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Explanatory Memorandum

Regulatory project regarding

The determination of the price cap for the provisioning of wholesale voice call termination on individual mobile networks (market 2/2014)

National public consultation

from 21st November to 21st December 2016

Public version

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Table of Contents

Table of figures

Table of tables

0 Introduction

(1) The provision of mobile termination represents an essential service for all active mobile operators. Therefore, it is necessary to set a price cap for this service, so that competition barriers in the sense of exceeding price settings are prohibited.

(2) Currently, the Institut Luxembourgeois de Régulation (ILR) is conducting a public consultation on the market analysis and the assessment of significant market power regarding the provision of wholesale voice call termination on individual mobile networks (market 2/2014)[1]. In this context, ILR concludes that the following operators have significant market power on their own networks: e-LUX Mobile Telecommunication Services S.A., Entreprise des postes et télécommunications, Join Experience S.A., Orange Communications Luxembourg S.A. et Tango S.A..

(3) During this market analysis, a price control obligation based on cost orientation is put on all operators having significant market power (SMP). Therefore, ILR has elaborated a cost model that calculates the costs generated in relation with the provisioning of mobile termination on a network of a hypothetical efficient operator in Luxembourg. Based on this cost model, ILR determines the price cap which has to be respected by all the SMP operators on the mobile termination market.

(4) This document represents the explanatory memorandum detailing how the ILR determines the price cap for the mobile termination rates (MTR) in Luxembourg :

- In Chapters 1 and 2, the background and the process of determining a price cap is elaborated as well as the legal context this work and the cost model rely on.
- Chapter 3 provides an overview of the resulting price cap, consisting of calculated costs.
- The hypothetical efficient operator, which represents the starting point for being able to conduct the calculations using the cost model, and its properties are determined in Chapter 4.
- Chapter 5 outlines the workflow of the calculations computed by the cost model in order to illustrate the different inputs and outputs of the model.
- The results of the sensitivity analyses performed in order to test the model by varying some input assumptions are presented in Chapter 6.

[1] Document d'analyse concernant le marché de la fourniture en gros de terminaison d'appel vocal sur réseaux mobiles individuels (marché 2/2014)

1 Legal context

(5) According to article 28 (1) e) of the law on electronic communication networks and services ("Loi du 27 février 2011 sur les réseaux et les services de communications électroniques" hereafter "the Law of 2011"), ILR may impose price control obligations as an ex ante market remedy to operators identified as having significant market power (SMP) in the relevant wholesale markets.

(6) The Law of 2011 further specifies in its article 33 the price control remedy which stipulates that prices set by SMP operators should be cost-oriented and allows the ILR to apply different costing methodologies as those used by the SMP operators.

(7) By the analysis of the relevant market for wholesale voice call termination on individual mobile networks (market 2/2014)[1] and the corresponding draft regulation 16/xxx/ILR[2], ILR proposes to withdraw the regulations 14/172/ILR[3] as well as 15/190/ILR[4], and to determine that the following market players have significant market power (SMP): e-LUX Mobile Telecommunication Services S.A., Entreprise des postes et télécommunications, Join Experience S.A., Orange Communications Luxembourg S.A. et Tango S.A..

(8) As a result and according to articles 28 (1) e) and 33 of the Law of 2011, a price control obligation is imposed on SMP operators on market 2/2014. ILR sets price caps based on a bottom-up pure LRIC method determined through the definition of a hypothetical efficient operator in Luxembourg as well as the implementation of a cost model. The concerned operators are free to choose their pricing as long as the price cap imposed by ILR is respected on an annual basis.

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[2] Projet de règlement 16/xxx/ILR du XX portant sur la définition des marchés pertinents de la terminaison d'appel vocal sur réseaux mobiles individuels (Marché 2), l'identification des opérateurs puissants sur ces marchés et les obligations imposées à ce titre

[3] Règlement 14/172/ILR du 6 janvier 2014 portant sur la définition des marchés pertinents de la terminaison d'appel vocal sur réseaux mobiles individuels (Marché 7), l'identification des opérateurs puissants sur ces marchés et les obligations imposées à ce titre

[4] Règlement 15/190/ILR du 17 mars 2015 complétant la définition des marchés pertinents de la terminaison d'appel vocal sur réseaux mobiles individuels (Marché 7), l'identification des opérateurs puissants sur ces marchés et les obligations imposées à ce titre pour Join Experience S.A. et portant modification du règlement 14/172/ILR sur la définition des marchés pertinents de la terminaison d'appel vocal sur réseaux mobiles individuels (Marché 7), l'identification des opérateurs puissants sur ces marchés et les obligations imposées à ce titre

2 Mobile Termination Rate Determination Process

(9) As already outlined in the previous chapter, ILR has defined in the market analysis[5] and according to the FTR-MTR recommendation[6] to use a bottom-up (BU) pure long run incremental costs (pure LRIC) approach in the context of determining the price caps.

(10) The bottom-up approach starts by evaluating the demand level of the market before defining an efficient network able to satisfy this forecasted demand level. The costs corresponding to the modelling of this network can thus be determined. Using this approach, a hypothetical efficient operator is modelled by creating a modern and efficient network (i.e. NGN-based core network, access network based on 2G, 3G and 4G). This reflects the principle of economic efficiency and avoids that access seekers would need to pay for potential inefficiencies remaining in the network of an existent operator.

(11) The pure long run incremental costs of the mobile termination corresponds to the additional costs associated with the production of termination with respect to the existing costs without providing termination. The LRIC method is forward looking and considers all costs as variables. This means, the method does not take into consideration any historical costs but calculates the costs that would be generated by an operator deciding today to deploy a new network for satisfying the forecasted demand.

(12) In the course of calculation of pure LRIC costs for termination, first of all the total costs (TCS) for all services (S) of an operator have to be calculated based on a bottom-up model. In a second step, total costs for all services excluding termination (T) have to be calculated (TCS-T). The deviation between those two calculations gives the absolute pure LRIC costs for the service termination (ICT).

