.1.1.3  TRX investment  5

           2.1.1.4  Total BTS investment  6

       2.1.2  BSC investment  6

           2.1.2.1  BSC site construction investment  6

           2.1.2.2  BSC equipment investment  7

           2.1.2.3  Total investment for BSCs  7

       2.1.3  TRAU investment  8

       2.1.4  MSC investment  8

           2.1.4.1  Site construction investment  8

           2.1.4.2  MSC hardware and software equipment investment  9

           2.1.4.3  Ports investment  11

           2.1.4.4  Total investment MSC and processor investment  11

       2.1.5  HLR investment  12

       2.1.6  SMSC investment  12

       2.1.7  BTS-BSC links investment  13

           2.1.7.1  BTS-BTS hub investment  13

           2.1.7.2  BTS hub-BSC investment  14

       2.1.8  BSC-MSC links investment  17

       2.1.9  MSC-MSC links  19

2.2  Investment in network support assets  20

   2.2.1  Network support assets investment for BTSs  20

       2.2.1.1  Indirect Investment for BTS sites  21
2.2.1.2 Indirect Investment for BTS equipment 21
2.2.1.3 Indirect Investment for TRX 22
2.2.1.4 Total indirect Investment for BTSs 22
2.2.2 Network support assets investment for BSCs 23
   2.2.2.1 Indirect Investment for BSC sites 23
   2.2.2.2 Indirect Investment for BSC equipment (hardware and software) 24
   2.2.2.3 Total indirect Investment for BSCs 24
2.2.3 Network support assets investment for TRAUs 25
2.2.4 Network support assets investment for MSCs 26
   2.2.4.1 Indirect Investment for MSC sites 26
   2.2.4.2 Indirect Investment for MSC units (hardware and software) 27
   2.2.4.3 Indirect Investment for MSC ports 27
   2.2.4.4 Indirect Investment for MSC interconnection ports 28
   2.2.4.5 Network support assets investment for BSC faced ports: 28
   2.2.4.6 Network support assets investment for MSC faced ports: 29
2.2.5 Network support assets investment for the HLR 30
2.2.6 Network support assets investment for SMSCs 31
2.2.7 Network support assets investment for BTS-BSC links 32
   2.2.7.1 Network support assets investment for the BTS-BTS hub links 32
   2.2.7.2 Network support assets investment for the BTS hub-BSC links 33
2.2.8 Network support assets investment for BSC-MSC links 35
2.2.9 Network support assets investment for MSC-MSC links 36
2.3 Output of the investment calculation 37

3 Cost calculation 39
3.1 Direct costs of the productive network assets 39
   3.1.1 Direct costs of the BTSs 39
      3.1.1.1 Direct costs of the BTS sites 39
      3.1.1.2 Direct costs of the BTS equipment 39
      3.1.1.3 Direct costs of the TRXs 40
      3.1.1.4 Total direct costs for the BTSs 40
   3.1.2 Direct costs of the BSC 41
3.1.2.1 Direct costs of the BSC sites
3.1.2.2 Direct costs of the BSC equipment
3.1.2.3 Total direct costs for the BSCs
3.1.3 Direct costs of the TRAUs
3.1.4 Direct costs of the MSCs
  3.1.4.1 Direct costs of the MSC sites
  3.1.4.2 Direct costs of the MSC (hardware and software) equipment
  3.1.4.3 Direct costs of the MSC ports
  3.1.4.4 Total direct costs for the MSC
3.1.5 Direct costs of the HLR
3.1.6 Direct costs of the SMSC
3.1.7 Direct costs of the BTS-BSC links
  3.1.7.1 Direct costs of the BTS-BTS hub links
  3.1.7.2 BTS hub-BSC links
3.1.8 Direct costs of the BSC-MSC links
3.1.9 Direct costs of the MSC-MSC links
3.2 Indirect costs (related to the network support assets)
  3.2.1 Indirect costs of the BTSs
    3.2.1.1 Indirect costs of the BTS sites
    3.2.1.2 Indirect costs of the BTS equipment
    3.2.1.3 Indirect costs of the TRX
    3.2.1.4 Total indirect costs of the BTSs
  3.2.2 Indirect costs of the BSCs
    3.2.2.1 Indirect costs of the BSC sites
    3.2.2.2 Indirect costs of the BSC equipment (hardware and software)
    3.2.2.3 Total indirect costs of the BSCs
  3.2.3 Indirect costs of the TRAUs
  3.2.4 Indirect costs of the MSCs
    3.2.4.1 Indirect costs of the MSC sites
    3.2.4.2 Indirect costs of the MSC units (hardware and software)
    3.2.4.3 Indirect costs of the MSC ports
3.2.4.4 Indirect costs of the MSC interconnection ports 54
3.2.4.5 Indirect costs of the BSC faced ports 54
3.2.4.6 Indirect costs of the MSC faced ports 54
3.2.4.7 Total indirect cost of the MSCs 55
3.2.5 Indirect costs of the HLR 56
3.2.6 Indirect costs of the SMSCs 56
3.2.7 Indirect costs of the BTS-BSC links 57
  3.2.7.1 Indirect costs of the BTS-BTS hub links 57
  3.2.7.2 Indirect costs of the BTS hub-BSC links 58
3.2.8 Indirect costs of the BSC-MSC links 59
3.2.9 Indirect costs of the MSC-MSC links 59

3.3 OPEX 60
  3.3.1 OPEX relating to the BTSs 60
  3.3.2 OPEX relating to the BSCs 62
  3.3.3 OPEX relating to the TRAUs 63
  3.3.4 OPEX relating to the MSCs 63
  3.3.5 OPEX relating to the HLR 66
  3.3.6 OPEX relating to the SMSCs 66
  3.3.7 OPEX relating to the BTS-BSC links 67
    3.3.7.1 OPEX relating to the BTS-BTS hub links 67
    3.3.7.2 OPEX relating to the BTS hub-BSC links 68
  3.3.8 OPEX relating to the BSC-MSC links 69
  3.3.9 OPEX relating to the MSC-MSC links 69

3.4 Total annual network costs 70
  3.4.1 Total direct cost 70
  3.4.2 Total indirect cost 70
  3.4.3 Total OPEX 71
  3.4.4 Common organisational-level costs 71
  3.4.5 Total annual network element costs 76
    3.4.5.1 Total cost for the BTSs 76
    3.4.5.2 Total cost for the BSCs 77
3.4.5.3 Total cost for TRAUs 77
3.4.5.4 Total cost for MSCs 77

3.5 Costs per minute 80
  3.5.1 Relevant services 80
  3.5.2 Annual traffic volumes 80
  3.5.3 Unit network element costs 82
  3.5.4 Usage factors 83
  3.5.5 Cost per service minute 84

3.6 Output of the cost calculation 84

3.7 Output of the network element quantities 88
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
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTPRAL</td>
<td>Point to Point Radio Links</td>
</tr>
<tr>
<td>RL</td>
<td>Radio Link</td>
</tr>
<tr>
<td>SDH</td>
<td>Synchronous Digital Hierarchy</td>
</tr>
<tr>
<td>SMS</td>
<td>Short Message Service</td>
</tr>
<tr>
<td>SMSC</td>
<td>Short Message Service Centre</td>
</tr>
<tr>
<td>SNPT</td>
<td>Strategic Network Planning Tool</td>
</tr>
<tr>
<td>SP</td>
<td>Signalling Processor</td>
</tr>
<tr>
<td>STM-1</td>
<td>Synchronous Transport Module -1</td>
</tr>
<tr>
<td>Sw</td>
<td>Software</td>
</tr>
<tr>
<td>TRAU</td>
<td>Transcoder and Rate Adaptation Unit</td>
</tr>
<tr>
<td>TRX</td>
<td>Transceivers</td>
</tr>
<tr>
<td>VLR</td>
<td>Visitor Location Register</td>
</tr>
<tr>
<td>WACC</td>
<td>Weighted Average Cost of Capital</td>
</tr>
<tr>
<td>WDM</td>
<td>Wavelength Division Multiplexing</td>
</tr>
<tr>
<td>WIK</td>
<td>WIK-Consult</td>
</tr>
<tr>
<td>WIK-MNCM</td>
<td>WIK Mobile Network and Cost Model</td>
</tr>
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</table>
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:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>p_bts_site_ma</td>
<td>( \geq 0 )</td>
<td>Average investment for site construction per BTS Macrocell</td>
<td>Input</td>
</tr>
<tr>
<td>p_bts_site_mi</td>
<td>( \geq 0 )</td>
<td>Average investment for site construction per BTS Microcell</td>
<td>Input</td>
</tr>
<tr>
<td>p_bts_site_pi</td>
<td>( \geq 0 )</td>
<td>Average investment for site construction per BTS Picocell</td>
<td>Input</td>
</tr>
<tr>
<td>sf_bts_site_ma</td>
<td>([0,1])</td>
<td>Sharing factor reflecting the average impact on investment due to sharing of a BTS Macrocell site with other operators</td>
<td>Input</td>
</tr>
<tr>
<td>sf_bts_site_mi</td>
<td>([0,1])</td>
<td>Sharing factor reflecting the average impact on investment due to sharing of a BTS Microcell site with other operators</td>
<td>Input</td>
</tr>
<tr>
<td>sf_bts_site_pi</td>
<td>([0,1])</td>
<td>Sharing factor reflecting the average impact on investment due to sharing of a BTS Picocell site with other operators</td>
<td>Input</td>
</tr>
<tr>
<td>nBTS_site_ma</td>
<td>( \geq 0 )</td>
<td>Number of base stations for Macrocell sites</td>
<td>Output</td>
</tr>
<tr>
<td>nBTS_site_mi</td>
<td>( \geq 0 )</td>
<td>Number of base stations for Microcell sites</td>
<td>Output</td>
</tr>
<tr>
<td>nBTS_site_pi</td>
<td>( \geq 0 )</td>
<td>Number of base stations for Picocell sites</td>
<td>Output</td>
</tr>
</tbody>
</table>

Total investment for site construction is calculated by the following:

\[
\begin{align*}
\text{di}_\text{bts}_\text{site}_\text{ma} & = n\text{BTS}_\text{site}_\text{ma} \times p\text{_bts}_\text{site}_\text{ma} \times sf\text{_bts}_\text{site}_\text{ma} \\
\text{di}_\text{bts}_\text{site}_\text{mi} & = n\text{BTS}_\text{site}_\text{mi} \times p\text{_bts}_\text{site}_\text{mi} \times sf\text{_bts}_\text{site}_\text{mi} \\
\text{di}_\text{bts}_\text{site}_\text{pi} & = n\text{BTS}_\text{site}_\text{pi} \times p\text{_bts}_\text{site}_\text{pi} \times sf\text{_bts}_\text{site}_\text{pi} \\
\text{di}_\text{bts}_\text{site} & = \text{di}_\text{bts}_\text{site}_\text{ma} + \text{di}_\text{bts}_\text{site}_\text{mi} + \text{di}_\text{bts}_\text{site}_\text{pi}
\end{align*}
\]

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:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>p_bts_ma_1</td>
<td>&gt;=0</td>
<td>Average investment for 1-sector base stations Macrocell in 900 or 1800 MHz</td>
<td>Input</td>
</tr>
<tr>
<td>p_bts_ma_2</td>
<td>&gt;=0</td>
<td>Average investment for 2-sectors base stations Macrocell in 900 or 1800 MHz</td>
<td>Input</td>
</tr>
<tr>
<td>p_bts_ma_3</td>
<td>&gt;=0</td>
<td>Average investment for 3-sectors base stations Macrocell in 900 or 1800 MHz</td>
<td>Input</td>
</tr>
<tr>
<td>p_bts_mi_3</td>
<td>&gt;=0</td>
<td>Average investment for 3-sectors base stations Microcell in 900 or 1800 MHz</td>
<td>Input</td>
</tr>
<tr>
<td>p_bts_pi_3</td>
<td>&gt;=0</td>
<td>Average investment for 3-sectors base stations Picocell in 900 or 1800 MHz</td>
<td>Input</td>
</tr>
</tbody>
</table>

Total investment for BTS equipment is calculated on the basis:

\[
d_{bts\_eq} = n_{BTS\_ma\_1} \cdot p_{bts\_ma\_1} + n_{BTS\_ma\_2} \cdot p_{bts\_ma\_2} + n_{BTS\_ma\_3} \cdot p_{bts\_ma\_3} + n_{BTS\_mi\_3} \cdot p_{bts\_mi\_3} + n_{BTS\_pi\_3} \cdot p_{bts\_pi\_3}
\]

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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Source</th>
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<tbody>
<tr>
<td>p_TRX</td>
<td>&gt;=0</td>
<td>Average investment for TRX in 900 or 1800 MHz</td>
<td>Input</td>
</tr>
<tr>
<td>nTRX_ma</td>
<td>&gt;=0</td>
<td>Number of TRXs in Macrocell BTS in 900 or 1800 MHz</td>
<td>Output</td>
</tr>
<tr>
<td>nTRX_mi</td>
<td>&gt;=0</td>
<td>Number of TRXs in Microcell BTS in 900 or 1800 MHz</td>
<td>Output</td>
</tr>
<tr>
<td>nTRX_pi</td>
<td>&gt;=0</td>
<td>Number of TRXs in Picocell BTS in 900 or 1800 MHz</td>
<td>Output</td>
</tr>
</tbody>
</table>
Total investment for TRXs is calculated by the following:

\[ \text{di}_{\text{trx}} = (\text{ntrx}_{\text{ma}} + \text{ntrx}_{\text{mi}} + \text{ntrx}_{\pi}) \times p_{\text{trx}} \]

2.1.1.4 Total BTS investment

\[ \text{di}_{\text{bts}} = \text{di}_{\text{bts}_{\text{site}}} + \text{di}_{\text{bts}_{\text{eq}}} + \text{di}_{\text{trx}} \]

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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>(p_{b_{\text{sc site}}})</td>
<td>(\geq 0)</td>
<td>Average investment for site construction per BSC</td>
<td>Input</td>
</tr>
<tr>
<td>(s_{f_{\text{sc site}}})</td>
<td>([0,1])</td>
<td>Sharing factor reflecting the average impact on investment due to sharing of a BSC site with other operators</td>
<td>Input</td>
</tr>
<tr>
<td>(n_{\text{BSC}})</td>
<td>(\geq 0)</td>
<td>Number of BSC sites</td>
<td>Output</td>
</tr>
</tbody>
</table>

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

\[ \text{di}_{\text{bsc}_{\text{site}}} = n_{\text{BSC}} \times p_{\text{b_{\text{sc site}}}} \times s_{f_{\text{sc site}}} \]
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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
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<tbody>
<tr>
<td>p_bsc_unit_hw</td>
<td>&gt;=0</td>
<td>Hardware investment per BSC unit</td>
<td>Input</td>
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<tr>
<td>p_bsc_unit_sw</td>
<td></td>
<td>Software investment per BSC unit</td>
<td>Input</td>
</tr>
<tr>
<td>cap_bsc_unit</td>
<td>&gt;=0</td>
<td>Maximum number of TRXs which can be controlled by one BSC unit</td>
<td>Input</td>
</tr>
<tr>
<td>n_bsc_unit</td>
<td>&gt;=0</td>
<td>Number of BSC units at one BSC site</td>
<td>Output</td>
</tr>
</tbody>
</table>

The number of BSC units is derived as follows:

\[ n_{\text{BSC\_Unit}} = \sum_{\text{BSC\_Sites\_i}} \left[ \frac{\text{No.\_of\_TRX\_at\_BSC\_Site\_i}}{\text{cap\_bsc\_unit}} \right] \]

The total investment for BSC equipment is then given by:

\[ \text{di\_bsc\_unit\_hw} = n_{\text{bsc\_unit}} \times p_{\text{bsc\_unit\_hw}} \]
\[ \text{di\_bsc\_unit\_sw} = n_{\text{bsc\_unit}} \times p_{\text{bsc\_unit\_sw}} \]
\[ \text{di\_bsc\_unit} = \text{di\_bsc\_unit\_hw} + \text{di\_bsc\_unit\_sw} \]

2.1.2.3 Total investment for BSCs

Total investment for BSCs is given by:

\[ \text{di\_bsc} = \text{di\_bsc\_site} + \text{di\_bsc\_unit\_hw} + \text{di\_bsc\_unit\_sw} \]
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:

\[
n_{\text{trau}} = \frac{\text{Number of TRX}}{(\text{Maximum Number TRX per TRAU})}
\]

\[
d_{\text{trau}} = n_{\text{trau}} \times p_{\text{trau}}
\]

<table>
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<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Source</th>
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<tr>
<td>( p_{\text{trau}} )</td>
<td>( \geq 0 )</td>
<td>Investment per TRAU</td>
<td>Input</td>
</tr>
<tr>
<td>( n_{\text{trau}} )</td>
<td>( \geq 0 )</td>
<td>Total number of TRAUs</td>
<td>Output</td>
</tr>
</tbody>
</table>

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.

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<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Source</th>
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</thead>
<tbody>
<tr>
<td>( p_{\text{msc site}} )</td>
<td>( \geq 0 )</td>
<td>Average investment per MSC site</td>
<td>Input</td>
</tr>
<tr>
<td>( sf_{\text{msc site}} )</td>
<td>([0,1])</td>
<td>Sharing factor reflecting the average impact on investment due to sharing of a MSC site with other operators</td>
<td>Input</td>
</tr>
<tr>
<td>( n_{\text{MSC}} )</td>
<td>( \geq 0 )</td>
<td>Total number of MSC sites</td>
<td>Output</td>
</tr>
</tbody>
</table>

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

\[
d_{\text{msc site}} = n_{\text{MSC}} \times p_{\text{msc site}} \times sf_{\text{msc site}}
\]
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.