$$ICT = TCS - TCS\text{-}T$$

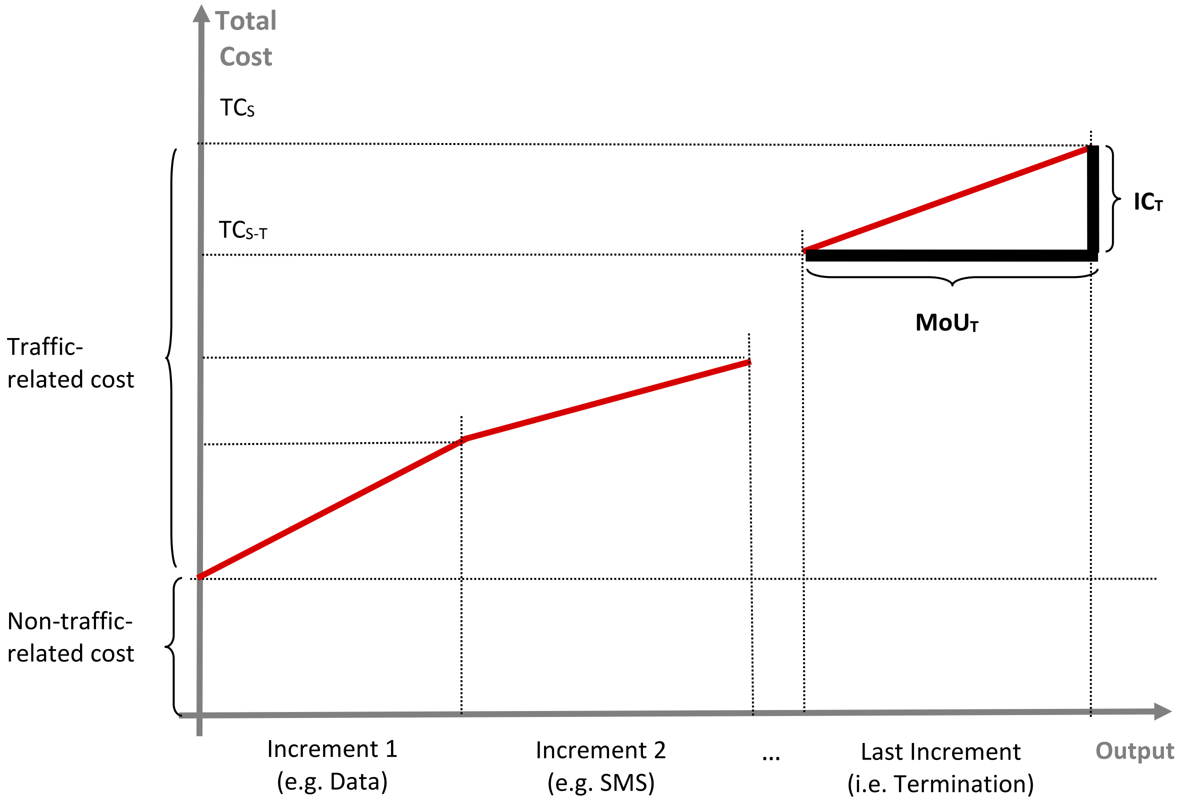
(13) The average pure LRIC costs per minute can be determined through the division of the absolute incremental costs by the termination minutes (MoUT).

$$AICT = ICT / MoUT$$

[5] Analyse du marché de la fourniture en gros de terminaison d'appel vocal sur réseaux mobiles individuels (Marché 2/2014)

[6] Commission Recommendation of 2009 on Regulatory Treatment of Fixed and Mobile Termination Rates in the EU (2009/396/EC)

Figure 2-1: Illustration of the pure LRIC concept



(14) The actual cost accounting approach recommended by the EC constitutes an approximation to the long-run marginal costs. The recommendation aims explicitly at traffic-related and therefore long-run variable costs. Traffic-related costs are caused by capacity enhancements, which are necessary to manage the increase in traffic. Non traffic-related (i.e. long run fix common and joint) costs are explicitly excluded, unless they can be directly attributed to the service increment in termination.

(15) Before being able to determine the pure LRIC costs related to mobile termination, the ILR needs to define the characteristics of the hypothetical efficient operator (HEO) in Luxembourg. It is important to note that the HEO is not an average operator based on eventual existing market players. By not taking the average of the market players, the integration of potential inefficiencies of the existing operators is avoided.

(16) Therefore, the demand is defined based on demographical and geographical input data. Data provided by the government statistics service "*STATEC*" and by the government cadastral and topology service "*ACT*" are considered in order to derive the subscriber distribution and penetration rate. Furthermore, ILR takes into account the data and information provided by the mobile operators in relation to the technical specifications of the network. More details for the determination of the hypothetical efficient operator are described in Chapter 4.

(17) The price cap is determined by ILR by calibrating the model based on the HEO's characteristics and validated by sensitivity analyses on relevant model input data (Chapter 6).

(18) The design and implementation details of the BU pure LRIC cost model are specified in the reference document[7] for which the national call for inputs was held from 22nd January to 29th February 2016 and thus validated.

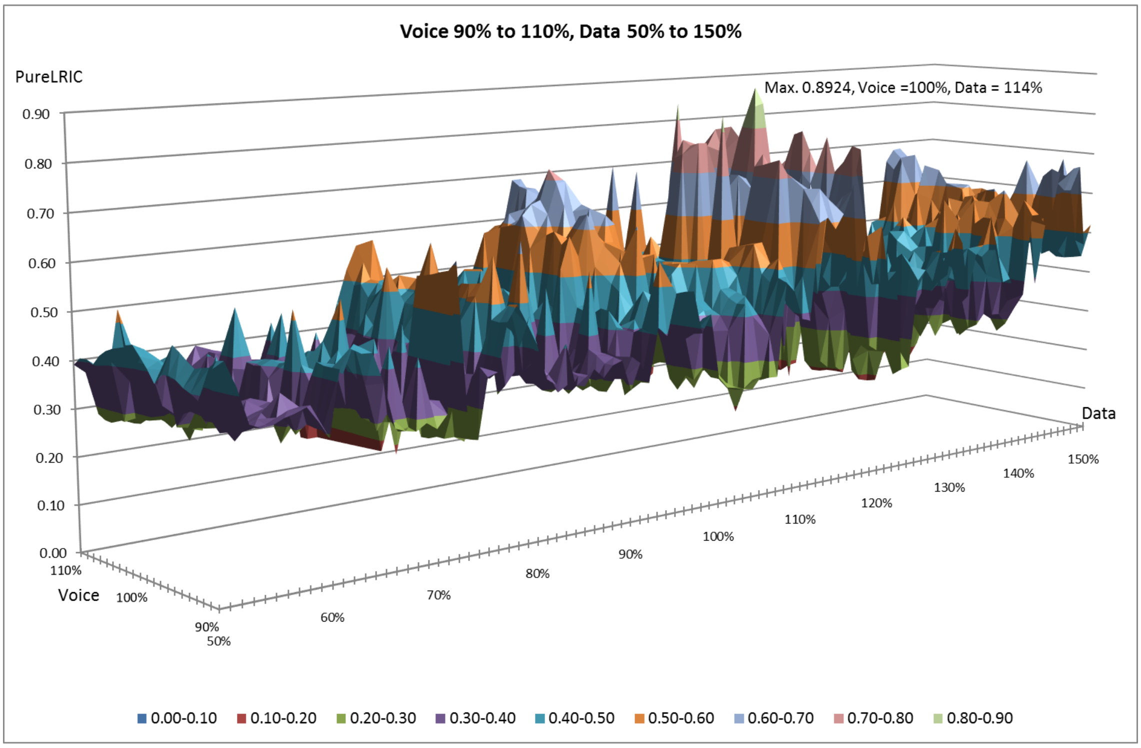
(19) The draft regulation concerning the determination of the mobile termination rate (Market 2/2014) will go through national public consultation from 21st November until 21st December 2016.

[7] Development of a Bottom-Up Mobile Network and Cost Model for the Determination of the Cost of Terminating Calls in Mobile Networks, Version 2.0 (22nd January 2016)

3 Results and Conclusion

(20) In order to determine the costs for the provision of mobile call termination, ILR considers different scenarios for the demand of voice services and of data services. The voice traffic is varied from 90% to 110% while the data traffic is sampled between 50% and 150% based on the defined traffic in Chapter 4.1.4. The data points for the related costs are shown in the Figure 3-1[8].

Figure 3-1: Determination of the costs given different scenarios [source: ILR, cost model, 2016]



(21) The ILR considers that the costs of the hypothetical efficient operator for the provision of mobile call termination are 0.8924 €cents/minute, which represents the highest result of the different scenarios. The maximum was selected in order to avoid that an operator has to recover the costs for the termination service from revenues of other services (i.e. cross-subsidising).

(22) The maximum value of 0.8924 €cents/minute corresponds to the calculated costs for 114% of data traffic and 100% of voice traffic. A total of 2 121 data points are calculated and evaluated.

(23) In order to assure that operators will be able to cover the incremental costs for providing the termination service, it is appropriate to select a price that represents the upper limit of the calculated costs. Due to the pure LRIC approach taken, a lower price would not necessarily

[8] The calculations needed for the 3D graphics showing the resulting costs related to different demand settings for voice and data services are time-expensive. For instance, it takes approx. 48 hours for generating the figure 3-1, where voice traffic is varied from 90% to 110% and data traffic from 50% to 150%.

In this context, it is also worth mentioning that a modification made in each technical and economical parameter leads to a recalculation of the network.

guarantee to cover the generated costs and thus the operators would need to cross-subsidise using other provided services. Therefore, the ILR considers that the calculated costs of 0.8924 €cents/minute are appropriate to determine the price cap, as set out in Table 3-1.

Table 3-1: Price cap [source: ILR, cost model, 2016]

Service	Price cap [€cts/min]
Voice call termination on individual mobile networks (market 2/2014)	0.89

(24) The price cap will be applicable from 2017 to 2019. The details concerning the determination of this price cap as well as the information collected and used are outlined in the following chapters.

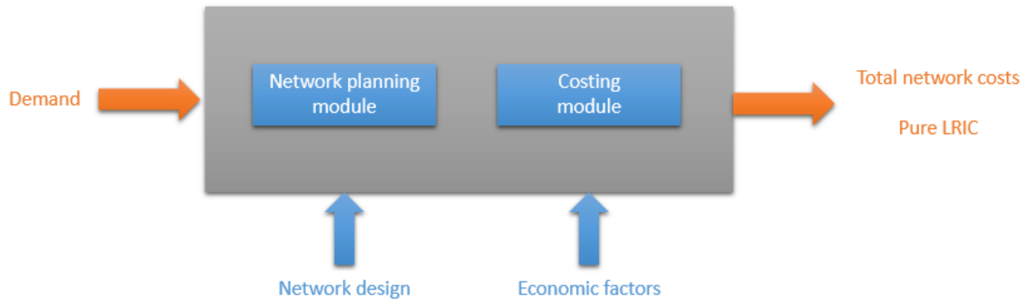
4 Determination of the hypothetical efficient operator

(25) This section describes the details of the hypothetical efficient operator (HEO) in Luxembourg, for which the termination tariffs are determined. The characteristics of the HEO are based on an efficient network as well as on efficient technologies. Therefore, this section is structured according to the following modelling blocks:

- Determination of the demand;
- Network design;
- Economic factors.

(26) As shown in Figure 4-1, these blocks are reflected by the cost model and allow the calculation of the total network costs, and hence the pure LRIC costs caused by the termination service provided by the HEO. Details regarding the mobile cost model are described in the reference document[7].

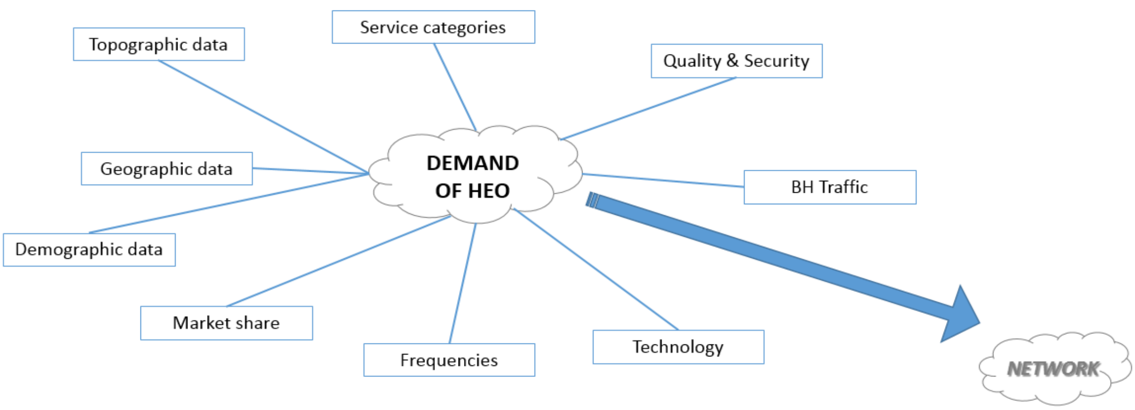
Figure 4-1: Overview of the mobile bottom-up model



4.1 Determination of the demand

(27) In order to define the network properties and its dimension, the demand that the HEO needs to satisfy has to be determined first. Therefore, fundamental settings such as demographic and geographic data, market share, service categories and technology mix are elaborated in this section. The inputs that are used for determining the demand are shown in Figure 4-2.

Figure 4-2: Demand determining factors [Source: ILR, 2016]



4.1.1 Demographic and geographic input data

4.1.1.1 Demographic input data

(28) The amount of potential users is determined based on available demographic data for Luxembourg. To define the demand, not only the population is considered but also travellers within Luxembourg. Furthermore, different points of interest (Hotspots) are taken into account in order to define the population density per area. Two peak loads are calculated, one for day-time and one for night-time. This is needed in order to take into account that residents will generate load at two places, e.g. at work during the day and at home in the evening, while travellers will only generate load at work. Finding the highest demand per geographical location is necessary for dimensioning the network. The complete process is described in Chapter 2 of the reference document[7].

(29) It is crucial for the model to capture the specificities of Luxembourg. One major point that needs to be considered for a correct modelling is the fact that on a daily basis approximately 160 000 commuters are crossing the borders towards their workplaces in Luxembourg[9].

(30) Based on the derived population density, different geo-types are elaborated. These geo-types are calculated using the maximum amount of users during the day as well as during the night. Table 4-1 shows the classification scheme of the geo-types as implemented in the cost model.

Table 4-1: Thresholds for the definition of geo-types (population/km^2) [Source: ILR, 2016]

Geo-type	Urban	Suburban	Rural
Population density	more than 602	602 to 172	less than 172

(31) The market penetration, meaning the SIM cards in use in the market, is set to 111% which results in a population coverage of 906 033. The amount of users per geo-type is shown in Table 4-2.

Table 4-2: Number of users per technology and geo-type [Source: ILR, 2016]

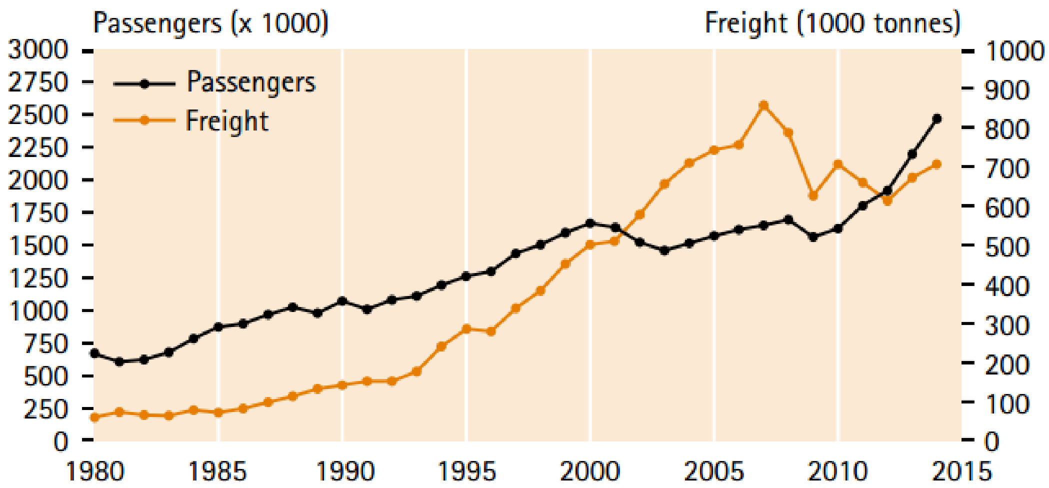
Geo-type Technology	Urban	Suburban	Rural	Total
GSM/EDGE/UMTS/HSPA/LTE	413 537	294 655	197 841	906 033

(32) Following the assumption that additional mobile demand arises along the motorways and major railway lines, additional mobile base stations are modelled along these traffic arteries, ensuring the provision of this supplementary supply.