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:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p_{\text{msc_hw}}$</td>
<td>$\geq 0$</td>
<td>Average hardware investment per switching machine</td>
<td>Input</td>
</tr>
<tr>
<td>$p_{\text{msc_sw}}$</td>
<td>$\geq 0$</td>
<td>Average software investment per switching machine</td>
<td>Input</td>
</tr>
<tr>
<td>$p_{\text{cp}}$</td>
<td>$\geq 0$</td>
<td>Average investment per CPU</td>
<td>Input</td>
</tr>
<tr>
<td>$p_{\text{sp}}$</td>
<td>$\geq 0$</td>
<td>Average investment per signalling processor</td>
<td>Input</td>
</tr>
<tr>
<td>max_ports</td>
<td>$\geq 0$</td>
<td>Maximum number of ports of one MSC base unit</td>
<td>Input</td>
</tr>
<tr>
<td>$cp_{\text{bhca}}$</td>
<td>$\geq 0$</td>
<td>Maximum number of BHCA per CPU</td>
<td>Input</td>
</tr>
<tr>
<td>$sp_{\text{bhca}}$</td>
<td>$\geq 0$</td>
<td>Maximum number of BHCA per signalling processor</td>
<td>Input</td>
</tr>
<tr>
<td>$ur_{\text{sp}}$</td>
<td>$\geq 0$</td>
<td>Average utilisation ratio of signalling processor</td>
<td>Input</td>
</tr>
<tr>
<td>$ur_{\text{cp}}$</td>
<td>$\geq 0$</td>
<td>Average utilisation ratio of central processor</td>
<td>Input</td>
</tr>
<tr>
<td>$n_{\text{mach}}$</td>
<td>$\geq 0$</td>
<td>Number of switching machines at a particular MSC site according to capacity limit in terms of ports.</td>
<td>Output</td>
</tr>
<tr>
<td>$n_{\text{BHCA}}$</td>
<td>$\geq 0$</td>
<td>Number of total (unsuccessful and successful) Busy Hour Call Attempts from circuit switched services</td>
<td>Output</td>
</tr>
<tr>
<td>$n_{\text{BHCA_sms}}$</td>
<td>$\geq 0$</td>
<td>Number of total (unsuccessful and successful) Busy Hour Call Attempts from SMS</td>
<td>Output</td>
</tr>
</tbody>
</table>

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 $i$:

$n_{\text{mach\_i}} = \text{Ceil}(\text{Number of Ports at Site } i / \text{max\_ports}) : \text{integer}$

Total Number of Switching machines in the network:

$n_{\text{mach}} = \text{Sum}(n_{\text{mach\_i}})$ for all $i$

Number of Central Processor Units required:

$n_{\text{cpu}} = (n_{\text{BHCA}}) / (cp_{\text{bhca}} * ur_{\text{cp}})$

Number of Signalling Processor Units required:

$n_{\text{sp}} = (n_{\text{BHCA}} + n_{\text{bhca\_sms}}) / (sp_{\text{bhca}} * ur_{\text{sp}})$

Total investment for MSC equipment is calculated as follows:

\[
\text{di}_{\text{msc\_hw}} = n_{\text{mach}} * p_{\text{msc\_hw}} \\
\text{di}_{\text{msc\_sw}} = n_{\text{mach}} * p_{\text{msc\_sw}} \\
\text{di}_{\text{msc\_unit}} = \text{di}_{\text{msc\_hw}} + \text{di}_{\text{msc\_sw}}
\]
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:

\[ di_{\text{sig}} = n_{\text{cpu}} \cdot p_{\text{cp}} + n_{\text{sp}} \cdot p_{\text{sp}} \]

### 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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>p_port</td>
<td>&gt;=0</td>
<td>Investment in material and installation per 2 Mbps port.</td>
<td>Input</td>
</tr>
<tr>
<td>n_icports</td>
<td>&gt;=0</td>
<td>Total number of interconnection-facing 2 Mbps ports</td>
<td>Output</td>
</tr>
<tr>
<td>n_bscports</td>
<td>&gt;=0</td>
<td>Total number of BSC-facing 2 Mbps ports</td>
<td>Output</td>
</tr>
<tr>
<td>n_mscports</td>
<td>&gt;=0</td>
<td>Total number of MSC-facing 2 Mbps ports</td>
<td>Output</td>
</tr>
</tbody>
</table>

\[ di_{\text{msc\_icports}} = n_{\text{icports}} \cdot p_{\text{port}} \]
\[ di_{\text{msc\_bscports}} = n_{\text{bscports}} \cdot p_{\text{port}} \]
\[ di_{\text{msc\_mscports}} = n_{\text{mscports}} \cdot p_{\text{port}} \]
\[ di_{\text{msc\_ports}} = di_{\text{msc\_icports}} + di_{\text{msc\_bscports}} + di_{\text{msc\_mscports}} \]

### 2.1.4.4 Total investment MSC and processor investment

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

**Total direct MSC investment:**

\[ di_{\text{msc}} = di_{\text{msc\_site}} + di_{\text{msc\_hw}} + di_{\text{msc\_sw}} + di_{\text{msc\_ports}} \]

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

\[ di_{\text{sig}} = di_{\text{sig}} \]
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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>p_hlr</td>
<td>&gt;=0</td>
<td>Investment in material and installation per HLR functionality</td>
<td>Input</td>
</tr>
<tr>
<td>max_hlr</td>
<td>&gt;=0</td>
<td>Maximum number of registered subscribers per HLR component</td>
<td>Input</td>
</tr>
<tr>
<td>ur_hlr</td>
<td>&gt;=0</td>
<td>Average utilisation ratio of a HLR component</td>
<td>Input</td>
</tr>
<tr>
<td>n_hlr</td>
<td>&gt;=0</td>
<td>Number of HLRs in the network</td>
<td>Output</td>
</tr>
</tbody>
</table>

The total number of HLR components is calculated as follows:

\[ n_{hlr} = \text{Max} \left( 2, \text{Ceil} \left( \frac{\text{Total Number of Subscribers}}{\text{max}_{hlr} \times \text{ur}_{hlr}} \right) \right) \]

Total investment in the HLR is given by:

\[ d_{HLR} = n_{hlr} \times p_{hlr} \]

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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>p_smsc</td>
<td>&gt;=0</td>
<td>Investment in material and installation per SMSC unit</td>
<td>Input</td>
</tr>
<tr>
<td>max_smsc</td>
<td>&gt;=0</td>
<td>Maximum capacity in terms of number of SMS per SMSC unit</td>
<td>Input</td>
</tr>
<tr>
<td>ur_smsc</td>
<td>&gt;=0</td>
<td>Average utilisation ratio of a SMSC</td>
<td>Input</td>
</tr>
<tr>
<td>n_smsc</td>
<td>&gt;=0</td>
<td>Number of SMSC units in the network</td>
<td>Output</td>
</tr>
</tbody>
</table>

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

\[ n_{smsc} = \text{Max} \left( 2, \text{Ceil} \left( \frac{\text{Number of SMS in the Busy Hour}}{\text{max}_{smsc} \times \text{ur}_{smsc}} \right) \right) \]
Total investment in SMSC components is given by:

\[ \text{di}_{\text{smsc}} = n_{\text{smsc}} \times p_{\text{smsc}} \]

### 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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>( p_{\text{RL2}} )</td>
<td>( \geq 0 )</td>
<td>Investment per 2 Mbps radio mini-link</td>
<td>Input</td>
</tr>
<tr>
<td>( n_{\text{RL2}} )</td>
<td>( \geq 0 )</td>
<td>Number of 2 Mbps radio links</td>
<td>Output</td>
</tr>
<tr>
<td>( p_{\text{RL fee}} )</td>
<td>( \geq 0 )</td>
<td>Licence charge per point-to-point</td>
<td>Input</td>
</tr>
</tbody>
</table>

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:**

\[ \text{di}_{\text{rl2, bts-btsh}} = n_{\text{RL2}} \times p_{\text{RL2}} \]

**Total direct investment in licence charges for radio links:**

\[ \text{di}_{\text{RL fee}} = n_{\text{RL2}} \times p_{\text{RL fee}} \]

---

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 \( n \times 2 \) 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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>( p_{RL2} )</td>
<td>( \geq 0 )</td>
<td>Investment per 2 Mbps radio link system</td>
<td>Input</td>
</tr>
<tr>
<td>( p_{RL8} )</td>
<td>( \geq 0 )</td>
<td>Investment per 8 Mbps radio link system</td>
<td>Input</td>
</tr>
<tr>
<td>( p_{RL34} )</td>
<td>( \geq 0 )</td>
<td>Investment per 34 Mbps radio link system</td>
<td>Input</td>
</tr>
<tr>
<td>( p_{RL140} )</td>
<td>( \geq 0 )</td>
<td>Investment per 140 Mbps radio link system</td>
<td>Input</td>
</tr>
<tr>
<td>( p_{rep_site} )</td>
<td>( \geq 0 )</td>
<td>Investment per repeater site</td>
<td>Input</td>
</tr>
<tr>
<td>( p_{RL2_rep} )</td>
<td>( \geq 0 )</td>
<td>Investment per repeater for a 2 Mbps radio link system</td>
<td>Input</td>
</tr>
<tr>
<td>( p_{RL8_rep} )</td>
<td>( \geq 0 )</td>
<td>Investment per repeater for a 8 Mbps radio link system</td>
<td>Input</td>
</tr>
<tr>
<td>( p_{RL34_rep} )</td>
<td>( \geq 0 )</td>
<td>Investment per repeater for a 34 Mbps radio link system</td>
<td>Input</td>
</tr>
<tr>
<td>( p_{RL140_rep} )</td>
<td>( \geq 0 )</td>
<td>Investment per repeater for a 140 Mbps radio link system</td>
<td>Input</td>
</tr>
<tr>
<td>sf_rep</td>
<td>[0,1]</td>
<td>Sharing factor for repeater sites</td>
<td></td>
</tr>
<tr>
<td>Dist_rl</td>
<td></td>
<td>Maximum distance for radio transmission in Km for which a repeater is not needed</td>
<td>Input</td>
</tr>
<tr>
<td>( N_{RL2_btsh_bsc} )</td>
<td>( \geq 0 )</td>
<td>Number of 2 Mbps radio links</td>
<td>Output</td>
</tr>
<tr>
<td>( N_{RL8_btsh_bsc} )</td>
<td>( \geq 0 )</td>
<td>Number of 8 Mbps radio links</td>
<td>Output</td>
</tr>
<tr>
<td>( N_{RL34_btsh_bsc} )</td>
<td>( \geq 0 )</td>
<td>Number of 34 Mbps radio links</td>
<td>Output</td>
</tr>
<tr>
<td>( N_{RL140_btsh_bsc} )</td>
<td>( \geq 0 )</td>
<td>Number of 140 Mbps radio links</td>
<td>Output</td>
</tr>
<tr>
<td>n_rep_sites</td>
<td></td>
<td>Number of repeater sites</td>
<td>Output</td>
</tr>
<tr>
<td>( n_{RL2_rep} )</td>
<td>( \geq 0 )</td>
<td>Number of repeaters for 2 Mbps radio link system</td>
<td>Input</td>
</tr>
<tr>
<td>( n_{RL8_rep} )</td>
<td>( \geq 0 )</td>
<td>Number of repeaters for 8 Mbps radio link system</td>
<td>Input</td>
</tr>
<tr>
<td>( n_{RL34_rep} )</td>
<td>( \geq 0 )</td>
<td>Number of repeaters for 34 Mbps radio link system</td>
<td>Input</td>
</tr>
<tr>
<td>( n_{RL140_rep} )</td>
<td>( \geq 0 )</td>
<td>Number of repeaters for 140 Mbps radio link system</td>
<td>Input</td>
</tr>
</tbody>
</table>
Direct investment in radio links:
\[ di_{RL2\_btsh\_bsc} = p_{RL2} \times N_{RL2\_btsh\_bsc} \]
\[ di_{RL8\_btsh\_bsc} = p_{RL8} \times N_{RL8\_btsh\_bsc} \]
\[ di_{RL34\_btsh\_bsc} = p_{RL34} \times N_{RL34\_btsh\_bsc} \]
\[ di_{RL140\_btsh\_bsc} = p_{RL140} \times N_{RL140\_btsh\_bsc} \]

Direct investment in licence charges:
\[ di_{rl\_fee\_btsh\_bsc} = p_{RL\_fee} \times (N_{RL2\_btsh\_bsc} + N_{RL8\_btsh\_bsc} + N_{RL34\_btsh\_bsc} + N_{RL140\_btsh\_bsc}) \]

Direct investment in repeater sites:
\[ di_{rep\_site} = n_{rep\_sites} \times p_{rep\_site} \times sf_{rep} \]
\[ n_{RL2\_rep} = \text{Link length} / \text{dist}_{rl} \]
\[ n_{RL8\_rep} = \text{Link length} / \text{dist}_{rl} \]
\[ n_{RL34\_rep} = \text{Link length} / \text{dist}_{rl} \]
\[ n_{RL140\_rep} = \text{Link length} / \text{dist}_{rl} \]
\[ di_{RL2\_rep} = n_{RL2\_rep} \times p_{RL2\_rep} \]
\[ di_{RL8\_rep} = n_{RL8\_rep} \times p_{RL8\_rep} \]
\[ di_{RL34\_rep} = n_{RL34\_rep} \times p_{RL34\_rep} \]
\[ di_{RL140\_rep} = n_{RL140\_rep} \times p_{RL140\_rep} \]

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.

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

---

\(^3\) 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:

\[
\begin{align*}
    dc_{LL2\_loc\_btsh\_bsc} &= p_{LL2\_loc} \times N_{LL2\_loc} \\
    dc_{LL2\_reg\_btsh\_bsc} &= p_{LL2\_reg} \times N_{LL2\_reg} \\
    dc_{LL2\_ld\_btsh\_bsc} &= p_{LL2\_ld} \times N_{LL2\_ld}
\end{align*}
\]

Total direct cost for leased lines:

\[
\begin{align*}
    dc_{LL2\_btsh\_bsc} &= dc_{LL2\_loc\_btsh\_bsc} \\
    &\quad + dc_{LL2\_reg\_btsh\_bsc} \\
    &\quad + dc_{LL2\_ld\_btsh\_bsc}
\end{align*}
\]

Direct investment by type of leased line:

\[
\begin{align*}
    di_{LL2f\_loc\_btsh\_bsc} &= p_{LL2f\_loc} \times N_{LL2f\_loc} \\
    di_{LL2f\_reg\_btsh\_bsc} &= p_{LL2f\_reg} \times N_{LL2f\_reg} \\
    di_{LL2f\_ld\_btsh\_bsc} &= p_{LL2f\_ld} \times N_{LL2f\_ld}
\end{align*}
\]

Total direct investment of leased lines:

\[
\begin{align*}
    di_{LL2f\_btsh\_bsc} &= di_{LL2f\_loc\_btsh\_bsc} \\
    &\quad + di_{LL2f\_reg\_btsh\_bsc} \\
    &\quad + di_{LL2f\_ld\_btsh\_bsc}
\end{align*}
\]

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.
### Specification of the Cost Module of the WIK Mobile Network and Cost Model

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

Annual costs for leased lines are calculated as follows:

\[
\begin{align*}
dc_{LL155\_loc\_bsc\_msc} &= p_{LL155\_loc} \times N_{LL155\_loc} \\
dc_{LL155\_reg\_bsc\_msc} &= p_{LL155\_reg} \times N_{LL155\_reg} \\
dc_{LL155\_ld\_bsc\_msc} &= p_{LL155\_ld} \times N_{LL155\_ld}
\end{align*}
\]

Total costs:

\[
\begin{align*}
dc_{LL155\_bsc\_msc} &= dc_{LL155\_loc\_bsc\_msc} \\
&+ dc_{LL155\_reg\_bsc\_msc} \\
&+ dc_{LL155\_ld\_bsc\_msc}
\end{align*}
\]

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:

\[
\begin{align*}
di_{LL155f\_loc\_bsc\_msc} &= p_{LL155f\_loc} \times N_{LL155f\_loc} \\
di_{LL155f\_reg\_bsc\_msc} &= p_{LL155f\_reg} \times N_{LL155f\_reg} \\
di_{LL155f\_ld\_bsc\_msc} &= p_{LL155f\_ld} \times N_{LL155f\_ld}
\end{align*}
\]

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

\[
\begin{align*}
di_{LL155f\_bsc\_msc} &= di_{LL155f\_loc\_bsc\_msc} \\
&+ di_{LL155f\_reg\_bsc\_msc} \\
&+ di_{LL155f\_ld\_bsc\_msc}
\end{align*}
\]
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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>p_LL155_core</td>
<td>&gt;=0</td>
<td>Annual STM-1 leased line price per Km for core network links</td>
<td>Input</td>
</tr>
<tr>
<td>p_LL155f_core</td>
<td>&gt;=0</td>
<td>Investment (one-off) for the provision of a core STM-1 leased line</td>
<td>Input</td>
</tr>
<tr>
<td>N_LL155_core</td>
<td>&gt;=0</td>
<td>Number of Km for local leased lines</td>
<td>Output</td>
</tr>
<tr>
<td>N_LL155f_core</td>
<td>&gt;=0</td>
<td>Number of local leased lines</td>
<td>Output</td>
</tr>
</tbody>
</table>

\[ dc\_LL155\_core = p\_LL155\_core \times N\_LL155\_core \]

\[ di\_LL155\_f\_core = p\_LL155f\_core \times N\_LL155f\_core \]

---

\(^5\) 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:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>iif_mv_bts</td>
<td>[0,1]</td>
<td>Investment for motor vehicles (allocated to BTS, equipment, TRX) as a</td>
<td>Input</td>
</tr>
<tr>
<td></td>
<td></td>
<td>percentage of direct investment in BTS</td>
<td></td>
</tr>
<tr>
<td>iif_of_bts</td>
<td>[0,1]</td>
<td>Investment for office equipment (allocated to BTS, equipment, TRX) as a</td>
<td>Input</td>
</tr>
<tr>
<td></td>
<td></td>
<td>percentage of direct investment in BTS</td>
<td></td>
</tr>
<tr>
<td>iif_wo_bts</td>
<td>[0,1]</td>
<td>Investment for workshop equipment (allocated to BTS, equipment, TRX) as a</td>
<td>Input</td>
</tr>
<tr>
<td></td>
<td></td>
<td>percentage of direct investment in BTS</td>
<td></td>
</tr>
<tr>
<td>iif_it_bts</td>
<td>[0,1]</td>
<td>Investment for IT network support equipment (allocated to BTS, equipment,</td>
<td>Input</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TRX) as a percentage of direct investment in BTS</td>
<td></td>
</tr>
<tr>
<td>iif_nm_bts</td>
<td>[0,1]</td>
<td>Investment for network management equipment (allocated to BTS, equipment,</td>
<td>Input</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TRX) as a percentage of direct investment in BTS</td>
<td></td>
</tr>
<tr>
<td>iif_lb_bts</td>
<td>[0,1]</td>
<td>Investment for land and buildings equipment (allocated to BTS, equipment,</td>
<td>Input</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TRX) as a percentage of direct investment in BTS</td>
<td></td>
</tr>
</tbody>
</table>
### 2.2.1.1 Indirect Investment for BTS sites

$$
\text{ii\_bts\_site\_mv} = \text{iif\_mv\_bts} \times \text{di\_bts\_site} \\
\text{ii\_bts\_site\_of} = \text{iif\_of\_bts} \times \text{di\_bts\_site} \\
\text{ii\_bts\_site\_wo} = \text{iif\_wo\_bts} \times \text{di\_bts\_site} \\
\text{ii\_bts\_site\_it} = \text{iif\_it\_bts} \times \text{di\_bts\_site} \\
\text{ii\_bts\_site\_nm} = \text{iif\_nm\_bts} \times \text{di\_bts\_site} \\
\text{ii\_bts\_site\_lb} = \text{iif\_lb\_bts} \times \text{di\_bts\_site}
$$

Total network support assets investment relating to BTS sites is:

$$
\text{ii\_bts\_site} = \text{ii\_bts\_site\_mv} + \text{ii\_bts\_site\_of} + \text{ii\_bts\_site\_wo} + \text{ii\_bts\_site\_it} + \text{ii\_bts\_site\_nm} + \text{ii\_bts\_site\_lb}
$$

### 2.2.1.2 Indirect Investment for BTS equipment

$$
\text{ii\_bts\_eq\_mv} = \text{iif\_mv\_bts} \times \text{di\_bts\_eq} \\
\text{ii\_bts\_eq\_of} = \text{iif\_of\_bts} \times \text{di\_bts\_eq} \\
\text{ii\_bts\_eq\_wo} = \text{iif\_wo\_bts} \times \text{di\_bts\_eq} \\
\text{ii\_bts\_eq\_it} = \text{iif\_it\_bts} \times \text{di\_bts\_eq} \\
\text{ii\_bts\_eq\_nm} = \text{iif\_nm\_bts} \times \text{di\_bts\_eq} \\
\text{ii\_bts\_eq\_lb} = \text{iif\_lb\_bts} \times \text{di\_bts\_eq}
$$

Total network support assets investment relating to BTS sites is:

$$
\text{ii\_bts\_eq} = \text{ii\_bts\_eq\_mv} + \text{ii\_bts\_eq\_of} + \text{ii\_bts\_eq\_wo} + \text{ii\_bts\_eq\_it} + \text{ii\_bts\_eq\_nm} + \text{ii\_bts\_eq\_lb}
$$
2.2.1.3 Indirect Investment for TRX

\[
\begin{align*}
\text{ii}_\text{trx}_\text{mv} &= \text{iif}_\text{mv}_\text{bts} \times \text{di}_\text{trx} \\
\text{ii}_\text{trx}_\text{of} &= \text{iif}_\text{of}_\text{bts} \times \text{di}_\text{trx} \\
\text{ii}_\text{trx}_\text{wo} &= \text{iif}_\text{wo}_\text{bts} \times \text{di}_\text{trx} \\
\text{ii}_\text{trx}_\text{it} &= \text{iif}_\text{it}_\text{bts} \times \text{di}_\text{trx} \\
\text{ii}_\text{trx}_\text{nm} &= \text{iif}_\text{nm}_\text{bts} \times \text{di}_\text{trx} \\
\text{ii}_\text{trx}_\text{lb} &= \text{iif}_\text{lb}_\text{bts} \times \text{di}_\text{trx}
\end{align*}
\]