(33) Besides the motorways and railways, specific hotspots are considered, e.g. the airport. Figure 4-3 illustrates the increase of passengers and thus the importance of the airport. Furthermore, during the call for input of the reference document, operators suggested to add the main bus station in Luxembourg upper city and some specific high schools in Luxembourg as hotspots.

[9] http://www.statistiques.public.lu/

Figure 4-3: Illustration of the increase in passengers at the Luxembourgish airport [Source: Statec, 2015]



4.1.1.2 Topographic input data

(34) The signal propagation is, among others, dependent on the surroundings, for instance whether or not there are obstacles. To take this into consideration, the topography of Luxembourg needs to be integrated into the model[7]. Accordingly the network needs to be adapted to ensure a full coverage of the country and population.

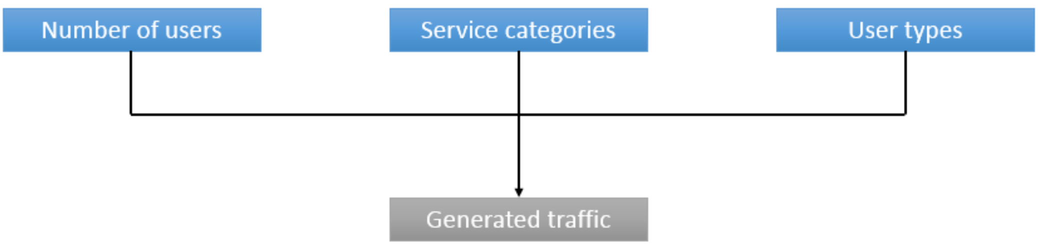
4.1.1.3 Network coverage of an efficient mobile operator

(35) In Luxembourg, a complete population coverage (pop-coverage) for mobile voice services can be presumed. Thus, a pop-coverage for 2G (voice, EDGE), 3G (UMTS, HSPA) as well as 4G (LTE, without VoLTE) of 100% is modelled. On top of this full pop-coverage, a surface coverage of the whole country is considered.

4.1.2 Service categories and user types

(36) The total demand in terms of traffic is needed for modelling the mobile network of the hypothetical efficient operator. The traffic is determined by multiplying the individual demand based on a representative (average) mobile user in the busy hour and the number of users of this operator. The busy hour is defined through the total traffic of all significant services. The number of users as well as the geographical distribution are determined by geographic and demographic data as well as market penetration.

Figure 4-4: Demand modelling process



(37) The following sections describe the service categories as well as the user types considered for demand modelling.

4.1.2.1 Service categories

(38) The cost model allows for a differentiation of service categories. Depending on the category, the parameters have different characteristics which influence the network planning for the traffic generated by an average mobile user. The parameters for a given service are composed of the following properties:

- Bandwidth required;
- Quality of Service (QoS) requirements;
- Direction of the route in the network.

(39) The model is able to emulate a network based on eight different service categories, as described in the reference document[7]. However, for the national circumstances it is considered to be appropriate to model the network for the HEO based on only four different service categories. The service categories that are not modelled (like SMS) do not provide any relevance to the demand modelling. The following service categories are considered:

- Real time voice over 2G GSM and 3G UMTS;
- Best effort over 2G EDGE;
- Mobile broadband access over 3G HSPA;
- Mobile broadband access over 4G LTE.

(40) The service categories describe the features of the generated traffic, without considering the frequency a service or service category is used. The degree of utilisation of a service or a service category will be defined by user types.

4.1.2.2 User types

(41) Users can ask for different services in varying degrees. Therefore, the model allows the clustering of the users in different categories based on their utilisation behaviour. The following three user types can be modelled[7]:

- Business user;
- Premium user;
- Standard user (customer).

(42) Despite these modelling possibilities, ILR took only one category into account (i.e "*standard user*"). This choice relies on the lack of information made available by the Luxembourgish mobile operators.

(43) The traffic (busy hour [BH] minutes for voice and BH gibibytes [GiB, equals 1024^3 bytes] for data services) per service category is captured during the busy hour for the given user type. As the busy hour is determined as a function of the total traffic, the traffic of all service categories has to be

considered. This total traffic forms the basis for dimensioning the whole network. Some network elements are only used by one service category (e.g. MSC-S, MGW) or/and are only used for voice traffic. To dimension these voice-specific network elements, the traffic per voice category and the voice specific busy hour is taken into account. To get the busy hour value for voice traffic, the busy hour value for the total traffic is adapted by using a conversion factor[10].

4.1.3 Market share of an efficient mobile operator

(44) Following the Commission recommendation, mobile termination rates[6] are to be defined for operators with an efficient scale of market share. Therefore, the market share considered for this cost determination must be higher than or equal to 20% of the retail market. In the Luxembourg market three operators have their own networks. Hence, ILR considers that a market share of 33.33% reflects a realistic situation.

(45) The market share is used in the model to derive the amount of subscribers based on the total amount of users in each area.

4.1.4 Determination of traffic volumes

(46) Determining the traffic volumes is a major part of the dimensioning process of the demand to be covered by the modelled network. Therefore, real volumes are taken into account. The market players were asked to provide their traffic volumes for 2015 with a forecast for 2016, 2017 and 2018.

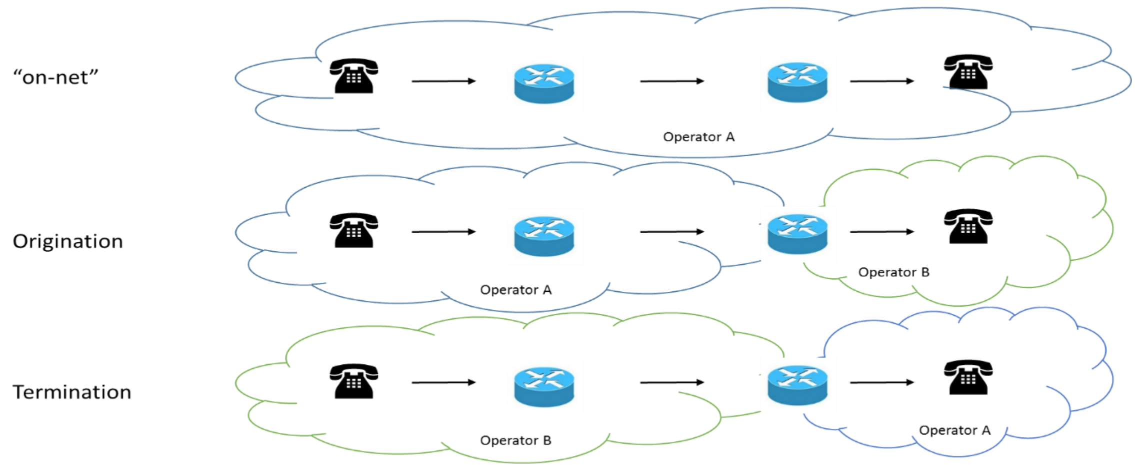
(47) The exact determination of the different traffic volumes is described in the following sections.

4.1.4.1 Determination of voice traffic

(48) The data used for the determination of voice traffic forms the annual traffic volumes of voice services (voice volumes measured in technical minutes), consisting of traffic volumes between own customers (on-net), origination to other networks (off-net-outgoing) as well as termination from other networks (off-net-incoming). The different voice traffic volumes are illustrated in Figure 4-5.

[10] cf Formula 10.

Figure 4-5: Differentiation between types of voice traffic [source: ILR, 2016]



Formula 1

$$TechnicalVolume\,[min] = TechnicalVolume_{on-net} + TechnicalVolume_{off-net\ outgoing} + TechnicalVolume_{off-net\ incoming}$$

(49) Based on stakeholders' data, the aggregated volume of voice traffic for 2015 is shown in Table 4-3.

Table 4-3: Aggregated technical voice volume and traffic shares for 2015 [Source: ILR, operators' data, 2016]

Voice – technical minutes	2015
On-net (in 1 000 minutes)	443 246
Origination (in 1 000 minutes)	469 366
Termination (in 1 000 minutes)	460 369
On-net + origination + termination (in 1 000 minutes)	1 372 981
Portion of on-net traffic	32.28 %
Portion of origination traffic	34.19 %
Portion of termination traffic	33.53 %

(50) To take into account the share of unbilled traffic, the voice volume is marked-up automatically by the model and also during the determination of the network busy hour with the following formula:

Formula 2

$$VoiceVolume\,[min] = \frac{TechnicalVolume}{(1 - Share\ Of\ Unbilled\ Traffic)}$$

(51) Normally a share of unbilled traffic provided by the operators resides between 1% and 4%. This value is included in *Formula 2* to incrementally apply on the respective technical volume of all operators. For the Luxemburgish context, the share of unbilled traffic used for the pure LRIC calculations is shown in Table 4-4.

Table 4-4: The share of unbilled traffic [source: ILR, operators' data, 2016]

Share of unbilled traffic	3.00%

Note: This value is also used for the pure LRIC calculations after the network dimensioning in the following way: The relevant network-dimensioning minutes are reduced by this factor by the application of Formula 2.

(52) Furthermore, the on-net volume is considered twice (see Formula 3) in order to reflect the double utilisation of network resources for a communication between two end-customers on the same network. This is done automatically by the model and also during the determination of the network busy hour.

Formula 3

$$VoiceVolume_{on-net\times 2} = VoiceVolume_{on-net} \times 2$$

(53) The daily voice volume as well as the Busy Hour (BH) of an operator are determined using the aggregated traffic distribution of all operators per hour during one day. This daily traffic and its distribution are based on the average of the most traffic intense 30 days of the year 2015. For the operators that didn't provide the average of the most traffic intense 30 days of the year 2015, the daily traffic is assumed as the 250th of the annual traffic. This would correspond to a mean daily traffic if a year had 250 days. The determination of this volume and the Busy Hour looks as follows:

Formula 4

$$VoiceVolumes_{i=[00h00-24h00]}\,[min] = DuringTheDay\ Volume\ Share_i \times VoiceVolume_{total}$$

Formula 5

$$VoiceVolume_{VoiceBusyHour}[min] = max\left(VoiceVolumes_{i=[00h00-24h00]}\right)$$

(54) Table 4-5 illustrates the traffic distribution of the aggregated voice volume per hour of all operators in Luxembourg, split on 2G GSM and 3G UMTS voice. For the operators that didn't provide the technology split for 2G and 3G, a weighted average of the rest of the operators was assumed. This table shows that the Voice Busy Hour is between 17h00 and 18h00 with a total of 625 351 minutes (sum of 2G and 3G), while the overall Network Busy Hour is also between 17h00 and 18h00. Based on the values of Table 4-5, the daily voice traffic amounts to 0.54% of the annual voice traffic.

Table 4-5: Aggregated daily voice volumes distribution per hour and technology [Source: ILR, operators' data, 2016]

Aggregated daily voice volumes per hour (in minutes) of the year 2015	2G GSM	3G UMTS
00h00 – 01h00	34 189	28 762
01h00 – 02h00	17 806	15 148
02h00 – 03h00	9 418	8 657
03h00 – 04h00	6 965	6 421
04h00 – 05h00	6 260	5 607
05h00 – 06h00	7 935	8 264
06h00 – 07h00	21 485	24 780
07h00 – 08h00	76 732	95 092
08h00 – 09h00	157 265	186 704
09h00 – 10h00	211 375	246 576
10h00 – 11h00	235 560	279 199
11h00 – 12h00	239 280	289 952
12h00 – 13h00	212 488	266 193
13h00 – 14h00	207 005	251 296
14h00 – 15h00	225 675	275 680
15h00 – 16h00	232 048	287 102
16h00 – 17h00	254 004	314 635
Voice Busy Hour = Network Busy Hour 17h00 – 18h00	**282 151**	**343 200**
18h00 – 19h00	262 306	318 184
19h00 – 20h00	209 040	236 456
20h00 – 21h00	174 211	185 979
21h00 – 22h00	146 691	153 393
22h00 – 23h00	104 147	106 432
23h00 – 24h00	58 003	59 468
Total	**3 392 039**	**3 993 181**

(55) The network is dimensioned based on the overall traffic of the busy hour for all service types, not only on voice traffic. Therefore a Busy Hour Voice factor is defined:

Formula 6

$$BusyHour\ VoiceFactor = \frac{VoiceVolume_{VoiceBusyHour}}{VoiceVolume_{NetworkBusyHour}}$$

(56) The portion of the voice volume in the network Busy Hour is put in relation to the total voice volume of one day.

Formula 7

$$DailyShareOfVoiceInNetwork\ BusyHour = \frac{VoiceVolume_{NetworkBusyHour}}{VoiceVolume_{day}}$$

(57) Using the Busy Hour for the aggregated traffic of all operators (defined in Section 4.1.4.3), the Busy Hour voice factor as well as the Daily Share of voice in the network Busy Hour can be calculated. The results are illustrated in Table 4-6.

Table 4-6: Busy Hour Voice Factor, Daily and Annual Share of Voice in Network Busy Hour [Source: ILR, 2016]

Busy Hour Voice Factor (bhvf)	1.00
Daily Share of Voice in Network Busy Hour	8.47%
Annual Share of Voice in Network Busy Hour	0.045547%

(58) A Busy Hour voice factor of 1.00 means that the voice volume in the Voice Busy coincides with the Network Busy Hour. The Daily Share of voice in the Network Busy Hour represents the portion of voice traffic in the Network Busy Hour in relation to the total voice day traffic. The Annual Share of voice in the Network Busy Hour represents the portion of voice traffic in the Network Busy Hour in relation to the total annual voice traffic correspondingly.

4.1.4.2 Determination of data traffic

(59) In order to determine the data traffic, annual traffic volumes of data services (volume in GiB[11]) were collected per operator. These traffic volumes are separated in those that go from the network to the subscriber (downlink) and in those that go from the subscriber to the network (uplink):

Formula 8

$$Data\,Volume\quad [GiB] = Volume_{downlink} + Volume_{uplink}$$

(60) The aggregated data volumes of all operators for 2015 as well as the corresponding technology and traffic shares are outlined in the following table. For operators which didn't provide data about technology and downlink shares, weighted averages of the other operators were assumed.