Total network support assets investment relating to TRX is:

\[
\text{ii}_\text{trx} = \text{ii}_\text{trx}_\text{mv} + \text{ii}_\text{trx}_\text{of} + \text{ii}_\text{trx}_\text{wo} + \text{ii}_\text{trx}_\text{it} + \text{ii}_\text{trx}_\text{nm} + \text{ii}_\text{trx}_\text{lb}
\]

2.2.1.4 Total indirect Investment for BTSs

\[
\begin{align*}
\text{ii}_\text{bts}_\text{mv} &= \text{iif}_\text{mv}_\text{bts} \times \text{di}_\text{bts} \\
\text{ii}_\text{bts}_\text{of} &= \text{iif}_\text{of}_\text{bts} \times \text{di}_\text{bts} \\
\text{ii}_\text{bts}_\text{wo} &= \text{iif}_\text{wo}_\text{bts} \times \text{di}_\text{bts} \\
\text{ii}_\text{bts}_\text{it} &= \text{iif}_\text{it}_\text{bts} \times \text{di}_\text{bts} \\
\text{ii}_\text{bts}_\text{nm} &= \text{iif}_\text{nm}_\text{bts} \times \text{di}_\text{bts} \\
\text{ii}_\text{bts}_\text{lb} &= \text{iif}_\text{lb}_\text{bts} \times \text{di}_\text{bts}
\end{align*}
\]

Total network support assets investment relating to BTSs is:

\[
\text{ii}_\text{bts} = \text{ii}_\text{bts}_\text{mv} + \text{ii}_\text{bts}_\text{of} + \text{ii}_\text{bts}_\text{wo} + \text{ii}_\text{bts}_\text{it} + \text{ii}_\text{bts}_\text{nm} + \text{ii}_\text{bts}_\text{lb}
\]
2.2.2 Network support assets investment for BSCs

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

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

2.2.2.1 Indirect Investment for BSC sites

\[
\begin{align*}
ii_{b\text{sc\_site\_mv}} &= iif_{mv\_b\text{sc}} \times di_{b\text{sc\_site}} \\
ii_{b\text{sc\_site\_of}} &= iif_{of\_b\text{sc}} \times di_{b\text{sc\_site}} \\
ii_{b\text{sc\_site\_wo}} &= iif_{wo\_b\text{sc}} \times di_{b\text{sc\_site}} \\
ii_{b\text{sc\_site\_it}} &= iif_{it\_b\text{sc}} \times di_{b\text{sc\_site}} \\
ii_{b\text{sc\_site\_nm}} &= iif_{nm\_b\text{sc}} \times di_{b\text{sc\_site}} \\
ii_{b\text{sc\_site\_lb}} &= iif_{lb\_b\text{sc}} \times di_{b\text{sc\_site}}
\end{align*}
\]

Total network support assets investment relating to BSC sites is:

\[
ii_{b\text{sc\_site}} = ii_{b\text{sc\_site\_mv}} + ii_{b\text{sc\_site\_of}} + ii_{b\text{sc\_site\_wo}} + ii_{b\text{sc\_site\_it}} + ii_{b\text{sc\_site\_nm}} + ii_{b\text{sc\_site\_lb}}
\]
2.2.2.2 Indirect Investment for BSC equipment (hardware and software)

\[
\begin{align*}
ii_{\text{bsc\_unit}} &= iif_{\text{mv\_bsc}} \times di_{\text{bsc\_unit}} \\
ii_{\text{bsc\_unit\_of}} &= iif_{\text{of\_bsc}} \times di_{\text{bsc\_unit}} \\
ii_{\text{bsc\_unit\_wo}} &= iif_{\text{wo\_bsc}} \times di_{\text{bsc\_unit}} \\
ii_{\text{bsc\_unit\_it}} &= iif_{\text{it\_bsc}} \times di_{\text{bsc\_unit}} \\
ii_{\text{bsc\_unit\_nm}} &= iif_{\text{nm\_bsc}} \times di_{\text{bsc\_unit}} \\
ii_{\text{bsc\_unit\_lb}} &= iif_{\text{lb\_bsc}} \times di_{\text{bsc\_unit}}
\end{align*}
\]

Total network support assets investment relating to BSC equipment is:

\[
\begin{align*}
ii_{\text{bsc\_unit}} &= ii_{\text{bsc\_unit\_mv}} \\
&+ ii_{\text{bsc\_unit\_of}} \\
&+ ii_{\text{bsc\_unit\_wo}} \\
&+ ii_{\text{bsc\_unit\_it}} \\
&+ ii_{\text{bsc\_unit\_nm}} \\
&+ ii_{\text{bsc\_unit\_lb}}
\end{align*}
\]

2.2.2.3 Total indirect Investment for BSCs

\[
\begin{align*}
ii_{\text{bsc\_mv}} &= iif_{\text{mv\_bsc}} \times di_{\text{bsc}} \\
ii_{\text{bsc\_of}} &= iif_{\text{of\_bsc}} \times di_{\text{bsc}} \\
ii_{\text{bsc\_wo}} &= iif_{\text{wo\_bsc}} \times di_{\text{bsc}} \\
ii_{\text{bsc\_it}} &= iif_{\text{it\_bsc}} \times di_{\text{bsc}} \\
ii_{\text{bsc\_nm}} &= iif_{\text{nm\_bsc}} \times di_{\text{bsc}} \\
ii_{\text{bsc\_lb}} &= iif_{\text{lb\_bsc}} \times di_{\text{bsc}}
\end{align*}
\]

Total network support assets investment relating to BSCs is:

\[
\begin{align*}
ii_{\text{bsc}} &= ii_{\text{bsc\_mv}} \\
&+ ii_{\text{bsc\_of}} \\
&+ ii_{\text{bsc\_wo}} \\
&+ ii_{\text{bsc\_it}} \\
&+ ii_{\text{bsc\_nm}} \\
&+ ii_{\text{bsc\_lb}}
\end{align*}
\]
2.2.3 Network support assets investment for TRAUs

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>iif_mv_trau</td>
<td>[0,1]</td>
<td>Investment for motor vehicles (allocated to TRAU) as a percentage of direct investment in TRAU</td>
</tr>
<tr>
<td>iif_of_trau</td>
<td>[0,1]</td>
<td>Investment for office equipment (allocated to TRAU) as a percentage of direct investment in TRAU</td>
</tr>
<tr>
<td>iif_wo_trau</td>
<td>[0,1]</td>
<td>Investment for workshop equipment (allocated to TRAU) as a percentage of direct investment in TRAU</td>
</tr>
<tr>
<td>iif_it_trau</td>
<td>[0,1]</td>
<td>Investment for IT network support equipment (allocated to TRAU) as a percentage of direct investment in TRAU</td>
</tr>
<tr>
<td>iif_nm_trau</td>
<td>[0,1]</td>
<td>Investment for network management equipment (allocated to TRAU) as a percentage of direct investment in TRAU</td>
</tr>
<tr>
<td>iif_lb_trau</td>
<td>[0,1]</td>
<td>Investment for land and buildings equipment (allocated to TRAU) as a percentage of direct investment in TRAU</td>
</tr>
</tbody>
</table>

\[
\begin{align*}
ii_{trau\_mv} &= iif_{mv\_trau} \times di_{trau} \\
ii_{trau\_of} &= iif_{of\_trau} \times di_{trau} \\
ii_{trau\_wo} &= iif_{wo\_trau} \times di_{trau} \\
ii_{trau\_it} &= iif_{it\_trau} \times di_{trau} \\
ii_{trau\_nm} &= iif_{nm\_trau} \times di_{trau} \\
ii_{trau\_lb} &= iif_{lb\_trau} \times di_{trau}
\end{align*}
\]

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:

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

2.2.4.1 Indirect Investment for MSC sites

\[
\begin{align*}
ii_{\text{msc\_site\_mv}} &= iif_{\text{mv\_msc}} \times di_{\text{msc\_site}} \\
ii_{\text{msc\_site\_of}} &= iif_{\text{of\_msc}} \times di_{\text{msc\_site}} \\
ii_{\text{msc\_site\_wo}} &= iif_{\text{wo\_msc}} \times di_{\text{msc\_site}} \\
ii_{\text{msc\_site\_it}} &= iif_{\text{it\_msc}} \times di_{\text{msc\_site}} \\
ii_{\text{msc\_site\_nm}} &= iif_{\text{nm\_msc}} \times di_{\text{msc\_site}} \\
ii_{\text{msc\_site\_lb}} &= iif_{\text{lb\_msc}} \times di_{\text{msc\_site}}
\end{align*}
\]

Total network support assets investment relating to MSC sites is:

\[
\begin{align*}
ii_{\text{msc\_site}} &= ii_{\text{msc\_site\_mv}} \\
&+ ii_{\text{msc\_site\_of}} \\
&+ ii_{\text{msc\_site\_wo}} \\
&+ ii_{\text{msc\_site\_it}} \\
&+ ii_{\text{msc\_site\_nm}} \\
&+ ii_{\text{msc\_site\_lb}}
\end{align*}
\]
2.2.4.2 Indirect Investment for MSC units (hardware and software)

\[ ii_{\text{msc\_unit\_mv}} = iif_{\text{mv\_msc}} \times di_{\text{msc\_unit}} \]
\[ ii_{\text{msc\_unit\_of}} = iif_{\text{of\_msc}} \times di_{\text{msc\_unit}} \]
\[ ii_{\text{msc\_unit\_wo}} = iif_{\text{wo\_msc}} \times di_{\text{msc\_unit}} \]
\[ ii_{\text{msc\_unit\_it}} = iif_{\text{it\_msc}} \times di_{\text{msc\_unit}} \]
\[ ii_{\text{msc\_unit\_nm}} = iif_{\text{nm\_msc}} \times di_{\text{msc\_unit}} \]
\[ ii_{\text{msc\_unit\_lb}} = iif_{\text{lb\_msc}} \times di_{\text{msc\_unit}} \]

Total network support assets investment relating to MSC units is:

\[ ii_{\text{msc\_unit}} = ii_{\text{msc\_unit\_mv}} + ii_{\text{msc\_unit\_of}} + ii_{\text{msc\_unit\_wo}} + ii_{\text{msc\_unit\_it}} + ii_{\text{msc\_unit\_nm}} + ii_{\text{msc\_unit\_lb}} \]

2.2.4.3 Indirect Investment for MSC ports

\[ ii_{\text{msc\_ports\_mv}} = iif_{\text{mv\_msc}} \times di_{\text{msc\_ports}} \]
\[ ii_{\text{msc\_ports\_of}} = iif_{\text{of\_msc}} \times di_{\text{msc\_ports}} \]
\[ ii_{\text{msc\_ports\_wo}} = iif_{\text{wo\_msc}} \times di_{\text{msc\_ports}} \]
\[ ii_{\text{msc\_ports\_it}} = iif_{\text{it\_msc}} \times di_{\text{msc\_ports}} \]
\[ ii_{\text{msc\_ports\_nm}} = iif_{\text{nm\_msc}} \times di_{\text{msc\_ports}} \]
\[ ii_{\text{msc\_ports\_lb}} = iif_{\text{lb\_msc}} \times di_{\text{msc\_ports}} \]

Total network support assets investment relating to MSC ports is:

\[ ii_{\text{msc\_ports}} = ii_{\text{msc\_ports\_mv}} + ii_{\text{msc\_ports\_of}} + ii_{\text{msc\_ports\_wo}} + ii_{\text{msc\_ports\_it}} + ii_{\text{msc\_ports\_nm}} + ii_{\text{msc\_ports\_lb}} \]
2.2.4.4 Indirect Investment for MSC interconnection ports

\[
\begin{align*}
\text{ii}_\text{msc\_icports\_mv} &= \text{iif}_\text{mv\_msc} \times \text{di}_\text{msc\_icports} \\
\text{ii}_\text{msc\_icports\_of} &= \text{iif}_\text{of\_msc} \times \text{di}_\text{msc\_icports} \\
\text{ii}_\text{msc\_icports\_wo} &= \text{iif}_\text{wo\_msc} \times \text{di}_\text{msc\_icports} \\
\text{ii}_\text{msc\_icports\_it} &= \text{iif}_\text{it\_msc} \times \text{di}_\text{msc\_icports} \\
\text{ii}_\text{msc\_icports\_nm} &= \text{iif}_\text{nm\_msc} \times \text{di}_\text{msc\_icports} \\
\text{ii}_\text{msc\_icports\_lb} &= \text{iif}_\text{lb\_msc} \times \text{di}_\text{msc\_icports}
\end{align*}
\]

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

\[
\text{ii}_\text{msc\_icports} = \text{ii}_\text{msc\_icports\_mv} + \text{ii}_\text{msc\_icports\_of} + \text{ii}_\text{msc\_icports\_wo} + \text{ii}_\text{msc\_icports\_it} + \text{ii}_\text{msc\_icports\_nm} + \text{ii}_\text{msc\_icports\_lb}
\]

2.2.4.5 Network support assets investment for BSC faced ports:

\[
\begin{align*}
\text{ii}_\text{msc\_bscports\_mv} &= \text{iif}_\text{mv\_msc} \times \text{di}_\text{msc\_bscports} \\
\text{ii}_\text{msc\_bscports\_of} &= \text{iif}_\text{of\_msc} \times \text{di}_\text{msc\_bscports} \\
\text{ii}_\text{msc\_bscports\_wo} &= \text{iif}_\text{wo\_msc} \times \text{di}_\text{msc\_bscports} \\
\text{ii}_\text{msc\_bscports\_it} &= \text{iif}_\text{it\_msc} \times \text{di}_\text{msc\_bscports} \\
\text{ii}_\text{msc\_bscports\_nm} &= \text{iif}_\text{nm\_msc} \times \text{di}_\text{msc\_bscports} \\
\text{ii}_\text{msc\_bscports\_lb} &= \text{iif}_\text{lb\_msc} \times \text{di}_\text{msc\_bscports}
\end{align*}
\]

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

\[
\text{ii}_\text{msc\_bscports} = \text{ii}_\text{msc\_bscports\_mv} + \text{ii}_\text{msc\_bscports\_of} + \text{ii}_\text{msc\_bscports\_wo} + \text{ii}_\text{msc\_bscports\_it} + \text{ii}_\text{msc\_bscports\_nm} + \text{ii}_\text{msc\_bscports\_lb}
\]
2.2.4.6 Network support assets investment for MSC faced ports:

\[
\begin{align*}
\text{ii}_\text{msc}_\text{mscports}_\text{mv} &= \text{iif}_\text{mv}_\text{msc} \times \text{di}_\text{msc}\_\text{mscports} \\
\text{ii}_\text{msc}_\text{mscports}_\text{of} &= \text{iif}_\text{of}_\text{msc} \times \text{di}_\text{msc}\_\text{mscports} \\
\text{ii}_\text{msc}_\text{mscports}_\text{wo} &= \text{iif}_\text{wo}_\text{msc} \times \text{di}_\text{msc}\_\text{mscports} \\
\text{ii}_\text{msc}_\text{mscports}_\text{it} &= \text{iif}_\text{it}_\text{msc} \times \text{di}_\text{msc}\_\text{mscports} \\
\text{ii}_\text{msc}_\text{mscports}_\text{nm} &= \text{iif}_\text{nm}_\text{msc} \times \text{di}_\text{msc}\_\text{mscports} \\
\text{ii}_\text{msc}_\text{mscports}_\text{lb} &= \text{iif}_\text{lb}_\text{msc} \times \text{di}_\text{msc}\_\text{mscports}
\end{align*}
\]

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

\[
\text{ii}_\text{msc}\_\text{mscports} = \text{ii}_\text{msc}_\text{mscports}_\text{mv} + \text{ii}_\text{msc}_\text{mscports}_\text{of} + \text{ii}_\text{msc}_\text{mscports}_\text{wo} + \text{ii}_\text{msc}_\text{mscports}_\text{it} + \text{ii}_\text{msc}_\text{mscports}_\text{nm} + \text{ii}_\text{msc}_\text{mscports}_\text{lb}
\]

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

\[
\begin{align*}
\text{ii}_\text{msc}_\text{mv} &= \text{iif}_\text{mv}_\text{msc} \times \text{di}_\text{msc} \\
\text{ii}_\text{msc}_\text{of} &= \text{iif}_\text{of}_\text{msc} \times \text{di}_\text{msc} \\
\text{ii}_\text{msc}_\text{wo} &= \text{iif}_\text{wo}_\text{msc} \times \text{di}_\text{msc} \\
\text{ii}_\text{msc}_\text{it} &= \text{iif}_\text{it}_\text{msc} \times \text{di}_\text{msc} \\
\text{ii}_\text{msc}_\text{nm} &= \text{iif}_\text{nm}_\text{msc} \times \text{di}_\text{msc} \\
\text{ii}_\text{msc}_\text{lb} &= \text{iif}_\text{lb}_\text{msc} \times \text{di}_\text{msc}
\end{align*}
\]

Network support assets investment for processor investment is:

Same \text{iif}_\text{xxx} used as for MSC.

\[
\begin{align*}
\text{ii}_\text{sig}_\text{mv} &= \text{iif}_\text{mv}_\text{msc} \times \text{di}_\text{sig} \\
\text{ii}_\text{sig}_\text{of} &= \text{iif}_\text{of}_\text{msc} \times \text{di}_\text{sig} \\
\text{ii}_\text{sig}_\text{wo} &= \text{iif}_\text{wo}_\text{msc} \times \text{di}_\text{sig} \\
\text{ii}_\text{sig}_\text{it} &= \text{iif}_\text{it}_\text{msc} \times \text{di}_\text{sig} \\
\text{ii}_\text{sig}_\text{nm} &= \text{iif}_\text{nm}_\text{msc} \times \text{di}_\text{sig} \\
\text{ii}_\text{sig}_\text{lb} &= \text{iif}_\text{lb}_\text{msc} \times \text{di}_\text{sig}
\end{align*}
\]
Total network support assets investment for MSCs (excluding processor investment) is:

\[
\text{ii}_\text{msc} = \text{ii}_\text{msc}_\text{mv} + \text{ii}_\text{msc}_\text{of} + \text{ii}_\text{msc}_\text{wo} + \text{ii}_\text{msc}_\text{it} + \text{ii}_\text{msc}_\text{nm} + \text{ii}_\text{msc}_\text{lb}
\]

Total network support assets investment for processor investment:

\[
\text{ii}_\text{sig} = \text{ii}_\text{sig}_\text{mv} + \text{ii}_\text{sig}_\text{of} + \text{ii}_\text{sig}_\text{wo} + \text{ii}_\text{sig}_\text{it} + \text{ii}_\text{sig}_\text{nm} + \text{ii}_\text{sig}_\text{lb}
\]

### 2.2.5 Network support assets investment for the HLR

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>iif_mv_hlr</td>
<td>[0,1]</td>
<td>Investment for motor vehicles (allocated to HLR) as a percentage of direct investment in HLR</td>
<td>Input</td>
</tr>
<tr>
<td>iif_of_hlr</td>
<td>[0,1]</td>
<td>Investment for office equipment (allocated to HLR) as a percentage of direct investment in HLR</td>
<td>Input</td>
</tr>
<tr>
<td>iif_wo_hlr</td>
<td>[0,1]</td>
<td>Investment for workshop equipment (allocated to HLR) as a percentage of direct investment in HLR</td>
<td>Input</td>
</tr>
<tr>
<td>iif_it_hlr</td>
<td>[0,1]</td>
<td>Investment for IT network support equipment (allocated to HLR) as a percentage of direct investment in HLR</td>
<td>Input</td>
</tr>
<tr>
<td>iif_nm_hlr</td>
<td>[0,1]</td>
<td>Investment for network management equipment (allocated to HLR) as a percentage of direct investment in HLR</td>
<td>Input</td>
</tr>
<tr>
<td>iif_lb_hlr</td>
<td>[0,1]</td>
<td>Investment for land and buildings equipment (allocated to HLR) as a percentage of direct investment in HLR</td>
<td>Input</td>
</tr>
</tbody>
</table>
\[ ii_{\text{hlr}}_{\text{mv}} = \text{iif}_{\text{mv}}_{\text{hlr}} \times \text{di}_{\text{hlr}} \]
\[ ii_{\text{hlr}}_{\text{of}} = \text{iif}_{\text{of}}_{\text{hlr}} \times \text{di}_{\text{hlr}} \]
\[ ii_{\text{hlr}}_{\text{wo}} = \text{iif}_{\text{wo}}_{\text{hlr}} \times \text{di}_{\text{hlr}} \]
\[ ii_{\text{hlr}}_{\text{it}} = \text{iif}_{\text{it}}_{\text{hlr}} \times \text{di}_{\text{hlr}} \]
\[ ii_{\text{hlr}}_{\text{nm}} = \text{iif}_{\text{nm}}_{\text{hlr}} \times \text{di}_{\text{hlr}} \]
\[ ii_{\text{hlr}}_{\text{lb}} = \text{iif}_{\text{lb}}_{\text{hlr}} \times \text{di}_{\text{hlr}} \]

Total network support assets investment for the HLR is:

\[ ii_{\text{hlr}} = ii_{\text{hlr}}_{\text{mv}} + ii_{\text{hlr}}_{\text{of}} + ii_{\text{hlr}}_{\text{wo}} + ii_{\text{hlr}}_{\text{it}} + ii_{\text{hlr}}_{\text{nm}} + ii_{\text{hlr}}_{\text{lb}} \]

### 2.2.6 Network support assets investment for SMSCs

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>iif_{mv}_smsc</td>
<td>[0,1]</td>
<td>Investment for motor vehicles (allocated to SMSC) as a percentage of direct investment in SMSC</td>
<td>Input</td>
</tr>
<tr>
<td>iif_{of}_smsc</td>
<td>[0,1]</td>
<td>Investment for office equipment (allocated to SMSC) as a percentage of direct investment in SMSC</td>
<td>Input</td>
</tr>
<tr>
<td>iif_{wo}_smsc</td>
<td>[0,1]</td>
<td>Investment for workshop equipment (allocated to SMSC) as a percentage of direct investment in SMSC</td>
<td>Input</td>
</tr>
<tr>
<td>iif_{it}_smsc</td>
<td>[0,1]</td>
<td>Investment for IT network support equipment (allocated to SMSC) as a percentage of direct investment in SMSC</td>
<td>Input</td>
</tr>
<tr>
<td>iif_{nm}_smsc</td>
<td>[0,1]</td>
<td>Investment for network management equipment (allocated to SMSC) as a percentage of direct investment in SMSC</td>
<td>Input</td>
</tr>
<tr>
<td>iif_{lb}_smsc</td>
<td>[0,1]</td>
<td>Investment for land and buildings equipment (allocated to SMSC) as a percentage of direct investment in SMSC</td>
<td>Input</td>
</tr>
</tbody>
</table>

\[ ii_{\text{smsc}}_{\text{mv}} = \text{iif}_{\text{mv}}_{\text{smsc}} \times \text{di}_{\text{smsc}} \]
\[ ii_{\text{smsc}}_{\text{of}} = \text{iif}_{\text{of}}_{\text{smsc}} \times \text{di}_{\text{smsc}} \]
\[ ii_{\text{smsc}}_{\text{wo}} = \text{iif}_{\text{wo}}_{\text{smsc}} \times \text{di}_{\text{smsc}} \]
\[ ii_{\text{smsc}}_{\text{it}} = \text{iif}_{\text{it}}_{\text{smsc}} \times \text{di}_{\text{smsc}} \]
\[ ii_{\text{smsc}}_{\text{nm}} = \text{iif}_{\text{nm}}_{\text{smsc}} \times \text{di}_{\text{smsc}} \]
\[ ii_{\text{smsc}}_{\text{lb}} = \text{iif}_{\text{lb}}_{\text{smsc}} \times \text{di}_{\text{smsc}} \]
Total network support assets investment relating to SMSCs:

\[
iii_{\text{smsc}} = iii_{\text{smsc \_mv}} + iii_{\text{smsc \_of}} + iii_{\text{smsc \_wo}} + iii_{\text{smsc \_it}} + iii_{\text{smsc \_nm}} + iii_{\text{smsc \_lb}}
\]

### 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:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>(iif_{\text{mv _rl2 _bts _btsh}})</td>
<td>([0,1])</td>
<td>Investment for motor vehicles (allocated to radio link system) as a percentage of direct investment in radio link system</td>
<td>Input</td>
</tr>
<tr>
<td>(iif_{\text{of _rl2 _bts _btsh}})</td>
<td>([0,1])</td>
<td>Investment for office equipment (allocated to radio link system) as a percentage of direct investment in radio link system</td>
<td>Input</td>
</tr>
<tr>
<td>(iif_{\text{wo _rl2 _bts _btsh}})</td>
<td>([0,1])</td>
<td>Investment for workshop equipment (allocated to radio link system) as a percentage of direct investment in radio link system</td>
<td>Input</td>
</tr>
<tr>
<td>(iif_{\text{it _rl2 _bts _btsh}})</td>
<td>([0,1])</td>
<td>Investment for IT network support equipment (allocated to radio link system) as a percentage of direct investment in radio link system</td>
<td>Input</td>
</tr>
<tr>
<td>(iif_{\text{nm _rl2 _bts _btsh}})</td>
<td>([0,1])</td>
<td>Investment for network management equipment (allocated to radio link system) as a percentage of direct investment in radio link system</td>
<td>Input</td>
</tr>
<tr>
<td>(iif_{\text{lb _rl2 _bts _btsh}})</td>
<td>([0,1])</td>
<td>Investment for land and buildings equipment (allocated to radio link system) as a percentage of direct investment in radio link system</td>
<td>Input</td>
</tr>
</tbody>
</table>

\[
ii_{\text{rl2 \_bts \_btsh \_mv}} \quad = \quad iif_{\text{mv \_rl2 \_bts \_btsh}} \times di_{\text{rl2 \_bts \_btsh}}
\]
\[
ii_{\text{rl2 \_bts \_btsh \_of}} \quad = \quad iif_{\text{of \_rl2 \_bts \_btsh}} \times di_{\text{rl2 \_bts \_btsh}}
\]
\[
ii_{\text{rl2 \_bts \_btsh \_wo}} \quad = \quad iif_{\text{wo \_rl2 \_bts \_btsh}} \times di_{\text{rl2 \_bts \_btsh}}
\]
\[
ii_{\text{rl2 \_bts \_btsh \_it}} \quad = \quad iif_{\text{it \_rl2 \_bts \_btsh}} \times di_{\text{rl2 \_bts \_btsh}}
\]
\[
ii_{\text{rl2 \_bts \_btsh \_nm}} \quad = \quad iif_{\text{nm \_rl2 \_bts \_btsh}} \times di_{\text{rl2 \_bts \_btsh}}
\]
\[
ii_{\text{rl2 \_bts \_btsh \_lb}} \quad = \quad iif_{\text{lb \_rl2 \_bts \_btsh}} \times di_{\text{rl2 \_bts \_btsh}}
\]
Total network support assets investment relating to BTS-BTS hub:

\[
\text{ii}_\text{bts_bts} = \text{ii}_\text{rl2_bts_bts\_mv} + \text{ii}_\text{rl2_bts_bts\_of} + \text{ii}_\text{rl2_bts_bts\_wo} + \text{ii}_\text{rl2_bts_bts\_it} + \text{ii}_\text{rl2_bts_bts\_nm} + \text{ii}_\text{rl2_bts_bts\_lb}
\]

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**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>\text{ii}_\text{mv}_\text{rlx}_\text{btsh}_\text{bsc}</td>
<td>[0,1]</td>
<td>Investment for motor vehicles (allocated to radio link system) as a percentage of direct investment in radio link system</td>
<td>Input</td>
</tr>
<tr>
<td>\text{ii}_\text{of}_\text{rlx}_\text{btsh}_\text{bsc}</td>
<td>[0,1]</td>
<td>Investment for office equipment (allocated to radio link system) as a percentage of direct investment in radio link system</td>
<td>Input</td>
</tr>
<tr>
<td>\text{ii}_\text{wo}_\text{rlx}_\text{btsh}_\text{bsc}</td>
<td>[0,1]</td>
<td>Investment for workshop equipment (allocated to radio link system) as a percentage of direct investment in radio link system</td>
<td>Input</td>
</tr>
<tr>
<td>\text{ii}_\text{it}_\text{rlx}_\text{btsh}_\text{bsc}</td>
<td>[0,1]</td>
<td>Investment for IT network support equipment (allocated to radio link system) as a percentage of direct investment in radio link system</td>
<td>Input</td>
</tr>
<tr>
<td>\text{ii}_\text{nm}_\text{rlx}_\text{btsh}_\text{bsc}</td>
<td>[0,1]</td>
<td>Investment for network management equipment (allocated to radio link system) as a percentage of direct investment in radio link system</td>
<td>Input</td>
</tr>
<tr>
<td>\text{ii}_\text{lb}_\text{rlx}_\text{btsh}_\text{bsc}</td>
<td>[0,1]</td>
<td>Investment for land and buildings equipment (allocated to radio link system) as a percentage of direct investment in radio link system</td>
<td>Input</td>
</tr>
</tbody>
</table>

\[
\text{ii}\_\text{rlx}\_\text{btsh}\_\text{bsc\_mv} = \text{ii}\_\text{mv}\_\text{rlx}\_\text{btsh}\_\text{bsc} \times \text{di}\_\text{rlx}\_\text{btsh}\_\text{bsc}
\]

\[
\text{ii}\_\text{rlx}\_\text{btsh}\_\text{bsc\_of} = \text{ii}\_\text{of}\_\text{rlx}\_\text{btsh}\_\text{bsc} \times \text{di}\_\text{rlx}\_\text{btsh}\_\text{bsc}
\]

\[
\text{ii}\_\text{rlx}\_\text{btsh}\_\text{bsc\_wo} = \text{ii}\_\text{wo}\_\text{rlx}\_\text{btsh}\_\text{bsc} \times \text{di}\_\text{rlx}\_\text{btsh}\_\text{bsc}
\]

\[
\text{ii}\_\text{rlx}\_\text{btsh}\_\text{bsc\_it} = \text{ii}\_\text{it}\_\text{rlx}\_\text{btsh}\_\text{bsc} \times \text{di}\_\text{rlx}\_\text{btsh}\_\text{bsc}
\]

\[
\text{ii}\_\text{rlx}\_\text{btsh}\_\text{bsc\_nm} = \text{ii}\_\text{nm}\_\text{rlx}\_\text{btsh}\_\text{bsc} \times \text{di}\_\text{rlx}\_\text{btsh}\_\text{bsc}
\]

\[
\text{ii}\_\text{rlx}\_\text{btsh}\_\text{bsc\_lb} = \text{ii}\_\text{lb}\_\text{rlx}\_\text{btsh}\_\text{bsc} \times \text{di}\_\text{rlx}\_\text{btsh}\_\text{bsc}
\]
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

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

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

\[
\begin{align*}
ii_{ll2f\_btsh\_bsc\_mv} &= iif_{mv\_ll2f\_btsh\_bsc} \times di_{LL2f\_btsh\_bsc} \\
ii_{ll2f\_btsh\_bsc\_of} &= iif_{of\_ll2f\_btsh\_bsc} \times di_{LL2f\_btsh\_bsc} \\
ii_{ll2f\_btsh\_bsc\_wo} &= iif_{wo\_ll2f\_btsh\_bsc} \times di_{LL2f\_btsh\_bsc} \\
ii_{ll2f\_btsh\_bsc\_it} &= iif_{it\_ll2f\_btsh\_bsc} \times di_{LL2f\_btsh\_bsc} \\
ii_{ll2f\_btsh\_bsc\_nm} &= iif_{nm\_ll2f\_btsh\_bsc} \times di_{LL2f\_btsh\_bsc} \\
ii_{ll2f\_btsh\_bsc\_lb} &= iif_{lb\_ll2f\_btsh\_bsc} \times di_{LL2f\_btsh\_bsc}
\end{align*}
\]

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

\[
\begin{align*}
ii_{ll2f\_btsh\_bsc} &= ii_{ll2f\_btsh\_bsc\_mv} + ii_{ll2f\_btsh\_bsc\_of} + ii_{ll2f\_btsh\_bsc\_wo} + ii_{ll2f\_btsh\_bsc\_it} + ii_{ll2f\_btsh\_bsc\_nm} + ii_{ll2f\_btsh\_bsc\_lb}
\end{align*}
\]
2.2.8 Network support assets investment for BSC-MSC links

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>iif_mv_ll155f_bsc_msc</td>
<td>[0,1]</td>
<td>Mark-up for motor vehicles (allocated to STM-1 leased lines) as a percentage of an upfront investment for STM-1 leased lines</td>
<td>Input</td>
</tr>
<tr>
<td>iif_of_ll155f_bsc_msc</td>
<td>[0,1]</td>
<td>Mark-up for office equipment (allocated to STM-1 leased lines) as a percentage of an upfront investment for STM-1 leased lines</td>
<td>Input</td>
</tr>
<tr>
<td>iif_wo_ll155f_bsc_msc</td>
<td>[0,1]</td>
<td>Mark-up for workshop equipment (allocated to STM-1 leased lines) as a percentage of an upfront investment for STM-1 leased lines</td>
<td>Input</td>
</tr>
<tr>
<td>iif_it_ll155f_bsc_msc</td>
<td>[0,1]</td>
<td>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</td>
<td>Input</td>
</tr>
<tr>
<td>iif_nm_ll155f_bsc_msc</td>
<td>[0,1]</td>
<td>Mark-up for network management equipment (allocated to STM-1 leased lines) as a percentage of an upfront investment for STM-1 leased lines</td>
<td>Input</td>
</tr>
<tr>
<td>iif_lb_ll155f_bsc_msc</td>
<td>[0,1]</td>
<td>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</td>
<td>Input</td>
</tr>
</tbody>
</table>

\[
\begin{align*}
ii_{ll155f\_bsc\_msc\_mv} &= iif_{mv\_ll155f\_bsc\_msc} \times di_{LL155f\_bsc\_msc} \\
ii_{ll155f\_bsc\_msc\_of} &= iif_{of\_ll155f\_bsc\_msc} \times di_{LL155f\_bsc\_msc} \\
ii_{ll155f\_bsc\_msc\_wo} &= iif_{wo\_ll155f\_bsc\_msc} \times di_{LL155f\_bsc\_msc} \\
ii_{ll155f\_bsc\_msc\_it} &= iif_{it\_ll155f\_bsc\_msc} \times di_{LL155f\_bsc\_msc} \\
ii_{ll155f\_bsc\_msc\_nm} &= iif_{nm\_ll155f\_bsc\_msc} \times di_{LL155f\_bsc\_msc} \\
ii_{ll155f\_bsc\_msc\_lb} &= iif_{lb\_ll155f\_bsc\_msc} \times di_{LL155f\_bsc\_msc}
\end{align*}
\]

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:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>iif_mv_ll155f_core</td>
<td>[0,1]</td>
<td>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</td>
<td>Input</td>
</tr>
<tr>
<td>iif_of_ll155f_core</td>
<td>[0,1]</td>
<td>Mark-up for office equipment (allocated to STM-1 core leased lines) as a percentage of an upfront investment for STM-1 core leased lines</td>
<td>Input</td>
</tr>
<tr>
<td>iif_wo_ll155f_core</td>
<td>[0,1]</td>
<td>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</td>
<td>Input</td>
</tr>
<tr>
<td>iif_it_ll155f_core</td>
<td>[0,1]</td>
<td>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</td>
<td>Input</td>
</tr>
<tr>
<td>iif_nm_ll155f_core</td>
<td>[0,1]</td>
<td>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</td>
<td>Input</td>
</tr>
<tr>
<td>iif_lb_ll155f_core</td>
<td>[0,1]</td>
<td>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</td>
<td>Input</td>
</tr>
</tbody>
</table>

Network support assets investment is calculated as follows:

\[
\begin{align*}
ii_{\text{ll155f_core_mv}} &= \text{iif}_\text{mv}_{\text{ll155f_core}} \times \text{di}_{\text{LL155f_core}} \\
ii_{\text{ll155f_core_of}} &= \text{iif}_\text{of}_{\text{ll155f_core}} \times \text{di}_{\text{LL155f_core}} \\
ii_{\text{ll155f_core_wo}} &= \text{iif}_\text{wo}_{\text{ll155f_core}} \times \text{di}_{\text{LL155f_core}} \\
ii_{\text{ll155f_core_it}} &= \text{iif}_\text{it}_{\text{ll155f_core}} \times \text{di}_{\text{LL155f_core}} \\
ii_{\text{ll155f_core_nm}} &= \text{iif}_\text{nm}_{\text{ll155f_core}} \times \text{di}_{\text{LL155f_core}} \\
ii_{\text{ll155f_core_lb}} &= \text{iif}_\text{lb}_{\text{ll155f_core}} \times \text{di}_{\text{LL155f_core}}
\end{align*}
\]

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

\[
ii_{\text{ll155f_core}} = ii_{\text{ll155f_core_mv}} + ii_{\text{ll155f_core_of}} + ii_{\text{ll155f_core_wo}} + ii_{\text{ll155f_core_it}} + ii_{\text{ll155f_core_nm}} + ii_{\text{ll155f_core_lb}}
\]
2.3 Output of the investment calculation

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

Total productive network assets investment:

\[
d_i = d_{i\_bts} + d_{i\_bsc} + d_{i\_trau} + d_{i\_msc} + d_{i\_sig} + d_{i\_HLR} + d_{i\_smsc} + d_{i\_rl2\_bts\_btsh} + d_{i\_RL\_fee} + d_{i\_rlx\_btsh\_bsc} + d_{i\_rl\_fee\_btsh\_bsc} + d_{i\_l12f\_btsh\_bsc} + d_{i\_l1155f\_bsc\_msc} + d_{i\_LL155f\_core}
\]

whereby

\[
d_{i\_bts}
\]
\[
d_{i\_bsc}
\]
\[
d_{i\_trau}
\]
\[
d_{i\_msc}
\]
\[
d_{i\_sig}
\]
\[
d_{i\_HLR}
\]
\[
d_{i\_smsc}
\]
\[
d_{i\_rl2\_bts\_btsh}
\]

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’).

\[
af_{bts\_site} = \frac{(WACC - dp_{bts\_site} - g_{bts\_site} - dp_{bts\_site} \times g_{bts\_site})}{(1 - ((1 + dp_{bts\_site}) \times (1 + g_{bts\_site})) / (1 + WACC))^{el_{bts\_site}}}
\]

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

\[
dc_{bts\_site} = di_{bts\_site} \times af_{bts\_site}
\]

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’).

\[
af_{bts\_eq} = \frac{(WACC - dp_{bts\_eq} - g_{bts\_eq} - dp_{bts\_eq} \times g_{bts\_eq})}{(1 - ((1 + dp_{bts\_eq}) \times (1 + g_{bts\_eq})) / (1 + WACC))^{el_{bts\_eq}}}
\]

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

\[
dc_{bts\_eq} = af_{bts\_eq} \times di_{bts\_eq}
\]
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’).

\[
af_{\text{trx}} = \frac{(WACC - dp_{\text{trx}} - g_{\text{trx}} - dp_{\text{trx}} \times g_{\text{trx}})}{(1-((1 + dp_{\text{trx}})*(1+ g_{\text{trx}})/(1 + WACC))^el_{\text{trx}})}
\]

Annual direct costs are then calculated by:

\[
dc_{\text{trx}} = af_{\text{trx}} \times di_{\text{trx}}
\]

3.1.1.4 Total direct costs for the BTSs

**Total direct costs for the BTSs are: *)**

\[
dc_{\text{bts}} = dc_{\text{bts\_site}} + dc_{\text{bts\_eq}} + dc_{\text{trx}} + lic_{\text{GSM900}} + lic_{\text{GSM1800}} + \text{gsm1800freq}
\]

whereby

\[
gsm1800freq = di_{\text{gsm1800freq}} \times [(WACC - dp_{\text{gsm1800freq}} - g_{\text{gsm1800freq}} - dp_{\text{gsm1800freq}} \times g_{\text{gsm1800freq}})}{(1-((1 + dp_{\text{gsm1800freq}})*(1+ g_{\text{gsm1800freq}})/(1 + WACC))^el_{\text{gsm1800freq}})}
\]