Table 4-7: Aggregated data volumes, technology and traffic shares for 2015 [Sources: ILR, operators' data, 2016]

Data traffic of the year 2015	2G EDGE	3G HSPA	4G LTE
Volume in GiB	225 683	5 188 708	6 294 048
Share of downlink volume	90.22%	90.74%	91.62%

(61) The daily volume as well as the Busy Hour (BH) of an operator are determined using the aggregated traffic distribution of all operators per hour during one day. This daily traffic and its distribution are based on the average of the most traffic intense 30 days of the year 2015. For the operators that didn't provide the average of the most traffic intense 30 days of the year 2015, the daily traffic is assumed as the 250th of the annual traffic. This would correspond to a mean daily traffic if a year had 250 days. The determination of this volume and the Busy Hour looks as follows, whereas the downlink is given as the most significant traffic direction for the network dimensioning:

[11] Using the Unit GB (Gibga Byte) for data volumes is not always clear. The prefix G (Giga) can be considered as a decimal prefix 10^9 (Système international d'unités – SI prefix). This would mean that 1GB = 1.000.000.000 Byte. Nevertheless, the prefix G can also be considered as a binary prefix 1024, which would result in 1GB = 1.073.741.824 Byte. To differentiate between the two prefixes, the IEC (International Electrotechnical Commission) introduced the binary prefix GiB (Gibibyte), so 1 GiB = 1.073.741.824 Byte.

Formula 9

$$Data\ VolumesDownlink_{i=[00h00,24h00]}[GiB] = DuringTheDayVolumeShare_i \times Data\ VolumeDownlink_{day}$$

Formula 10

$$Data\ VolumeDownlink_{DataBusyHour}\ [GiB] = max\left(Data\ VolumesDownlink_{i=[00h00,24h00]}\right)$$

(62) The calculated distribution for the aggregated annual data volume is shown in Table 4-8, which indicates that the Data Busy Hour is between 5 pm and 6 pm.

Table 4-8: Distribution of the aggregated daily downlink data volumes per hour and technology [Sources: ILR, operators' data, 2016]

Aggregated dailiy data volumes per hour (in GiB) of the year 2015	2G EDGE downlink	3G HSPA downlink	4G LTE downlink
00h00 – 01h00	14.194	498.171	1 015.701
01h00 – 02h00	9.534	319.095	685.839
02h00 – 03h00	6.882	197.357	440.524
03h00 – 04h00	5.459	143.747	307.190
04h00 – 05h00	5.318	121.378	228.716
05h00 – 06h00	6.613	134.046	216.646
06h00 – 07h00	12.476	290.597	375.619
07h00 – 08h00	22.247	628.682	762.633
08h00 – 09h00	26.589	632.002	930.966
09h00 – 10h00	29.718	658.487	1 101.635
10h00 – 11h00	32.170	714.055	1 273.399
11h00 – 12h00	33.405	758.722	1 413.184
12h00 – 13h00	39.885	906.625	1 571.268
13h00 – 14h00	37.618	876.111	1 598.015
14h00 – 15h00	35.588	897.039	1 631.251
15h00 – 16h00	34.782	911.463	1 621.335
16h00 – 17h00	34.839	962.081	1 668.781
Data Busy Hour = Network Busy Hour 17h00 – 18h00	**33.974**	**994.340**	**1 722.368**
18h00 – 19h00	33.066	968.930	1 692.586
19h00 – 20h00	31.749	910.749	1 660.860
20h00 – 21h00	31.396	916.966	1 705.805
21h00 – 22h00	31.314	924.509	1 747.047
22h00 – 23h00	27.034	869.459	1 678.006
23h00 – 24h00	20.466	695.582	1 322.944
Total	**596.313**	**15 930.194**	**28 372.319**

(63) The share of data traffic of 6.13% in the Network Busy Hour for both uplink and downlink is calculated with respect to the overall total data traffic per day, leading to an annual share of the data traffic in the Network Busy Hour of 0.025719%.

4.1.4.3 Determination of total traffic in the network

(64) The network dimensioning is based on the total traffic of the Busy Hour of all services. In order to define the Busy Hour of the overall traffic, the traffic for voice and data needs to be combined. The network is an all-IP NGN network and therefore all the services are transported over the same IP based network. For this reason it is necessary to convert the voice volume, expressed in minutes, to an equivalent of data volume.

(65) The conversion of the voice volume into data volume is related to the voice coding. In mobile networks, the voice coding is generally done using the Adaptive Multi-Rate (AMR) Codec. For the HEO, the wideband variant AMR-WB with a bit rate of 12.65 kbps per communication way (mouth to ear) is assumed. The daily voice volume distribution over one day is calculated as follows:

Formula 11

$$Voice\ Volumes_{i=[00h00,24h00]}[GiB] = \frac{Voice\ Volumes_{i=[00h00,24h00]}[min] \times 60\ [s/min] \times (12.650 \times 1000\ [bps])}{8\ [bit/Byte] \times 1073741824[Byte/GiB]}$$

(66) The above voice volumes are increased by applying the doubling of the on-net traffic and adding the unbilled traffic as described in Section 4.1.4.1. Using this calculation, the voice volumes can now be put together with the downlink of the data volumes as follows:

Formula 12

$$Total\ Volumes_{i=[00h00,24h00]}[GiB] = Voice\ Volume_i\ [GiB] + Data\ VolumesDownlink_i\ [GiB]$$

(67) Accordingly, the Network Busy Hour can be defined as shown in *Formula 17*. The corresponding results are shown in Table 4-9.

Formula 13

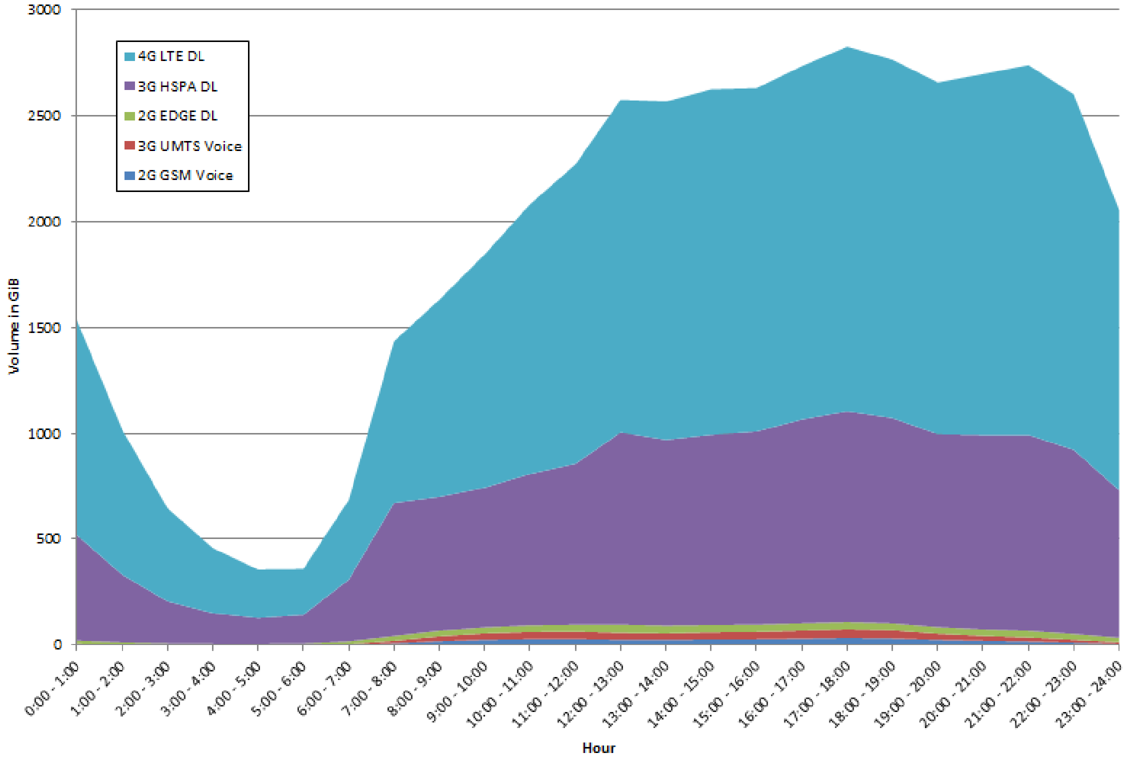
$$Total\ Volume_{NetworkBusyHour}\ [GiB] = max\left(Total\ Volume_{i=[00h00,24h00]}\right)$$

Table 4-9: The distribution of the aggregated total network volume [Sources: ILR, operators' data, 2016]

Aggregated daily voice and data volumes per hour (in GiB) of the year 2015	Voice	Data (downlink)	Network (Voice + Data)
00h00 – 01h00	7.505	1 528.066	1 535.571
01h00 – 02h00	3.917	1 014.469	1 018.386
02h00 – 03h00	2.138	644.762	646.900
03h00 – 04h00	1.574	456.397	457.971
04h00 – 05h00	1.395	355.412	356.808
05h00 – 06h00	1.918	357.305	359.223
06h00 – 07h00	5.547	678.692	684.239
07h00 – 08h00	20.620	1 413.562	1 434.182
08h00 – 09h00	41.173	1 589.556	1 630.729
09h00 – 10h00	54.782	1 789.840	1 844.622
10h00 – 11h00	61.597	2 019.624	2 081.222
11h00 – 12h00	63.368	2 205.311	2 268.678
12h00 – 13h00	57.467	2 517.778	2 575.245
13h00 – 14h00	54.894	2 511.744	2 566.638
14h00 – 15h00	60.062	2 563.877	2 623.939
15h00 – 16h00	62.231	2 567.580	2 629.811
16h00 – 17h00	68.209	2 665.701	2 733.910
Network Busy Hour 17h00 – 18h00	**74.990**	**2 750.683**	**2 825.672**
18h00 – 19h00	69.601	2 694.582	2 764.183
19h00 – 20h00	53.387	2 603.358	2 656.745
20h00 – 21h00	43.074	2 654.168	2 697.241
21h00 – 22h00	35.902	2 702.870	2 738.772
22h00 – 23h00	25.194	2 574.498	2 599.692
23h00 – 24h00	14.049	2 038.992	2 053.041
Total	**884.594**	**44 898.826**	**45 783.420**

(68) The busy hour of the total network traffic of all services is between 5 pm and 6 pm. Figure 4-6 shows the graphical distribution of the voice, downlink data and total volume. It can be observed that the voice traffic is far less important compared to the data traffic. With the exploding HSPA and LTE data traffic, the volume share of voice traffic is expected to be constantly declining in the future as well.

Figure 4-6: Hourly distribution of voice, data and total volume for 2015 divided technology [source: ILR, operators' data, 2016]



4.1.4.4 Setting of traffic for different service categories as input of the model

(69) In Section 4.1.2.2 it is explained that per service category different traffic is captured.

(70) For network dimensioning purposes, the traffic of the most utilised direction (e.g. of a link) is relevant. Therefore for data services only the downlink data traffic is used for the calculation. For voice services is the direction not relevant, because of the symmetric nature of the voice traffic which is generally the same in both directions.

(71) The traffic distribution of the voice, best-effort and mobile broadband services over HSPA and LTE are based on the contributions of the operators as described in the previous sections.

(72) In order to represent undelivered or dropped traffic, a blocking factor is integrated into the model. The amount of traffic provided by the operators represent the delivered traffic. Therefore this traffic is increased automatically by the model based on the blocking probability. This is necessary in order to correctly dimension the network. The blocking probability can be separately defined based on the service category and is shown in Table 4-10.

(73) Furthermore, Table 4-10 also summarises the inputs for the service categories in the busy hour for the model, which were calculated in the previous sections. In order to consider the exponential increase of the future data traffic, the traffic values for the best-effort and mobile broadband services are doubled for the input of the model, as depicted in Table 4-10.

Table 4-10: Input values into the bottom-up cost model for different services [source: ILR, mobile cost model, 2016]

Service name	Voice	Best effort over EDGE	Mobile broadband over HSPA	Mobile broadband over LTE
Traffic value in minutes for voice and GiB for data	625 351	67.948 (= 33.974 * 2)	1 988.681 (= 994.340 * 2)	3 444.737 (= 1 722.368 * 2)
Average data rate required for the service in the fixed network for uplink [kbps]	12.65	20	30	500
Average data rate required for the service in the fixed network for downlink [kbps]	12.65	80	270	1 000
Average data packet length in bytes in uplink	32	200	200	200
Average data packet length in bytes in downlink	32	200	1 150	1 150
Average service session duration in minutes	3	3	5	5
Blocking probability	0.02	0.02	0.02	0.02

4.1.5 Quality and Security

(74) A major aspect for dimensioning the network is the guarantee of network security and quality. The network needs to guarantee a specific quality for delivering the various services. Especially voice and real-time services require a given level of quality of service to remain fully functional. On the other hand, a network also needs to be able to adapt to unforeseen incidents, which means that a network needs to be redundant so that even when facing a failure, the services can still be delivered.

(75) Respecting the quality and security requirements implies that some equipment will be required twice, even though only one is needed to satisfy the demand.

4.2 Network design

(76) The model provides the ability to define the network design based on numerous parameters as shown in the Reference document[7]. Two different types of parameters can be distinguished. On the one hand, parameters that are accessible for optimisation, such as the number of sites per network layer. On the other hand, parameters which are not accessible for optimisation. These parameters are e.g. parameters that have to be set from a regulatory point of view or with which the degree of redundancy or resilience against failure of network components is determined (e.g. doubled connections, protection level). The total network costs are (as expected) lower, the lower the redundancy or the selected security is. The corresponding parameters are thus set in the model corresponding to an acceptable business practice level regarding redundancy and protection.

(77) The determination of the parameters is based on regulatory decisions, input from Luxembourg operators and past experience[7]. This forms the starting point for the network optimisation process.

(78) Optimising and determining the effective network is carried out as follows:

- First, the required frequency spectrum and the necessary 2G, 3G as well as 4G coverage is determined from a regulatory point of view.
- Then, the number of controller locations and the optimal number of core network locations are elaborated;
- With these nodes, the minimum distances between the controller/core network locations are optimised;
- All the previous results are iteratively verified in order to consider possible changes resulting from the optimisation process.

(79) In the next sections the results of these steps are shown in detail.

4.2.1 Frequency spectrum

(80) The Luxembourg mobile operators use allocated frequencies in the 800 MHz, 900 MHz, 1800 MHz and 2100 MHz frequency bands. According to the regulatory decision to apply a market share of 33% (see Section 4.1.3) on the HEO, the latter is modelled with the following spectrum (Table 4-11).

Table 4-11 Frequency spectrum of the hypothetical 33% operator [source: ILR, mobile cost model (2016)]

800 MHz band	900 MHz band	1800 MHz band	2100 MHz band
10MHZ (4G)	12 MHz (2G)	5 MHz (2G), 20 MHz (4G)	10 MHz (3G)

Note: The values are rounded since these frequency bands are used for GSM and UMTS and therefore only 0.2 and 5 MHz blocks can be utilised respectively.