*) **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').

\[ af_{bsc\_site} = \frac{(WACC - dp_{bsc\_site} - g_{bsc\_site} - dp_{bsc\_site} \cdot g_{bsc\_site})}{(1-((1 + dp_{bsc\_site}) \cdot (1+ g_{bsc\_site})) / (1 + WACC))^{el_{bsc\_site}}} \]

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

\[ dc_{bsc\_site} = af_{bsc\_site} \cdot di_{bsc\_site} \]

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').

\[ af_{bsc\_unit\_hw} = \frac{(WACC - dp_{bsc\_unit\_hw} - g_{bsc\_unit\_hw} - dp_{bsc\_unit\_hw} \cdot g_{bsc\_unit\_hw})}{(1-((1 + dp_{bsc\_unit\_hw}) \cdot (1+ g_{bsc\_unit\_hw})) / (1 + WACC))^{el_{bsc\_unit\_hw}}} \]
\[ af_{bsc\_unit\_sw} = \frac{(WACC - dp_{bsc\_unit\_sw} - g_{bsc\_unit\_sw} - dp_{bsc\_unit\_sw} \cdot g_{bsc\_unit\_sw})}{(1-((1 + dp_{bsc\_unit\_sw}) \cdot (1+ g_{bsc\_unit\_sw})) / (1 + WACC))^{el_{bsc\_unit\_sw}}} \]

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

\[ dc_{bsc\_unit} = af_{bsc\_unit\_hw} \cdot di_{bsc\_unit\_hw} + af_{bsc\_unit\_sw} \cdot di_{bsc\_unit\_sw} \]
3.1.2.3 Total direct costs for the BSCs

Total direct costs for the BSCs are:

\[ dc_{\text{bsc}} = dc_{\text{bsc\_site}} + dc_{\text{bsc\_unit}} \]

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 (\(g_x\)).

\[
af_{\text{trau}} = \frac{(WACC - dp_{\text{trau}} - g_{\text{trau}} - dp_{\text{trau}} \times g_{\text{trau}})}{(1-((1 + dp_{\text{trau}})\times(1 + g_{\text{trau}})/(1 + WACC))^{el_{\text{trau}}})}
\]

Annual direct costs for the TRAUs are calculated by:

\[ dc_{\text{trau}} = af_{\text{trau}} \times di_{\text{trau}} \]

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 (\(g_x\)).

\[
af_{\text{msc\_site}} = \frac{(WACC - dp_{\text{msc\_site}} - g_{\text{msc\_site}} - dp_{\text{msc\_site}} \times g_{\text{msc\_site}})}{(1-((1 + dp_{\text{msc\_site}})\times(1 + g_{\text{msc\_site}})/(1 + WACC))^{el_{\text{msc\_site}}})}
\]

Annual direct costs for the MSC sites are calculated by:

\[ dc_{\text{msc\_site}} = af_{\text{msc\_site}} \times di_{\text{msc\_site}} \]
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 (\(\text{'dp}_x\)) , the economic lifetime (\(\text{'el}_x\)) as well as the growth rate for mobile services (\(\text{'g}_x\)).

\[
af_{\text{msc\_hw}} = \frac{(\text{WACC} - \text{dp}_x - \text{g}_x - \text{dp}_x \times \text{g}_x)}{(1-((1 + \text{dp}_x)(1 + \text{g}_x)/(1 + \text{WACC}))^{\text{el}_x})}
\]

\[
af_{\text{msc\_sw}} = \frac{(\text{WACC} - \text{dp}_x - \text{g}_x - \text{dp}_x \times \text{g}_x)}{(1-((1 + \text{dp}_x)(1 + \text{g}_x)/(1 + \text{WACC}))^{\text{el}_x})}
\]

Annual direct costs for the MSC equipment are calculated by:

\[
dc_{\text{msc\_unit}} = af_{\text{msc\_hw}} \times di_{\text{msc\_hw}} + af_{\text{msc\_sw}} \times di_{\text{msc\_sw}}
\]

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

\[
dc_{\text{sig}} = af_{\text{msc\_hw}} \times di_{\text{sig}}
\]

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 (\(\text{'dp}_x\)) , the economic lifetime (\(\text{'el}_x\)) as well as the growth rate for mobile services (\(\text{'g}_x\)).

\[
af_{\text{ports}} = \frac{(\text{WACC} - \text{dp}_x - \text{g}_x - \text{dp}_x \times \text{g}_x)}{(1-((1 + \text{dp}_x)(1 + \text{g}_x)/(1 + \text{WACC}))^{\text{el}_x})}
\]

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

\[
dc_{\text{msc\_icports}} = af_{\text{ports}} \times di_{\text{msc\_icports}}
\]

\[
dc_{\text{msc\_bscports}} = af_{\text{ports}} \times di_{\text{msc\_bscports}}
\]

\[
dc_{\text{msc\_mscports}} = af_{\text{ports}} \times di_{\text{msc\_mscports}}
\]

\[
dc_{\text{msc\_ports}} = dc_{\text{msc\_icports}} + dc_{\text{msc\_bscports}} + dc_{\text{msc\_mscports}}
\]
3.1.4.4 Total direct costs for the MSC

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

\[
dc_{\text{msc}} = dc_{\text{msc\_site}} + dc_{\text{msc\_unit}} + dc_{\text{msc\_ports}}
\]

Total direct cost for processor and signalling

\[
dc_{\text{sig}} = dc_{\text{sig}}
\]

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').

\[
af_{\text{hlr}} = \frac{(WACC - dp_{\text{hlr}} - g_{\text{hlr}} - dp_{\text{hlr}} \times g_{\text{hlr}})}{(1-((1 + dp_{\text{hlr}})(1 + g_{\text{hlr}})/(1 + WACC))^el_{\text{hlr}})}
\]

Annual direct costs for the HLR are calculated by:

\[
dc_{\text{hlr}} = af_{\text{hlr}} \times di_{\text{hlr}}
\]

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').

\[
af_{\text{smsc}} = \frac{(WACC - dp_{\text{smsc}} - g_{\text{smsc}} - dp_{\text{smsc}} \times g_{\text{smsc}})}{(1-((1 + dp_{\text{smsc}})(1 + g_{\text{smsc}})/(1 + WACC))^el_{\text{smsc}})}
\]

Annual direct costs for the SMSCs are calculated by:

\[
dc_{\text{smsc}} = af_{\text{smsc}} \times di_{\text{smsc}}
\]
3.1.7 Direct costs of the BTS-BTSH 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’).

\[
af_{rl2} = \frac{(WACC - dp_{rl2} - g_{rl2} - dp_{rl2} \times g_{rl2})}{(1-((1 + dp_{rl2})\times(1 + g_{rl2})/(1 + WACC))^{el_{rl2}})}
\]

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

\[
dc_{rl2_bts_btsh} = af_{rl2} \times di_{rl2_bts_btsh} + n_{kzh_bts_btsh} \times p_{kzh_bts_btsh} + di_{RL_fee} \times af_{rl2}
\]

where \( n_{kzh_bts_btsh} \) 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

\[
af_{rlx_btsh_bsc} = \frac{(WACC - dp_{rlx_btsh_bsc} - g_{rlx_btsh_bsc} - dp_{rlx_btsh_bsc} \times g_{rlx_btsh_bsc})}{(1-((1 + dp_{rlx_btsh_bsc})\times(1 + g_{rlx_btsh_bsc})/(1 + WACC))^{el_{rlx_btsh_bsc}})}
\]

\[
af_{rep_btsh_bsc} = \frac{(WACC - dp_{rep_btsh_bsc} - g_{rep_btsh_bsc} - dp_{rep_btsh_bsc} \times g_{rep_btsh_bsc})}{(1-((1 + dp_{rep_btsh_bsc})\times(1 + g_{rep_btsh_bsc})/(1 + WACC))^{el_{rep_btsh_bsc}})}
\]

\[
af_{rep_site} = \frac{(WACC - dp_{rep_site} - g_{rep_site} - dp_{rep_site} \times g_{rep_site})}{(1-((1 + dp_{rep_site})\times(1 + g_{rep_site})/(1 + WACC))^{el_{rep_site}})}
\]
Annual direct costs of the radio links are calculated by:

**Direct costs for the radio link systems are calculated by:**

\[
dc_{rlx\_btsh\_bsc} = af_{rlx\_btsh\_bsc} \times di_{rl2\_btsh\_bsc} \\
+ af_{rlx\_btsh\_bsc} \times di_{rl8\_btsh\_bsc} \\
+ af_{rlx\_btsh\_bsc} \times di_{rl34\_btsh\_bsc} \\
+ af_{rlx\_btsh\_bsc} \times di_{rl140\_btsh\_bsc} \\
+ n_{khz\_btsh\_bsc} \times p_{khz\_btsh\_bsc} \\
+ af_{rlx\_btsh\_bsc} \times di_{rl\_fee\_btsh\_bsc}
\]

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:**

\[
dc_{rep\_btsh\_bsc} = af_{rep\_btsh\_bsc} \times di_{rl2\_rep} \\
+ af_{rep\_btsh\_bsc} \times di_{rl8\_rep} \\
+ af_{rep\_btsh\_bsc} \times di_{rl34\_rep} \\
+ af_{rep\_btsh\_bsc} \times di_{rl140\_rep} \\
+ af_{rep\_site} \times di_{rep\_site}
\]

**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**

\[
af_{LL2f\_btsh\_bsc} = \frac{(WACC - dp_{LL2f\_btsh\_bsc} - g_{LL2f\_btsh\_bsc} - dp_{LL2f\_btsh\_bsc} \times g_{LL2f\_btsh\_bsc})}{(1 - ((1 + dp_{LL2f\_btsh\_bsc} \times (1 + g_{LL2f\_btsh\_bsc}) / (1 + WACC))^{el_{LL2f\_btsh\_bsc}})}
\]

**Annual direct costs for the leased lines are calculated by:**

**Direct costs for the upfront investment in leased lines:**

\[
dc_{LL2f\_btsh\_bsc} = af_{LL2f\_btsh\_bsc} \times di_{LL2f\_btsh\_bsc}
\]

**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:

$$af_{mv} = \frac{(WACC - dp_{mv} - g_{mv} - dp_{mv} \times g_{mv})}{(1-((1 + dp_{mv})(1 + g_{mv})/(1 + WACC))^el_{mv})}$$

Office equipment:

$$af_{of} = \frac{(WACC - dp_{of} - g_{of} - dp_{of} \times g_{of})}{(1-((1 + dp_{of})(1 + g_{of})/(1 + WACC))^el_{of})}$$

Workshop facilities:

$$af_{wo} = \frac{(WACC - dp_{wo} - g_{wo} - dp_{wo} \times g_{wo})}{(1-((1 + dp_{wo})(1 + g_{wo})/(1 + WACC))^el_{wo})}$$

General IT:

$$af_{it} = \frac{(WACC - dp_{it} - g_{it} - dp_{it} \times g_{it})}{(1-((1 + dp_{it})(1 + g_{it})/(1 + WACC))^el_{it})}$$

Network management:

$$af_{nm} = \frac{(WACC - dp_{nm} - g_{nm} - dp_{nm} \times g_{nm})}{(1-((1 + dp_{nm})(1 + g_{nm})/(1 + WACC))^el_{nm})}$$

Land and buildings:

$$af_{lb} = \frac{(WACC - dp_{lb} - g_{lb} - dp_{lb} \times g_{lb})}{(1-((1 + dp_{lb})(1 + g_{lb})/(1 + WACC))^el_{lb})}$$
**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

\[
\begin{align*}
    ic_{\text{bts_site_mv}} &= ii_{\text{bts_site_mv}} \times af_{\text{mv}} \\
    ic_{\text{bts_site_of}} &= ii_{\text{bts_site_of}} \times af_{\text{of}} \\
    ic_{\text{bts_site_wo}} &= ii_{\text{bts_site_wo}} \times af_{\text{wo}} \\
    ic_{\text{bts_site_it}} &= ii_{\text{bts_site_it}} \times af_{\text{it}} \\
    ic_{\text{bts_site_nm}} &= ii_{\text{bts_site_nm}} \times af_{\text{nm}} \\
    ic_{\text{bts_site_lb}} &= ii_{\text{bts_site_lb}} \times af_{\text{lb}} \\
    ic_{\text{bts_site}} &= ic_{\text{bts_site_mv}} + ic_{\text{bts_site_of}} + ic_{\text{bts_site_wo}} + ic_{\text{bts_site_it}} + ic_{\text{bts_site_nm}} + ic_{\text{bts_site_lb}}
\end{align*}
\]

#### 3.2.1.2 Indirect costs of the BTS equipment

\[
\begin{align*}
    ic_{\text{bts_eq_mv}} &= ii_{\text{bts_eq_mv}} \times af_{\text{mv}} \\
    ic_{\text{bts_eq_of}} &= ii_{\text{bts_eq_of}} \times af_{\text{of}} \\
    ic_{\text{bts_eq_wo}} &= ii_{\text{bts_eq_wo}} \times af_{\text{wo}} \\
    ic_{\text{bts_eq_it}} &= ii_{\text{bts_eq_it}} \times af_{\text{it}} \\
    ic_{\text{bts_eq_nm}} &= ii_{\text{bts_eq_nm}} \times af_{\text{nm}} \\
    ic_{\text{bts_eq_lb}} &= ii_{\text{bts_eq_lb}} \times af_{\text{lb}} \\
    ic_{\text{bts_eq}} &= ic_{\text{bts_eq_mv}} + ic_{\text{bts_eq_of}} + ic_{\text{bts_eq_wo}} + ic_{\text{bts_eq_it}} + ic_{\text{bts_eq_nm}} + ic_{\text{bts_eq_lb}}
\end{align*}
\]
3.2.1.3 Indirect costs of the TRX

\[
\begin{align*}
\text{ic}_{\text{trx}}_{\text{mv}} &= \text{ii}_{\text{trx}}_{\text{mv}} \times \text{af}_{\text{mv}} \\
\text{ic}_{\text{trx}}_{\text{of}} &= \text{ii}_{\text{trx}}_{\text{of}} \times \text{af}_{\text{of}} \\
\text{ic}_{\text{trx}}_{\text{wo}} &= \text{ii}_{\text{trx}}_{\text{wo}} \times \text{af}_{\text{wo}} \\
\text{ic}_{\text{trx}}_{\text{it}} &= \text{ii}_{\text{trx}}_{\text{it}} \times \text{af}_{\text{it}} \\
\text{ic}_{\text{trx}}_{\text{nm}} &= \text{ii}_{\text{trx}}_{\text{nm}} \times \text{af}_{\text{nm}} \\
\text{ic}_{\text{trx}}_{\text{lb}} &= \text{ii}_{\text{trx}}_{\text{lb}} \times \text{af}_{\text{lb}} \\
\text{ic}_{\text{trx}} &= \text{ic}_{\text{trx}}_{\text{mv}} + \text{ic}_{\text{trx}}_{\text{of}} + \text{ic}_{\text{trx}}_{\text{wo}} + \text{ic}_{\text{trx}}_{\text{it}} + \text{ic}_{\text{trx}}_{\text{nm}} + \text{ic}_{\text{trx}}_{\text{lb}}
\end{align*}
\]

3.2.1.4 Total indirect costs of the BTSs

\[
\begin{align*}
\text{ic}_{\text{bts}}_{\text{mv}} &= \text{ii}_{\text{bts}}_{\text{mv}} \times \text{af}_{\text{mv}} \\
\text{ic}_{\text{bts}}_{\text{of}} &= \text{ii}_{\text{bts}}_{\text{of}} \times \text{af}_{\text{of}} \\
\text{ic}_{\text{bts}}_{\text{wo}} &= \text{ii}_{\text{bts}}_{\text{wo}} \times \text{af}_{\text{wo}} \\
\text{ic}_{\text{bts}}_{\text{it}} &= \text{ii}_{\text{bts}}_{\text{it}} \times \text{af}_{\text{it}} \\
\text{ic}_{\text{bts}}_{\text{nm}} &= \text{ii}_{\text{bts}}_{\text{nm}} \times \text{af}_{\text{nm}} \\
\text{ic}_{\text{bts}}_{\text{lb}} &= \text{ii}_{\text{bts}}_{\text{lb}} \times \text{af}_{\text{lb}} \\
\text{ic}_{\text{bts}} &= \text{ic}_{\text{bts}}_{\text{mv}} + \text{ic}_{\text{bts}}_{\text{of}} + \text{ic}_{\text{bts}}_{\text{wo}} + \text{ic}_{\text{bts}}_{\text{it}} + \text{ic}_{\text{bts}}_{\text{nm}} + \text{ic}_{\text{bts}}_{\text{lb}}
\end{align*}
\]

3.2.2 Indirect costs of the BSCs

3.2.2.1 Indirect costs of the BSC sites

\[
\begin{align*}
\text{ic}_{\text{bsc}}_{\text{site}}_{\text{mv}} &= \text{ii}_{\text{bsc}}_{\text{site}}_{\text{mv}} \times \text{af}_{\text{mv}} \\
\text{ic}_{\text{bsc}}_{\text{site}}_{\text{of}} &= \text{ii}_{\text{bsc}}_{\text{site}}_{\text{of}} \times \text{af}_{\text{of}} \\
\text{ic}_{\text{bsc}}_{\text{site}}_{\text{wo}} &= \text{ii}_{\text{bsc}}_{\text{site}}_{\text{wo}} \times \text{af}_{\text{wo}}
\end{align*}
\]
3.2.2.2 Indirect costs of the BSC equipment (hardware and software)

\[
\begin{align*}
\text{ic\_bsc\_unit\_mv} &= \text{ii\_bsc\_unit\_mv} \times \text{af\_mv} \\
\text{ic\_bsc\_unit\_of} &= \text{ii\_bsc\_unit\_of} \times \text{af\_of} \\
\text{ic\_bsc\_unit\_wo} &= \text{ii\_bsc\_unit\_wo} \times \text{af\_wo} \\
\text{ic\_bsc\_unit\_it} &= \text{ii\_bsc\_unit\_it} \times \text{af\_it} \\
\text{ic\_bsc\_unit\_nm} &= \text{ii\_bsc\_unit\_nm} \times \text{af\_nm} \\
\text{ic\_bsc\_unit\_lb} &= \text{ii\_bsc\_unit\_lb} \times \text{af\_lb}
\end{align*}
\]

\[
\text{ic\_bsc\_unit} = \text{ic\_bsc\_unit\_mv} + \text{ic\_bsc\_unit\_of} + \text{ic\_bsc\_unit\_wo} + \text{ic\_bsc\_unit\_it} + \text{ic\_bsc\_unit\_nm} + \text{ic\_bsc\_unit\_lb}
\]

3.2.2.3 Total indirect costs of the BSCs

\[
\begin{align*}
\text{ic\_bsc\_mv} &= \text{ii\_bsc\_mv} \times \text{af\_mv} \\
\text{ic\_bsc\_of} &= \text{ii\_bsc\_of} \times \text{af\_of} \\
\text{ic\_bsc\_wo} &= \text{ii\_bsc\_wo} \times \text{af\_wo} \\
\text{ic\_bsc\_it} &= \text{ii\_bsc\_it} \times \text{af\_it} \\
\text{ic\_bsc\_nm} &= \text{ii\_bsc\_nm} \times \text{af\_nm} \\
\text{ic\_bsc\_lb} &= \text{ii\_bsc\_lb} \times \text{af\_lb}
\end{align*}
\]
Total indirect costs associated with the BSCs:

\[
\text{ic}_\text{bsc} = \text{ic}_\text{bsc}_\text{mv} + \text{ic}_\text{bsc}_\text{of} + \text{ic}_\text{bsc}_\text{wo} + \text{ic}_\text{bsc}_\text{it} + \text{ic}_\text{bsc}_\text{nm} + \text{ic}_\text{bsc}_\text{lb}
\]

3.2.3 Indirect costs of the TRAUs

\[
\text{ic}_\text{trau}_\text{mv} = \text{ii}_\text{trau}_\text{mv} \times \text{af}_\text{mv} \\
\text{ic}_\text{trau}_\text{of} = \text{ii}_\text{trau}_\text{of} \times \text{af}_\text{of} \\
\text{ic}_\text{trau}_\text{wo} = \text{ii}_\text{trau}_\text{wo} \times \text{af}_\text{wo} \\
\text{ic}_\text{trau}_\text{it} = \text{ii}_\text{trau}_\text{it} \times \text{af}_\text{it} \\
\text{ic}_\text{trau}_\text{nm} = \text{ii}_\text{trau}_\text{nm} \times \text{af}_\text{nm} \\
\text{ic}_\text{trau}_\text{lb} = \text{ii}_\text{trau}_\text{lb} \times \text{af}_\text{lb}
\]

Total indirect costs associated with the TRAUs:

\[
\text{ic}_\text{trau} = \text{ic}_\text{trau}_\text{mv} + \text{ic}_\text{trau}_\text{of} + \text{ic}_\text{trau}_\text{wo} + \text{ic}_\text{trau}_\text{it} + \text{ic}_\text{trau}_\text{nm} + \text{ic}_\text{trau}_\text{lb}
\]

3.2.4 Indirect costs of the MSCs

3.2.4.1 Indirect costs of the MSC sites

\[
\text{ic}_\text{msc}_\text{site}_\text{mv} = \text{ii}_\text{msc}_\text{site}_\text{mv} \times \text{af}_\text{mv} \\
\text{ic}_\text{msc}_\text{site}_\text{of} = \text{ii}_\text{msc}_\text{site}_\text{of} \times \text{af}_\text{of} \\
\text{ic}_\text{msc}_\text{site}_\text{wo} = \text{ii}_\text{msc}_\text{site}_\text{wo} \times \text{af}_\text{wo} \\
\text{ic}_\text{msc}_\text{site}_\text{it} = \text{ii}_\text{msc}_\text{site}_\text{it} \times \text{af}_\text{it} \\
\text{ic}_\text{msc}_\text{site}_\text{nm} = \text{ii}_\text{msc}_\text{site}_\text{nm} \times \text{af}_\text{nm} \\
\text{ic}_\text{msc}_\text{site}_\text{lb} = \text{ii}_\text{msc}_\text{site}_\text{lb} \times \text{af}_\text{lb}
\]
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

\[
\begin{align*}
ic_{\text{msc\_icports\_mv}} &= ii_{\text{msc\_icports\_mv}} \times af_{\text{mv}} \\
nic_{\text{msc\_icports\_of}} &= ii_{\text{msc\_icports\_of}} \times af_{\text{of}} \\
nic_{\text{msc\_icports\_wo}} &= ii_{\text{msc\_icports\_wo}} \times af_{\text{wo}} \\
nic_{\text{msc\_icports\_it}} &= ii_{\text{msc\_icports\_it}} \times af_{\text{it}} \\
nic_{\text{msc\_icports\_nm}} &= ii_{\text{msc\_icports\_nm}} \times af_{\text{nm}} \\
nic_{\text{msc\_icports\_lb}} &= ii_{\text{msc\_icports\_lb}} \times af_{\text{lb}}
\end{align*}
\]

\[
\begin{align*}
ic_{\text{msc\_icports}} &= nic_{\text{msc\_icports\_mv}} \\
&\quad + nic_{\text{msc\_icports\_of}} \\
&\quad + nic_{\text{msc\_icports\_wo}} \\
&\quad + nic_{\text{msc\_icports\_it}} \\
&\quad + nic_{\text{msc\_icports\_nm}} \\
&\quad + nic_{\text{msc\_icports\_lb}}
\end{align*}
\]

3.2.4.5 Indirect costs of the BSC faced ports

\[
\begin{align*}
ic_{\text{msc\_bscports\_mv}} &= ii_{\text{msc\_bscports\_mv}} \times af_{\text{mv}} \\
nic_{\text{msc\_bscports\_of}} &= ii_{\text{msc\_bscports\_of}} \times af_{\text{of}} \\
nic_{\text{msc\_bscports\_wo}} &= ii_{\text{msc\_bscports\_wo}} \times af_{\text{wo}} \\
nic_{\text{msc\_bscports\_it}} &= ii_{\text{msc\_bscports\_it}} \times af_{\text{it}} \\
nic_{\text{msc\_bscports\_nm}} &= ii_{\text{msc\_bscports\_nm}} \times af_{\text{nm}} \\
nic_{\text{msc\_bscports\_lb}} &= ii_{\text{msc\_bscports\_lb}} \times af_{\text{lb}}
\end{align*}
\]

\[
\begin{align*}
ic_{\text{msc\_bscports}} &= nic_{\text{msc\_bscports\_mv}} \\
&\quad + nic_{\text{msc\_bscports\_of}} \\
&\quad + nic_{\text{msc\_bscports\_wo}} \\
&\quad + nic_{\text{msc\_bscports\_it}} \\
&\quad + nic_{\text{msc\_bscports\_nm}} \\
&\quad + nic_{\text{msc\_bscports\_lb}}
\end{align*}
\]

3.2.4.6 Indirect costs of the MSC faced ports

\[
\begin{align*}
ic_{\text{msc\_mscports\_mv}} &= ii_{\text{msc\_mscports\_mv}} \times af_{\text{mv}} \\
nic_{\text{msc\_mscports\_of}} &= ii_{\text{msc\_mscports\_of}} \times af_{\text{of}} \\
nic_{\text{msc\_mscports\_wo}} &= ii_{\text{msc\_mscports\_wo}} \times af_{\text{wo}} \\
nic_{\text{msc\_mscports\_it}} &= ii_{\text{msc\_mscports\_it}} \times af_{\text{it}} \\
nic_{\text{msc\_mscports\_nm}} &= ii_{\text{msc\_mscports\_nm}} \times af_{\text{nm}} \\
nic_{\text{msc\_mscports\_lb}} &= ii_{\text{msc\_mscports\_lb}} \times af_{\text{lb}}
\end{align*}
\]
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

\[
\begin{align*}
\text{ic}_{\text{hlr} \_\text{mv}} &= \text{ii}_{\text{hlr} \_\text{mv}} \times \text{af}_{\text{mv}} \\
\text{ic}_{\text{hlr} \_\text{of}} &= \text{ii}_{\text{hlr} \_\text{of}} \times \text{af}_{\text{of}} \\
\text{ic}_{\text{hlr} \_\text{wo}} &= \text{ii}_{\text{hlr} \_\text{wo}} \times \text{af}_{\text{wo}} \\
\text{ic}_{\text{hlr} \_\text{it}} &= \text{ii}_{\text{hlr} \_\text{it}} \times \text{af}_{\text{it}} \\
\text{ic}_{\text{hlr} \_\text{nm}} &= \text{ii}_{\text{hlr} \_\text{nm}} \times \text{af}_{\text{nm}} \\
\text{ic}_{\text{hlr} \_\text{lb}} &= \text{ii}_{\text{hlr} \_\text{lb}} \times \text{af}_{\text{lb}} \\
\end{align*}
\]

Total indirect costs associated with the HLR:

\[
\text{ic}_{\text{hlr}} = \text{ic}_{\text{hlr} \_\text{mv}} + \text{ic}_{\text{hlr} \_\text{of}} + \text{ic}_{\text{hlr} \_\text{wo}} + \text{ic}_{\text{hlr} \_\text{it}} + \text{ic}_{\text{hlr} \_\text{nm}} + \text{ic}_{\text{hlr} \_\text{lb}}
\]

3.2.6 Indirect costs of the SMSCs

\[
\begin{align*}
\text{ic}_{\text{smsc} \_\text{mv}} &= \text{ii}_{\text{smsc} \_\text{mv}} \times \text{af}_{\text{mv}} \\
\text{ic}_{\text{smsc} \_\text{of}} &= \text{ii}_{\text{smsc} \_\text{of}} \times \text{af}_{\text{of}} \\
\text{ic}_{\text{smsc} \_\text{wo}} &= \text{ii}_{\text{smsc} \_\text{wo}} \times \text{af}_{\text{wo}} \\
\text{ic}_{\text{smsc} \_\text{it}} &= \text{ii}_{\text{smsc} \_\text{it}} \times \text{af}_{\text{it}} \\
\text{ic}_{\text{smsc} \_\text{nm}} &= \text{ii}_{\text{smsc} \_\text{nm}} \times \text{af}_{\text{nm}} \\
\text{ic}_{\text{smsc} \_\text{lb}} &= \text{ii}_{\text{smsc} \_\text{lb}} \times \text{af}_{\text{lb}} \\
\end{align*}
\]

Total indirect costs associated with the SMSCs:

\[
\text{ic}_{\text{smsc}} = \text{ic}_{\text{smsc} \_\text{mv}} + \text{ic}_{\text{smsc} \_\text{of}} + \text{ic}_{\text{smsc} \_\text{wo}} + \text{ic}_{\text{smsc} \_\text{it}} + \text{ic}_{\text{smsc} \_\text{nm}} + \text{ic}_{\text{smsc} \_\text{lb}}
\]
3.2.7 Indirect costs of the BTS-BSC links

3.2.7.1 Indirect costs of the BTS-BTS hub links

\[
\begin{align*}
\text{ic}_{\text{r12}\text{-bts-btsh\_mv}} &= \text{ii}_{\text{r12}\text{-bts-btsh\_mv}} \times \text{af\_mv} \\
\text{ic}_{\text{r12}\text{-bts-btsh\_of}} &= \text{ii}_{\text{r12}\text{-bts-btsh\_of}} \times \text{af\_of} \\
\text{ic}_{\text{r12}\text{-bts-btsh\_wo}} &= \text{ii}_{\text{r12}\text{-bts-btsh\_wo}} \times \text{af\_wo} \\
\text{ic}_{\text{r12}\text{-bts-btsh\_it}} &= \text{ii}_{\text{r12}\text{-bts-btsh\_it}} \times \text{af\_it} \\
\text{ic}_{\text{r12}\text{-bts-btsh\_nm}} &= \text{ii}_{\text{r12}\text{-bts-btsh\_nm}} \times \text{af\_nm} \\
\text{ic}_{\text{r12}\text{-bts-btsh\_lb}} &= \text{ii}_{\text{r12}\text{-bts-btsh\_lb}} \times \text{af\_lb}
\end{align*}
\]

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

\[
\begin{align*}
\text{ic}_{\text{r12}\text{-bts-btsh}} &= \text{ic}_{\text{r12}\text{-bts-btsh\_mv}} \\
&\quad + \text{ic}_{\text{r12}\text{-bts-btsh\_of}} \\
&\quad + \text{ic}_{\text{r12}\text{-bts-btsh\_wo}} \\
&\quad + \text{ic}_{\text{r12}\text{-bts-btsh\_it}} \\
&\quad + \text{ic}_{\text{r12}\text{-bts-btsh\_nm}} \\
&\quad + \text{ic}_{\text{r12}\text{-bts-btsh\_lb}}
\end{align*}
\]

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:**

  \[
  \begin{align*}
  \text{ic}\_rl\_btsh\_bsc\_mv &= \text{ii}\_rl\_btsh\_bsc\_mv \times \text{af}\_mv \\
  \text{ic}\_rl\_btsh\_bsc\_of &= \text{ii}\_rl\_btsh\_bsc\_of \times \text{af}\_of \\
  \text{ic}\_rl\_btsh\_bsc\_wo &= \text{ii}\_rl\_btsh\_bsc\_wo \times \text{af}\_wo \\
  \text{ic}\_rl\_btsh\_bsc\_it &= \text{ii}\_rl\_btsh\_bsc\_it \times \text{af}\_it \\
  \text{ic}\_rl\_btsh\_bsc\_nm &= \text{ii}\_rl\_btsh\_bsc\_nm \times \text{af}\_nm \\
  \text{ic}\_rl\_btsh\_bsc\_lb &= \text{ii}\_rl\_btsh\_bsc\_lb \times \text{af}\_lb \\
  \end{align*}
  \]

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

  \[
  \begin{align*}
  \text{ic}\_rl\_btsh\_bsc &= \text{ic}\_rl\_btsh\_bsc\_mv \\
  &\quad + \text{ic}\_rl\_btsh\_bsc\_of \\
  &\quad + \text{ic}\_rl\_btsh\_bsc\_wo \\
  &\quad + \text{ic}\_rl\_btsh\_bsc\_it \\
  &\quad + \text{ic}\_rl\_btsh\_bsc\_nm \\
  &\quad + \text{ic}\_rl\_btsh\_bsc\_lb \\
  \end{align*}
  \]

  Note: RL fees not considered.

- Indirect costs of the leased lines

  \[
  \begin{align*}
  \text{ic}\_ll2f\_btsh\_bsc\_mv &= \text{ii}\_ll2f\_btsh\_bsc\_mv \times \text{af}\_mv \\
  \text{ic}\_ll2f\_btsh\_bsc\_of &= \text{ii}\_ll2f\_btsh\_bsc\_of \times \text{af}\_of \\
  \text{ic}\_ll2f\_btsh\_bsc\_wo &= \text{ii}\_ll2f\_btsh\_bsc\_wo \times \text{af}\_wo \\
  \text{ic}\_ll2f\_btsh\_bsc\_it &= \text{ii}\_ll2f\_btsh\_bsc\_it \times \text{af}\_it \\
  \text{ic}\_ll2f\_btsh\_bsc\_nm &= \text{ii}\_ll2f\_btsh\_bsc\_nm \times \text{af}\_nm \\
  \text{ic}\_ll2f\_btsh\_bsc\_lb &= \text{ii}\_ll2f\_btsh\_bsc\_lb \times \text{af}\_lb \\
  \end{align*}
  \]

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

  \[
  \begin{align*}
  \text{ic}\_btsh\_bsc &= \text{ic}\_rl\_btsh\_bsc \\
  &\quad + \text{ic}\_ll2f\_btsh\_bsc \\
  \end{align*}
  \]
3.2.8 Indirect costs of the BSC-MSC links

\[
\begin{align*}
\text{ic}_\text{ll1155f}_\text{bsc_msc}_{\text{mv}} &= \text{ii}_\text{ll1155f}_\text{bsc_msc} \cdot \text{af}_\text{mv} \\
\text{ic}_\text{ll1155f}_\text{bsc_msc}_{\text{of}} &= \text{ii}_\text{ll1155f}_\text{bsc_msc} \cdot \text{af}_\text{of} \\
\text{ic}_\text{ll1155f}_\text{bsc_msc}_{\text{wo}} &= \text{ii}_\text{ll1155f}_\text{bsc_msc} \cdot \text{af}_\text{wo} \\
\text{ic}_\text{ll1155f}_\text{bsc_msc}_{\text{it}} &= \text{ii}_\text{ll1155f}_\text{bsc_msc} \cdot \text{af}_\text{it} \\
\text{ic}_\text{ll1155f}_\text{bsc_msc}_{\text{nm}} &= \text{ii}_\text{ll1155f}_\text{bsc_msc} \cdot \text{af}_\text{nm} \\
\text{ic}_\text{ll1155f}_\text{bsc_msc}_{\text{lb}} &= \text{ii}_\text{ll1155f}_\text{bsc_msc} \cdot \text{af}_\text{lb}
\end{align*}
\]

\[
\text{ic}_\text{ll1155f}_\text{bsc_msc} = \text{ic}_\text{ll1155f}_\text{bsc_msc}_{\text{mv}} + \text{ic}_\text{ll1155f}_\text{bsc_msc}_{\text{of}} + \text{ic}_\text{ll1155f}_\text{bsc_msc}_{\text{wo}} + \text{ic}_\text{ll1155f}_\text{bsc_msc}_{\text{it}} + \text{ic}_\text{ll1155f}_\text{bsc_msc}_{\text{nm}} + \text{ic}_\text{ll1155f}_\text{bsc_msc}_{\text{lb}}
\]

3.2.9 Indirect costs of the MSC-MSC links

\[
\begin{align*}
\text{ic}_\text{ll1155f}_\text{core}_{\text{mv}} &= \text{ii}_\text{ll1155f}_\text{core} \cdot \text{af}_\text{mv} \\
\text{ic}_\text{ll1155f}_\text{core}_{\text{of}} &= \text{ii}_\text{ll1155f}_\text{core} \cdot \text{af}_\text{of} \\
\text{ic}_\text{ll1155f}_\text{core}_{\text{wo}} &= \text{ii}_\text{ll1155f}_\text{core} \cdot \text{af}_\text{wo} \\
\text{ic}_\text{ll1155f}_\text{core}_{\text{it}} &= \text{ii}_\text{ll1155f}_\text{core} \cdot \text{af}_\text{it} \\
\text{ic}_\text{ll1155f}_\text{core}_{\text{nm}} &= \text{ii}_\text{ll1155f}_\text{core} \cdot \text{af}_\text{nm} \\
\text{ic}_\text{ll1155f}_\text{core}_{\text{lb}} &= \text{ii}_\text{ll1155f}_\text{core} \cdot \text{af}_\text{lb}
\end{align*}
\]

\[
\text{ic}_\text{ll1155f}_\text{core} = \text{ic}_\text{ll1155f}_\text{core}_{\text{mv}} + \text{ic}_\text{ll1155f}_\text{core}_{\text{of}} + \text{ic}_\text{ll1155f}_\text{core}_{\text{wo}} + \text{ic}_\text{ll1155f}_\text{core}_{\text{it}} + \text{ic}_\text{ll1155f}_\text{core}_{\text{nm}} + \text{ic}_\text{ll1155f}_\text{core}_{\text{lb}}
\]
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.

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

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

\[
\begin{align*}
oc_{di\_bts\_site} &= ocf_{bts} \times di_{bts\_site} \\
oc_{ii\_bts\_site} &= ocf_{mv} \times ii_{bts\_site\_mv} \\
&+ ocf_{of} \times ii_{bts\_site\_of} \\
&+ ocf_{wo} \times ii_{bts\_site\_wo} \\
&+ ocf_{it} \times ii_{bts\_site\_it} \\
&+ ocf_{nm} \times ii_{bts\_site\_nm} \\
&+ ocf_{lb} \times ii_{bts\_site\_lb}
\end{align*}
\]
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

\[
\begin{align*}
oc_{\text{di bsc site}} &= ocf_{\text{bsc}} \times \text{di bsc site} \\
oc_{\text{ii bsc site}} &= ocf_{\text{mv}} \times \text{ii bsc site mv} \\
&+ ocf_{\text{of}} \times \text{ii bsc site of} \\
&+ ocf_{\text{wo}} \times \text{ii bsc site wo} \\
&+ ocf_{\text{it}} \times \text{ii bsc site it} \\
&+ ocf_{\text{nm}} \times \text{ii bsc site nm} \\
&+ ocf_{\text{lb}} \times \text{ii bsc site lb} \\
oc_{\text{bsc site} -} &= oc_{\text{di bsc site}} - \\
&+ oc_{\text{ii bsc site}}
\end{align*}
\]

OPEX relating to the BSC equipment (hardware and software)

\[
\begin{align*}
oc_{\text{di bsc unit}} &= ocf_{\text{bsc}} \times \text{di bsc unit} \\
oc_{\text{ii bsc unit}} &= ocf_{\text{mv}} \times \text{ii bsc unit mv} \\
&+ ocf_{\text{of}} \times \text{ii bsc unit of} \\
&+ ocf_{\text{wo}} \times \text{ii bsc unit wo} \\
&+ ocf_{\text{it}} \times \text{ii bsc unit it} \\
&+ ocf_{\text{nm}} \times \text{ii bsc unit nm} \\
&+ ocf_{\text{lb}} \times \text{ii bsc unit lb} \\
oc_{\text{bsc unit} -} &= oc_{\text{di bsc unit}} - \\
&+ oc_{\text{ii bsc unit}}
\end{align*}
\]

Total OPEX relating to the BSCs

\[
\begin{align*}
oc_{\text{di bsc}} &= ocf_{\text{bsc}} \times \text{di bsc} \\
oc_{\text{ii bsc}} &= ocf_{\text{mv}} \times \text{ii bsc mv} \\
&+ ocf_{\text{of}} \times \text{ii bsc of} \\
&+ ocf_{\text{wo}} \times \text{ii bsc wo} \\
&+ ocf_{\text{it}} \times \text{ii bsc it} \\
&+ ocf_{\text{nm}} \times \text{ii bsc nm} \\
&+ ocf_{\text{lb}} \times \text{ii bsc lb} \\
oc_{\text{bsc}} &= oc_{\text{di bsc}} - \\
&+ oc_{\text{ii bsc}}
\end{align*}
\]
3.3.3 OPEX relating to the TRAUks

\[
\text{oc}_\text{di}_\text{trau} = \text{ocf}_\text{trau} \times \text{di}_\text{trau}
\]
\[
\text{oc}_\text{ii}_\text{trau} = \text{ocf}_\text{mv} \times \text{ii}_\text{trau}_\text{mv} \\
+ \text{ocf}_\text{of} \times \text{ii}_\text{trau}_\text{of} \\
+ \text{ocf}_\text{wo} \times \text{ii}_\text{trau}_\text{wo} \\
+ \text{ocf}_\text{it} \times \text{ii}_\text{trau}_\text{it} \\
+ \text{ocf}_\text{nm} \times \text{ii}_\text{trau}_\text{nm} \\
+ \text{ocf}_\text{lb} \times \text{ii}_\text{trau}_\text{lb}
\]
\[
\text{oc}_\text{trau} = \text{oc}_\text{di}_\text{trau} \\
+ \text{oc}_\text{ii}_\text{trau}
\]

3.3.4 OPEX relating to the MSCs

**OPEX relating to the MSC sites**

\[
\text{oc}_\text{di}_\text{msc}_\text{site} = \text{ocf}_\text{msc} \times \text{di}_\text{msc}_\text{site} 
\]
\[
\text{oc}_\text{ii}_\text{msc}_\text{site} = \text{ocf}_\text{mv} \times \text{ii}_\text{msc}_\text{site}_\text{mv} \\
+ \text{ocf}_\text{of} \times \text{ii}_\text{msc}_\text{site}_\text{of} \\
+ \text{ocf}_\text{wo} \times \text{ii}_\text{msc}_\text{site}_\text{wo} \\
+ \text{ocf}_\text{it} \times \text{ii}_\text{msc}_\text{site}_\text{it} \\
+ \text{ocf}_\text{nm} \times \text{ii}_\text{msc}_\text{site}_\text{nm} \\
+ \text{ocf}_\text{lb} \times \text{ii}_\text{msc}_\text{site}_\text{lb}
\]
\[
\text{oc}_\text{msc}_\text{site} = \text{oc}_\text{di}_\text{msc}_\text{site} \\
+ \text{oc}_\text{ii}_\text{msc}_\text{site}
\]

**OPEX relating to the MSC units**

\[
\text{oc}_\text{di}_\text{msc}_\text{unit} = \text{ocf}_\text{msc} \times \text{di}_\text{msc}_\text{unit} 
\]
\[
\text{oc}_\text{ii}_\text{msc}_\text{unit} = \text{ocf}_\text{mv} \times \text{ii}_\text{msc}_\text{unit}_\text{mv} \\
+ \text{ocf}_\text{of} \times \text{ii}_\text{msc}_\text{unit}_\text{of} \\
+ \text{ocf}_\text{wo} \times \text{ii}_\text{msc}_\text{unit}_\text{wo} \\
+ \text{ocf}_\text{it} \times \text{ii}_\text{msc}_\text{unit}_\text{it} \\
+ \text{ocf}_\text{nm} \times \text{ii}_\text{msc}_\text{unit}_\text{nm} \\
+ \text{ocf}_\text{lb} \times \text{ii}_\text{msc}_\text{unit}_\text{lb}
\]
\[
\text{oc}_\text{msc}_\text{unit} = \text{oc}_\text{di}_\text{msc}_\text{unit} \\
+ \text{oc}_\text{ii}_\text{msc}_\text{unit}
\]
OPEX relating to the MSC ports

\[
\begin{align*}
\text{oc_di_msc_ports} &= \text{ocf_msc} \times \text{di_msc_ports} \\
\text{oc_ii_msc_ports} &= \text{ocf_mv} \times \text{ii_msc_ports_mv} \\
&+ \text{ocf_of} \times \text{ii_msc_ports_of} \\
&+ \text{ocf_wo} \times \text{ii_msc_ports_wo} \\
&+ \text{ocf_it} \times \text{ii_msc_ports_it} \\
&+ \text{ocf_nm} \times \text{ii_msc_ports_nm} \\
&+ \text{ocf_lb} \times \text{ii_msc_ports_lb} \\
\text{oc_msc_ports} &= \text{oc_di_msc_ports} \\
&+ \text{oc_ii_msc_ports}
\end{align*}
\]

OPEX relating to the MSC interconnection ports

\[
\begin{align*}
\text{oc_di_msc_icports} &= \text{ocf_msc} \times \text{di_msc_icports} \\
\text{oc_ii_msc_icports} &= \text{ocf_mv} \times \text{ii_msc_icports_mv} \\
&+ \text{ocf_of} \times \text{ii_msc_icports_of} \\
&+ \text{ocf_wo} \times \text{ii_msc_icports_wo} \\
&+ \text{ocf_it} \times \text{ii_msc_icports_it} \\
&+ \text{ocf_nm} \times \text{ii_msc_icports_nm} \\
&+ \text{ocf_lb} \times \text{ii_msc_icports_lb} \\
\text{oc_msc_icports} &= \text{oc_di_msc_icports} \\
&+ \text{oc_ii_msc_icports}
\end{align*}
\]

OPEX relating to the BSC faced ports

\[
\begin{align*}
\text{oc_di_msc_bscports} &= \text{ocf_msc} \times \text{di_msc_bscports} \\
\text{oc_ii_msc_bscports} &= \text{ocf_mv} \times \text{ii_msc_bscports_mv} \\
&+ \text{ocf_of} \times \text{ii_msc_bscports_of} \\
&+ \text{ocf_wo} \times \text{ii_msc_bscports_wo} \\
&+ \text{ocf_it} \times \text{ii_msc_bscports_it} \\
&+ \text{ocf_nm} \times \text{ii_msc_bscports_nm} \\
&+ \text{ocf_lb} \times \text{ii_msc_bscports_lb} \\
\text{oc_msc_bscports} &= \text{oc_di_msc_bscports} \\
&+ \text{oc_ii_msc_bscports}
\end{align*}
\]
OPEX relating to the MSC faced ports

\begin{align*}
\text{oc}_\text{di}_\text{msc}_\text{mscports} &= \text{ocf}_\text{msc} \times \text{di}_\text{msc}_\text{mscports} \\
\text{oc}_\text{ii}_\text{msc}_\text{mscports} &= \text{ocf}_\text{mv} \times \text{ii}_\text{msc}_\text{mscports}_\text{mv} \\
&+ \text{ocf}_\text{of} \times \text{ii}_\text{msc}_\text{mscports}_\text{of} \\
&+ \text{ocf}_\text{wo} \times \text{ii}_\text{msc}_\text{mscports}_\text{wo} \\
&+ \text{ocf}_\text{it} \times \text{ii}_\text{msc}_\text{mscports}_\text{it} \\
&+ \text{ocf}_\text{nm} \times \text{ii}_\text{msc}_\text{mscports}_\text{nm} \\
&+ \text{ocf}_\text{lb} \times \text{ii}_\text{msc}_\text{mscports}_\text{lb}
\end{align*}

\begin{align*}
\text{oc}_\text{msc}_\text{mscports} &= \text{oc}_\text{di}_\text{msc}_\text{mscports} \\
&+ \text{oc}_\text{ii}_\text{msc}_\text{mscports}
\end{align*}

OPEX relating to the MSCs (excluding signalling):

\begin{align*}
\text{oc}_\text{di}_\text{msc} &= \text{ocf}_\text{msc} \times \text{di}_\text{msc} \\
\text{oc}_\text{ii}_\text{msc} &= \text{ocf}_\text{mv} \times \text{ii}_\text{msc}_\text{mv} \\
&+ \text{ocf}_\text{of} \times \text{ii}_\text{msc}_\text{of} \\
&+ \text{ocf}_\text{wo} \times \text{ii}_\text{msc}_\text{wo} \\
&+ \text{ocf}_\text{it} \times \text{ii}_\text{msc}_\text{it} \\
&+ \text{ocf}_\text{nm} \times \text{ii}_\text{msc}_\text{nm} \\
&+ \text{ocf}_\text{lb} \times \text{ii}_\text{msc}_\text{lb}
\end{align*}

OPEX relating to the processor:

Same OC factor (operating cost factor) as for MSC used.

\begin{align*}
\text{oc}_\text{di}_\text{sig} &= \text{ocf}_\text{msc} \times \text{di}_\text{sig} \\
\text{oc}_\text{ii}_\text{sig} &= \text{ocf}_\text{mv} \times \text{ii}_\text{sig}_\text{mv} \\
&+ \text{ocf}_\text{of} \times \text{ii}_\text{sig}_\text{of} \\
&+ \text{ocf}_\text{wo} \times \text{ii}_\text{sig}_\text{wo} \\
&+ \text{ocf}_\text{it} \times \text{ii}_\text{sig}_\text{it} \\
&+ \text{ocf}_\text{nm} \times \text{ii}_\text{sig}_\text{nm} \\
&+ \text{ocf}_\text{lb} \times \text{ii}_\text{sig}_\text{lb}
\end{align*}

\begin{align*}
\text{oc}_\text{msc} &= \text{oc}_\text{di}_\text{msc} \\
&+ \text{oc}_\text{ii}_\text{msc} \\
\text{oc}_\text{sig} &= \text{oc}_\text{di}_\text{sig} \\
&+ \text{oc}_\text{ii}_\text{sig}
\end{align*}
3.3.5 OPEX relating to the HLR

Input parameters:

<table>
<thead>
<tr>
<th>ocf_hlr</th>
<th>&gt;0</th>
<th>Annual OPEX for HLR as a percentage of investment</th>
<th>Input</th>
</tr>
</thead>
</table>

OPEX relating to the HLR:

\[
\begin{align*}
oc_{\text{di}_hlr} & = di_{hlr} \times ocf_{hlr} \\
oc_{\text{ii}_hlr} & = ocf_{nv} \times ii_{hlr_{nv}} \\
& + ocf_{of} \times ii_{hlr_{of}} \\
& + ocf_{wo} \times ii_{hlr_{wo}} \\
& + ocf_{it} \times ii_{hlr_{it}} \\
& + ocf_{nm} \times ii_{hlr_{nm}} \\
& + ocf_{lb} \times ii_{hlr_{lb}} \\
\end{align*}
\]

Total OPEX relating to the HLR:

\[
oc_{hlr} = oc_{\text{di}_hlr} + oc_{\text{ii}_hlr}
\]

3.3.6 OPEX relating to the SMSCs

Input parameters:

<table>
<thead>
<tr>
<th>ocf_smsc</th>
<th>&gt;0</th>
<th>Annual OPEX for SMSC as a percentage of investment</th>
<th>Input</th>
</tr>
</thead>
</table>

OPEX relating to the SMSCs:

\[
\begin{align*}
oc_{\text{di}_smsc} & = di_{smsc} \times ocf_{smsc} \\
oc_{\text{ii}_smsc} & = ocf_{nv} \times ii_{smsc_{nv}} \\
& + ocf_{of} \times ii_{smsc_{of}} \\
& + ocf_{wo} \times ii_{smsc_{wo}} \\
& + ocf_{it} \times ii_{smsc_{it}} \\
& + ocf_{nm} \times ii_{smsc_{nm}} \\
& + ocf_{lb} \times ii_{smsc_{lb}} \\
\end{align*}
\]

Total OPEX relating to the SMSCs:

\[
oc_{smsc} = oc_{\text{di}_smsc} + oc_{\text{ii}_smsc}
\]
3.3.7 OPEX relating to the BTS-BSC links

3.3.7.1 OPEX relating to the BTS-BTS hub links

\[
\begin{align*}
\text{oc\_di\_bts\_btsh} & \quad = \text{ocf\_bts\_btsh} \times \text{di\_r12\_bts\_btsh} \\
\text{oc\_ii\_bts\_btsh} & \quad = \text{ocf\_mv} \times \text{ii\_r12\_bts\_btsh\_mv} \\
& \quad \quad + \text{ocf\_of} \times \text{ii\_r12\_bts\_btsh\_of} \\
& \quad \quad + \text{ocf\_wo} \times \text{ii\_r12\_bts\_btsh\_wo} \\
& \quad \quad + \text{ocf\_it} \times \text{ii\_r12\_bts\_btsh\_it} \\
& \quad \quad + \text{ocf\_nm} \times \text{ii\_r12\_bts\_btsh\_nm} \\
& \quad \quad + \text{ocf\_lb} \times \text{ii\_r12\_bts\_btsh\_lb} \\
\text{oc\_bts\_btsh} & \quad = \text{oc\_di\_bts\_btsh} \\
& \quad \quad + \text{oc\_ii\_bts\_btsh}
\end{align*}
\]

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**

\[
\begin{align*}
\text{o}_\text{di}_\text{rl}_\text{btsh}_\text{bsc} & = \text{ocf}_\text{rl}_\text{btsh}_\text{bsc} \times \text{di}_\text{rlx}_\text{btsh}_\text{bsc} \\
\text{o}_\text{ii}_\text{rl}_\text{btsh}_\text{bsc} & = \text{ocf}_\text{mv} \times \text{ii}_\text{rlx}_\text{btsh}_\text{bsc}_\text{mv} \\
& + \text{ocf}_\text{of} \times \text{ii}_\text{rlx}_\text{btsh}_\text{bsc}_\text{of} \\
& + \text{ocf}_\text{wo} \times \text{ii}_\text{rlx}_\text{btsh}_\text{bsc}_\text{wo} \\
& + \text{ocf}_\text{it} \times \text{ii}_\text{rlx}_\text{btsh}_\text{bsc}_\text{it} \\
& + \text{ocf}_\text{nm} \times \text{ii}_\text{rlx}_\text{btsh}_\text{bsc}_\text{nm} \\
& + \text{ocf}_\text{lb} \times \text{ii}_\text{rlx}_\text{btsh}_\text{bsc}_\text{lb} \\
\end{align*}
\]

\[
\text{oc}_\text{rl}_\text{btsh}_\text{bsc} = \text{oc}_\text{di}_\text{rl}_\text{btsh}_\text{bsc} + \text{oc}_\text{ii}_\text{rl}_\text{btsh}_\text{bsc}
\]

Note: RL fees not considered.

- OPEX relating to the leased lines

\[
\begin{align*}
\text{o}_\text{di}_\text{ll2f}_\text{btsh}_\text{bsc} & = \text{ocf}_\text{ll2f}_\text{btsh}_\text{bsc} \times \text{di}_\text{ll2f}_\text{btsh}_\text{bsc} \\
\text{o}_\text{ii}_\text{ll2f}_\text{btsh}_\text{bsc} & = \text{ocf}_\text{mv} \times \text{ii}_\text{ll2f}_\text{btsh}_\text{bsc}_\text{mv} \\
& + \text{ocf}_\text{of} \times \text{ii}_\text{ll2f}_\text{btsh}_\text{bsc}_\text{of} \\
& + \text{ocf}_\text{wo} \times \text{ii}_\text{ll2f}_\text{btsh}_\text{bsc}_\text{wo} \\
& + \text{ocf}_\text{it} \times \text{ii}_\text{ll2f}_\text{btsh}_\text{bsc}_\text{it} \\
& + \text{ocf}_\text{nm} \times \text{ii}_\text{ll2f}_\text{btsh}_\text{bsc}_\text{nm} \\
& + \text{ocf}_\text{lb} \times \text{ii}_\text{ll2f}_\text{btsh}_\text{bsc}_\text{lb} \\
\end{align*}
\]

\[
\text{oc}_\text{ll2f}_\text{btsh}_\text{bsc} = \text{oc}_\text{di}_\text{ll2f}_\text{btsh}_\text{bsc} + \text{oc}_\text{ii}_\text{ll2f}_\text{btsh}_\text{bsc}
\]

- Total OPEX relating to BTS hub-BSC links:

\[
\text{oc}_\text{btsh}_\text{bsc} = \text{oc}_\text{rl}_\text{btsh}_\text{bsc} + \text{oc}_\text{ll2f}_\text{btsh}_\text{bsc}
\]
3.3.8 OPEX relating to the BSC-MSC links

\[
\begin{align*}
oc_{di\_l1l155f\_bsc\_msc} &= ocf_{l1l155f\_bsc\_msc} \times di_{l1l155f\_bsc\_msc} \\
oc_{ii\_l1l155f\_bsc\_msc} &= ocf_{mv} \times ii_{l1l155f\_bsc\_msc\_mv} \\
&\quad + ocf_{of} \times ii_{l1l155f\_bsc\_msc\_of} \\
&\quad + ocf_{wo} \times ii_{l1l155f\_bsc\_msc\_wo} \\
&\quad + ocf_{it} \times ii_{l1l155f\_bsc\_msc\_it} \\
&\quad + ocf_{nm} \times ii_{l1l155f\_bsc\_msc\_nm} \\
&\quad + ocf_{lb} \times ii_{l1l155f\_bsc\_msc\_lb}
\end{align*}
\]

Total OPEX relating to the BSC-MSC links:

\[
\begin{align*}
oc_{l1l155f\_bsc\_msc} &= oc_{di\_l1l155f\_bsc\_msc} \\
&\quad + oc_{ii\_l1l155f\_bsc\_msc}
\end{align*}
\]

3.3.9 OPEX relating to the MSC-MSC links

\[
\begin{align*}
oc_{di\_l1l155f\_core} &= ocf_{l1f155\_core} \times di_{l1l155f\_core} \\
oc_{ii\_l1l155f\_core} &= ocf_{mv} \times ii_{l1l155f\_core\_mv} \\
&\quad + ocf_{of} \times ii_{l1l155f\_core\_of} \\
&\quad + ocf_{wo} \times ii_{l1l155f\_core\_wo} \\
&\quad + ocf_{it} \times ii_{l1l155f\_core\_it} \\
&\quad + ocf_{nm} \times ii_{l1l155f\_core\_nm} \\
&\quad + ocf_{lb} \times ii_{l1l155f\_core\_lb}
\end{align*}
\]

Total OPEX relating to the MSC-MSC links:

\[
\begin{align*}
oc_{l1l155f\_core} &= oc_{di\_l1l155f\_core} \\
&\quad + oc_{ii\_l1l155f\_core}
\end{align*}
\]
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:

\[
\text{totdc} = \text{dc}_\text{bts} + \text{dc}_\text{bsc} + \text{dc}_\text{trau} + \text{dc}_\text{msc} + \text{dc}_\text{sig} + \text{dc}_\text{hlr} + \text{dc}_\text{smac} + \text{dc}_\text{rl2_bts_btsh} + \text{dc}_\text{rl_btsh_bsc} + \text{dc}_\text{ll2_btsh_bsc} + \text{dc}_\text{ll2f_btsh_bsc} + \text{dc}_\text{ll155_bsc_msc} + \text{dc}_\text{ll155f_bsc_msc} + \text{dc}_\text{ll155_core} + \text{dc}_\text{ll155f_core}
\]

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:

\[
\text{totic} = \text{ic}_\text{bts} + \text{ic}_\text{bsc} + \text{ic}_\text{trau} + \text{ic}_\text{msc} + \text{ic}_\text{sig} + \text{ic}_\text{hlr} + \text{ic}_\text{smac} + \text{ic}_\text{rl2_bts_bths} + \text{ic}_\text{rl_bths_bsc}
\]
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).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coco</td>
<td>[0;1]</td>
<td>Mark-up for common cost (in per cent)</td>
<td>Input</td>
</tr>
<tr>
<td>coco_fix</td>
<td>&gt;= 0</td>
<td>(Additional) common cost as a fixed annual amount</td>
<td>Input</td>
</tr>
</tbody>
</table>

Common organisational-level cost mark-up on network assets

\[
\begin{align*}
coco_{bts\_var} &= (dc_{bts} + ic_{bts} + oc_{bts}) \times coco \\
coco_{bts\_site\_var} &= (dc_{bts\_site} + ic_{bts\_site} + oc_{bts\_site}) \times coco \\
coco_{bts\_eq\_var} &= (dc_{bts\_eq} + ic_{bts\_eq} + oc_{bts\_eq}) \times coco \\
coco_{trx\_var} &= (dc_{trx} + ic_{trx} + oc_{trx}) \times coco \\
coco_{lic\_GSM900\_var} &= (lic_{GSM900}) \times coco \\
coco_{lic\_GSM1800\_var} &= (lic_{GSM1800}) \times coco \\
coco_{GSM1800\_freq\_var} &= (GSM1800\_freq) \times coco
\end{align*}
\]
coco_bsc_var = (dc_bsc + ic_bsc + oc_bsc) * coco

\begin{align*}
\texttt{coco_bsc_site_var} &= (\texttt{dc_bsc_site} + \texttt{ic_bsc_site} + \texttt{oc_bsc_site}) \times \texttt{coco} \\
\texttt{coco_bsc_unit_var} &= (\texttt{dc_bsc_unit} + \texttt{ic_bsc_unit} + \texttt{oc_bsc_unit}) \times \texttt{coco} \\
\end{align*}

\begin{align*}
\texttt{coco_trau_var} &= (\texttt{dc_trau} + \texttt{ic_trau} + \texttt{oc_trau}) \times \texttt{coco} \\
\texttt{coco_msc_var} &= (\texttt{dc_msc} + \texttt{ic_msc} + \texttt{oc_msc}) \times \texttt{coco} \\
\texttt{coco_msc_site_var} &= (\texttt{dc_msc_site} + \texttt{ic_msc_site} + \texttt{oc_msc_site}) \times \texttt{coco} \\
\texttt{coco_msc_unit_var} &= (\texttt{dc_msc_unit} + \texttt{ic_msc_unit} + \texttt{oc_msc_unit}) \times \texttt{coco} \\
\texttt{coco_msc_ports_var} &= (\texttt{dc_msc_ports} + \texttt{ic_msc_ports} + \texttt{oc_msc_ports}) \times \texttt{coco} \\
\texttt{coco_msc_icports_var} &= (\texttt{dc_msc_icports} + \texttt{ic_msc_icports} + \texttt{oc_msc_icports}) \times \texttt{coco} \\
\texttt{coco_msc_bscports_var} &= (\texttt{dc_msc_bscports} + \texttt{ic_msc_bscports} + \texttt{oc_msc_bscports}) \times \texttt{coco} \\
\texttt{coco_msc_mscports_var} &= (\texttt{dc_msc_mscports} + \texttt{ic_msc_mscports} + \texttt{oc_msc_mscports}) \times \texttt{coco} \\
\texttt{coco_sig_var} &= (\texttt{dc_sig} + \texttt{ic_sig} + \texttt{oc_sig}) \times \texttt{coco} \\
\texttt{coco_hlr_var} &= (\texttt{dc_hlr} + \texttt{ic_hlr} + \texttt{oc_hlr}) \times \texttt{coco} \\
\texttt{coco_smsc_var} &= (\texttt{dc_smsc} + \texttt{ic_smsc} + \texttt{oc_smsc}) \times \texttt{coco} \\
\texttt{coco_r12_bts_btsh_var} &= (\texttt{dc_r12_bts_btsh} + \texttt{ic_r12_bts_btsh} + \texttt{oc_r12_bts_btsh}) \times \texttt{coco} \\
\texttt{coco_r1_btsh_bsc_var} &= (\texttt{dc_r1.btsh_bsc} + \texttt{ic_r1.btsh_bsc} + \texttt{oc_r1.btsh_bsc}) \times \texttt{coco} \\
\texttt{coco_l12f_btsh_bsc_var} &= (\texttt{dc_l12f_btsh_bsc} + \texttt{ic_l12f_btsh_bsc} + \texttt{oc_l12f_btsh_bsc}) \times \texttt{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_l12_btsh_bsc_var = dc_l12_btsh_bsc * coco

coco_l155_bsc_msc_var = dc_l155_bsc_msc * coco

coco_l155_core_var = dc_l155_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_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_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_smssc_fix = coco_fix * (dc_smssc + ic_smssc + oc_smssc)/div_fix

coco_rl2_bts_bts_bts = coco_fix * (dc_rl2_bts_bts + ic_rl2_bts_bts + oc_bts_bts)/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_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_lic_MSC1800 = coco_lic_MSC1800_var + coco_lic_MSC1800_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_ports = coco_msc_ports_var + coco_msc_ports_fix
    coco_msc_bscports = coco_msc_bscports_var + coco_msc_bscports_fix
    coco_msc_mscports = coco_msc_mscports_var + coco_msc_mscports_fix
<table>
<thead>
<tr>
<th>Variable</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>coco_sig</td>
<td>coco_sig_var + coco_sig_fix</td>
</tr>
<tr>
<td>coco_hlr</td>
<td>coco_hlr_var + coco_hlr_fix</td>
</tr>
<tr>
<td>coco_smssc</td>
<td>coco_smssc_var + coco_smssc_fix</td>
</tr>
<tr>
<td>coco_r12_bts_btsh</td>
<td>coco_r12_bts_btsh_var + coco_r12_bts_btsh_fix</td>
</tr>
<tr>
<td>coco_r1_btsh_bsc</td>
<td>coco_r1_btsh_bsc_var + coco_r1_btsh_bsc_fix</td>
</tr>
<tr>
<td>coco_LL2f_btsh_bsc</td>
<td>coco_LL2f_btsh_bsc_var + coco_LL2f_btsh_bsc_fix</td>
</tr>
<tr>
<td>coco_LL155f_bsc_msc</td>
<td>coco_LL155f_bsc_msc_var + coco_LL155f_bsc_msc_fix</td>
</tr>
<tr>
<td>coco_LL155f_core</td>
<td>coco_LL155f_core_var + coco_LL155f_core_fix</td>
</tr>
<tr>
<td>coco_LL2_btsh_bsc</td>
<td>coco_LL2_btsh_bsc_var + coco_LL2_btsh_bsc_fix</td>
</tr>
<tr>
<td>coco_LL155_bsc_msc</td>
<td>coco_LL155_bsc_msc_var + coco_LL155_bsc_msc_fix</td>
</tr>
<tr>
<td>coco_LL155_core</td>
<td>coco_LL155_core_var + coco_LL155_core_fix</td>
</tr>
<tr>
<td>totcoco</td>
<td>coco_bts + coco_bsc + coco_trau + coco_msc + coco_sig + coco_hlr + coco_smssc + coco_r12_bts_btsh + coco_r1_bth_bsc + coco_LL2f_btsh_bsc + coco_LL155f_bsc_msc + coco_LL155f_core + coco_LL2_bth_bsc + coco_LL155_bsc_msc + coco_LL155_core</td>
</tr>
</tbody>
</table>

**Effective common organisational-level cost mark-up**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>coco_bts_eff</td>
<td>coco_bts / (dc_bts + ic_bts + oc_bts)</td>
</tr>
<tr>
<td>coco_bsc_eff</td>
<td>coco_bsc / (dc_bsc + ic_bsc + oc_bsc)</td>
</tr>
<tr>
<td>coco_trau_eff</td>
<td>coco_trau / (dc_trau + ic_trau + oc_trau)</td>
</tr>
<tr>
<td>coco_msc_eff</td>
<td>coco_msc / (dc_msc + ic_msc + oc_msc)</td>
</tr>
<tr>
<td>coco_sig_eff</td>
<td>coco_sig / (dc_sig + ic_sig + oc_sig)</td>
</tr>
<tr>
<td>coco_hlr_eff</td>
<td>coco_hlr / (dc_hlr + ic_hlr + oc_hlr)</td>
</tr>
<tr>
<td>coco_smssc_eff</td>
<td>coco_smssc / (dc_smssc + ic_smssc + oc_smssc)</td>
</tr>
<tr>
<td>coco_r12_bts_btsh_eff</td>
<td>coco_r12_bts_btsh / (dc_r12_bts_btsh + ic_r12_bts_btsh + oc_bts_btsh)</td>
</tr>
<tr>
<td>coco_r1_btsh_bsc_eff</td>
<td>coco_r1_btsh_bsc</td>
</tr>
</tbody>
</table>
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

\[
tot_{\text{bts\_site}} = dc_{\text{bts\_site}} + ic_{\text{bts\_site}} + oc_{\text{bts\_site}} + coco_{\text{bts\_site}}
\]

Total cost for BTS equipment

\[
tot_{\text{bts\_eq}} = dc_{\text{bts\_eq}} + ic_{\text{bts\_eq}} + oc_{\text{bts\_eq}} + coco_{\text{bts\_eq}}
\]

Total cost for TRX

\[
tot_{\text{trx}} = dc_{\text{trx}} + ic_{\text{trx}} + oc_{\text{trx}} + coco_{\text{trx}}
\]

Total cost for annual license fee (GSM 900 frequency)

\[
tot_{\text{lic\_GSM900}} = lic_{\text{GSM900}} + coco_{\text{lic\_GSM900}}
\]

Total cost for annual license fee (GSM 1800 frequency)

\[
tot_{\text{lic\_GSM1800}} = lic_{\text{GSM1800}} + coco_{\text{lic\_GSM1800}}
\]
Total cost for license fee (Annualised investment in GSM 1800 frequency)

\[
tot_{\text{GSM1800freq}} = \text{GSM1800freq} + \text{coco}_{\text{GSM1800freq}}
\]

Total cost for BTS

\[
tot_{\text{bts}} = \text{dc}_{\text{bts}} + \text{ic}_{\text{bts}} + \text{oc}_{\text{bts}} + \text{coco}_{\text{bts}}
\]

3.4.5.2 Total cost for the BSCs

Total cost for BSC sites

\[
tot_{\text{bsc site}} = \text{dc}_{\text{bsc site}} + \text{ic}_{\text{bsc site}} + \text{oc}_{\text{bsc site}} + \text{coco}_{\text{bsc site}}
\]

Total cost for BSC equipment (hardware and software)

\[
tot_{\text{bsc unit}} = \text{dc}_{\text{bsc unit}} + \text{ic}_{\text{bsc unit}} + \text{oc}_{\text{bsc unit}} + \text{coco}_{\text{bsc unit}}
\]

Total cost for the BSCs

\[
tot_{\text{bsc}} = \text{dc}_{\text{bsc}} + \text{ic}_{\text{bsc}} + \text{oc}_{\text{bsc}} + \text{coco}_{\text{bsc}}
\]

3.4.5.3 Total cost for TRAUs

\[
tot_{\text{trau}} = \text{dc}_{\text{trau}} + \text{ic}_{\text{trau}} + \text{oc}_{\text{trau}} + \text{coco}_{\text{trau}}
\]

3.4.5.4 Total cost for MSCs

Total cost for MSC sites

\[
tot_{\text{msc site}} = \text{dc}_{\text{msc site}} + \text{ic}_{\text{msc site}} + \text{oc}_{\text{msc site}} + \text{coco}_{\text{msc site}}
\]

Total cost for MSC units (hardware and software)

\[
tot_{\text{msc unit}} = \text{dc}_{\text{msc unit}} + \text{ic}_{\text{msc unit}} + \text{oc}_{\text{msc unit}} + \text{coco}_{\text{msc unit}}
\]

Total cost for MSC ports

\[
tot_{\text{msc ports}} = \text{dc}_{\text{msc ports}} + \text{ic}_{\text{msc ports}} + \text{oc}_{\text{msc ports}} + \text{coco}_{\text{msc ports}}
\]
Total cost for MSC interconnection ports

\[
t_{\text{tot msc icports}} = \text{dc msc icports} + \text{ic msc icports} + \text{oc msc icports} + \text{coco msc icports}
\]

Total cost for BSC faced ports

\[
t_{\text{tot msc bscports}} = \text{dc msc bscports} + \text{ic msc bscports} + \text{oc msc bscports} + \text{coco msc bscports}
\]

Total cost for MSC faced ports

\[
t_{\text{tot msc mscports}} = \text{dc msc mscports} + \text{ic msc mscports} + \text{oc msc mscports} + \text{coco msc mscports}
\]

Total cost for the MSCs (excluding processing)

\[
t_{\text{tot msc}} = \text{dc msc} + \text{ic msc} + \text{oc msc} + \text{coco msc}
\]

Total cost for the processor

\[
t_{\text{tot sig}} = \text{dc sig} + \text{ic sig} + \text{oc sig} + \text{coco sig}
\]

\[
t_{\text{tot hlr}} = \text{dc hlr} + \text{ic hlr} + \text{oc hlr} + \text{coco hlr}
\]

\[
t_{\text{tot smsc}} = \text{dc smsc} + \text{ic smsc} + \text{oc smsc} + \text{coco smsc}
\]

\[
t_{\text{tot rl2 bts btsh}} = \text{dc rl2 bts btsh} + \text{ic rl2 bts btsh} + \text{oc bts btsh} + \text{coco rl2 bts btsh}
\]

\[
t_{\text{tot rl btsh bsc}} = \text{dc rl btsh bsc} + \text{ic rl btsh bsc} + \text{oc rl btsh bsc} + \text{coco rl btsh bsc}
\]

\[
t_{\text{tot ll2f btsh bsc}} = \text{dc ll2f btsh bsc} + \text{ic ll2f btsh bsc} + \text{oc ll2f btsh bsc} + \text{coco ll2f btsh bsc}
\]

\[
t_{\text{tot ll155f bsc_msc}} = \text{dc ll155f bsc_msc} + \text{ic ll155f bsc_msc} + \text{oc ll155f bsc_msc} + \text{coco ll155f bsc_msc}
\]

\[
t_{\text{tot ll155f core}} = \text{dc ll155f core} + \text{ic ll155f core} + \text{oc ll155f core} + \text{coco ll155f core}
\]

\[
t_{\text{tot ll2 btsh bsc}} = \text{dc ll2 btsh bsc} + \text{coco ll2 btsh bsc}
\]
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_r12_bts_btsh + tot_r1_btsh_bsc + tot_ll2f_btsh_bsc + tot_ll155f_bsc_msc + tot_ll155f_core + tot_ll12_btsh_bsc + tot_ll1155_bsc_msc + tot_ll1155_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

<table>
<thead>
<tr>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>8</td>
</tr>
</tbody>
</table>

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

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:

\[
\text{Annual traffic} = \left( \frac{\text{Busy hour traffic} \cdot (1 - \text{Ratio } \text{unbillable } \text{minutes})}{\text{Percentage busy hour of the day}} \right) \cdot \text{Number of days}
\]

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

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

<table>
<thead>
<tr>
<th>Network Element</th>
<th>Total traffic per year for service (i) routed over network element (j)</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network Element</td>
<td>(j=1) ... (i)</td>
<td></td>
</tr>
<tr>
<td>BTS</td>
<td>at(_1)_bts ... at(_i)_bts at(_bts)</td>
<td></td>
</tr>
<tr>
<td>BSC</td>
<td>at(_1)_bsc ... at(_i)_bsc at(_bsc)</td>
<td></td>
</tr>
<tr>
<td>TRAU</td>
<td>at(_1)_trau ... at(_i)_trau at(_trau)</td>
<td></td>
</tr>
<tr>
<td>MSC</td>
<td>at(_1)_msc ... at(_i)_msc at(_msc)</td>
<td></td>
</tr>
<tr>
<td>SP and CP</td>
<td>at(_1)_sig ... at(_i)_sig at(\ldots)</td>
<td>Measured in terms of call attempts</td>
</tr>
<tr>
<td>HLR</td>
<td>at(_1)_HLR ... at(_i)_HLR at(\ldots)</td>
<td></td>
</tr>
<tr>
<td>SMSC</td>
<td>at(_1)_smsc ... at(\ldots) at(\ldots)</td>
<td></td>
</tr>
<tr>
<td>BTS-BTS hub</td>
<td>at(\ldots) ... at(\ldots) at(\ldots)</td>
<td></td>
</tr>
<tr>
<td>BTS hub – BSC</td>
<td>at(\ldots) ... at(\ldots) at(\ldots)</td>
<td></td>
</tr>
<tr>
<td>BSC-MSC</td>
<td>at(\ldots) ... at(\ldots) at(\ldots)</td>
<td></td>
</tr>
<tr>
<td>MSC-MSC</td>
<td>at(\ldots) ... at(\ldots) at(\ldots)</td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td>...</td>
<td></td>
</tr>
</tbody>
</table>

### 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:

\[
Unit \_ \text{costs}_{\text{sig}} = \frac{\text{tot}_{\text{sig}}}{\text{Annual number of call attempts}} \times \text{Average number of call attempts per min.}
\]

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:

<table>
<thead>
<tr>
<th>Subscribers</th>
<th>By subscriber generated ('outgoing') total traffic demand per year for service (i)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subscriber</td>
<td>(g_{t1}, \ldots, g_{t_i}, g_t)</td>
</tr>
</tbody>
</table>

With these values the usage factors are calculated as follows:

\[
uf_{\text{Service}_i \_\text{Network element group}_j} = \frac{\text{Annual traffic of service i routed over network element group}_j}{\text{Generated annual traffic of service i}}
\]

<table>
<thead>
<tr>
<th>Network element</th>
<th>Network element usage factors for service (i)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i=1)</td>
<td></td>
</tr>
<tr>
<td>BTS</td>
<td>(uf_{bts} = at_{bts} / gt_{t1}, \ldots, ufi_{bts} = at_{bts} / gt_{t_i})</td>
</tr>
<tr>
<td>BSC</td>
<td>(uf_{bsc} = at_{bsc} / gt_{t1}, \ldots, ufi_{bsc} = at_{bsc} / gt_{t_i})</td>
</tr>
<tr>
<td>MSC</td>
<td>(uf_{msc} = at_{msc} / gt_{t1}, \ldots, ufi_{msc} = at_{msc} / gt_{t_i})</td>
</tr>
<tr>
<td>Signalling</td>
<td></td>
</tr>
<tr>
<td>HLR</td>
<td>**</td>
</tr>
<tr>
<td>SMSC</td>
<td></td>
</tr>
<tr>
<td>BTS-BTS hub</td>
<td>(uf_{\ldots} = at_{\ldots} / gt_{t1}, \ldots, ufi_{\ldots} = at_{\ldots} / gt_{t_i})</td>
</tr>
</tbody>
</table>
### 3.5.5 Cost per service minute

The costs per minute of service $i$ are calculated by:

$$\text{Costs per minute}_{\text{Service } i} = \sum_{\text{Network elements } j} \text{Unit costs}_{\text{Network element } j} * \text{uf}_{\text{Network element } j}$$

### 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_bascports
    - dc_msc_mspports
- dc_sig
- dc_hlr
- dc_smrc
- dc_rl2_bts_btsh
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_bts_bsc
- ic_ll2f_bts_bsc
- ic_ll155f_bsc_msc
- ic_ll155f_core
- 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_bts_bsc
  - oc_ll2f_bts_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_smuc

coco_r12_bts_btsh
coco_r1_bts_bsc
coco_l12f_bts_bsc
coco_l115f_bsc_msc
coco_l115f_core
coco_ll2_bts_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_smuc_eff
coco_r12_bts_btsh_eff
coco_r1_bts_bsc_eff
coco_l12f_bts_bsc_eff
coco_l115f_bsc_msc_eff
coco_l115f_core_eff
coco_ll2_bts_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_r12_bts_btsh

tot_r1_btsh_bsc

tot_l12f_btsh_bsc

tot_l1l55f_bsc_msc

tot_l1l55f_core


tot_l12_btsh_bsc

tot_l1l55_bsc_msc

tot_l1l55_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:

\[ n_{\text{hlr}} \]  \hspace{1cm} \text{Total number of HLR units in the network}

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

\[ n_{\text{BSC}_{\text{unit}}}_{i} \]  \hspace{1cm} \text{Number of BSC units in site } i
\[ n_{\text{mach}}_{i} \]  \hspace{1cm} \text{Number of switching units in site } i
\[ n_{\text{cpu}}_{i} \]  \hspace{1cm} \text{Number of switching units in site } i
\[ n_{\text{sp}}_{i} \]  \hspace{1cm} \text{Number of signalling processor units in site } i
\[ n_{\text{smac}}_{i} \]  \hspace{1cm} \text{Number of SMS center units in site } i