4.2.2 Radio access network

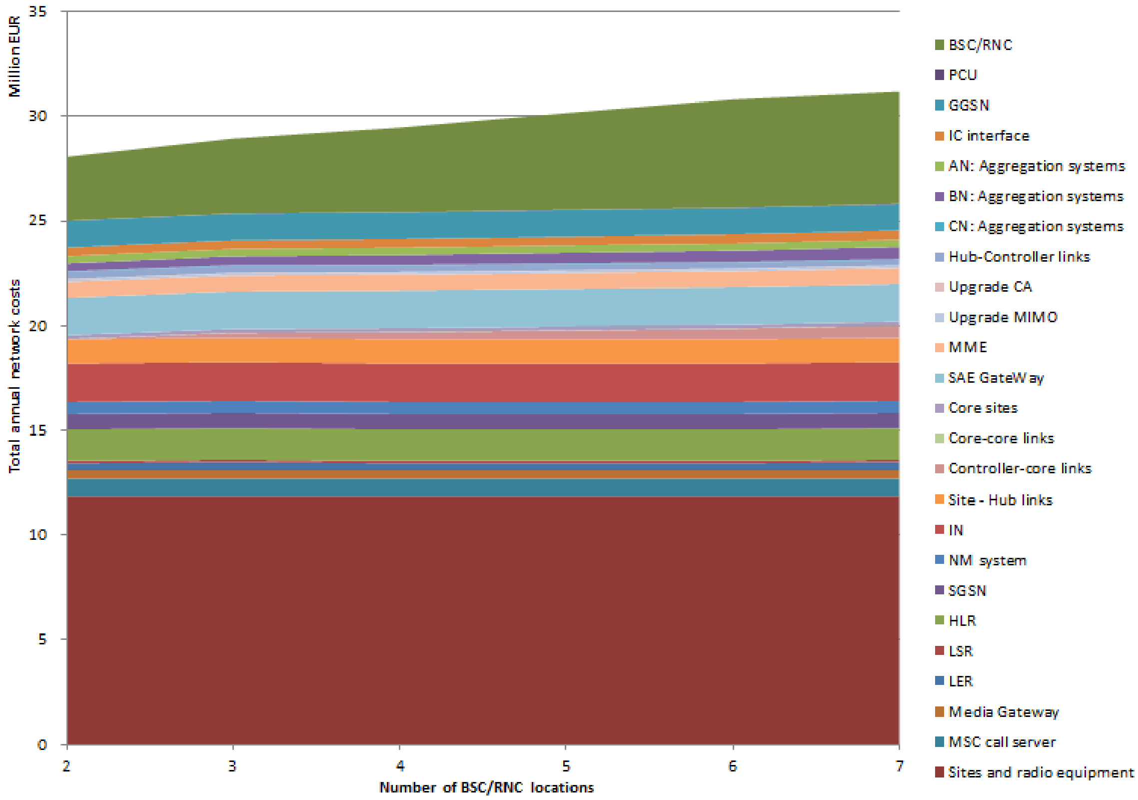
(81) According to Section 4.1.1.3, the modelled hypothetical operator provides full area and full population coverage for 2G, 3G and 4G services.

(82) The optimised mobile network of the hypothetical operator has approx. 358 sites with 2G, 3G and/or 4G base stations, approx. 318 BTSs, approx. 275 NodeBs, approx. 113 e-NodeBs, approx. 732 TRXs, approx. 1539 3G carriers and 33 cell hubs.

4.2.3 Controller locations

(83) For these comparative static model calculations, the number of controller locations (i.e. locations with BSC and RNC nodes) are varied[12] between 2 and 7. The results are shown in Figure 4-7.

Figure 4-7 : Total annual network costs depending on the number of controller locations[13] [source: ILR, mobile cost model, 2016]



(84) The minimum of the total network costs is achieved with two controller locations, which is also in line with the amount of controller locations deployed by some Luxembourg operators due to redundancy reasons. Hence for the network of the hypothetical operator the number of controller locations has been set to two.

(85) The differences in the overall network costs for up to seven locations and between the costs in case of two locations is up to 11.11%.

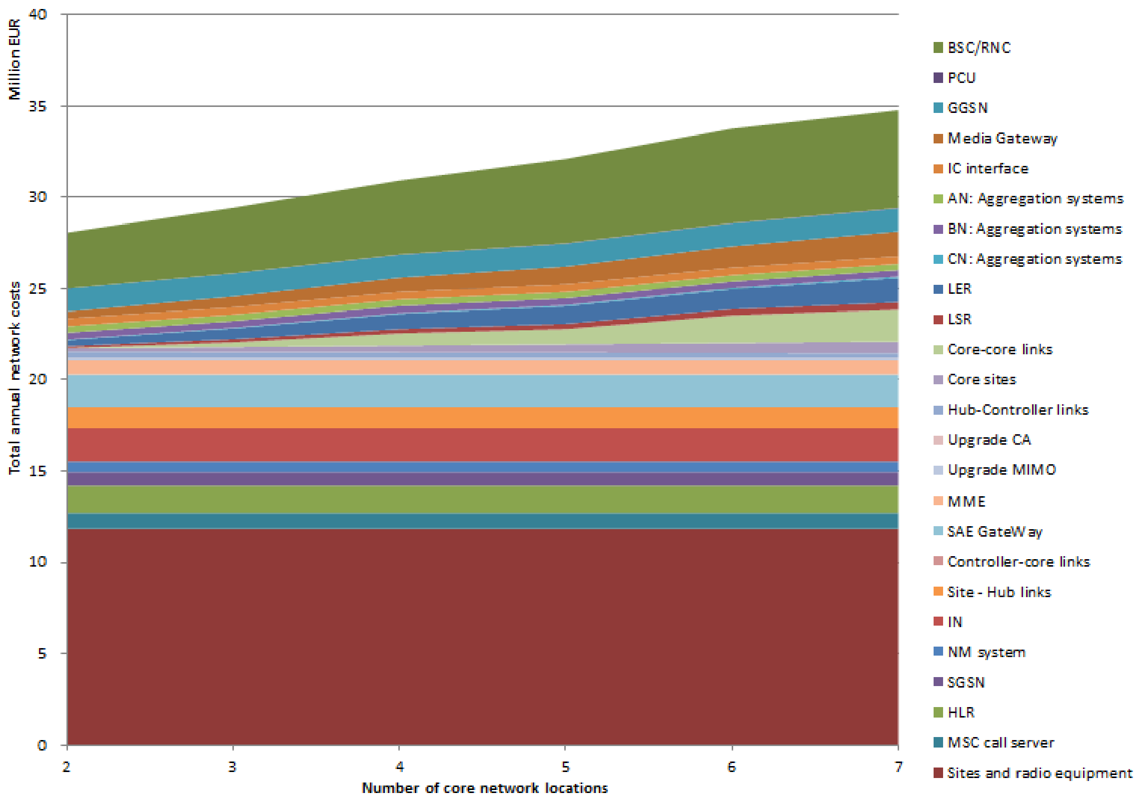
[12] Less than two controller locations are not considered as a viable option because of a negative impact for 100% of all network services in case of such a single point of failure. This holds true for the core network locations investigated later on too.

[13] This is a cumulative diagram representation of the costs. The values are stacked in the order of Sites and radio equipment (e.g. BTS/NodeB/eNodeB), MSC call server, Media Gateway, LER etc. finally up to IC interface, GGSN, PCU and BSC/RNC.

4.2.4 Core network locations

(86) In this section, the analysis regarding the optimal number of core network locations with MGWs are presented. The following figure shows the dependence of the total annual network costs and the number of core network locations.

Figure 4-8: Total annual network costs depending on the number of core network locations [source: ILR, mobile cost model, 2016]



(87) From Figure 4-8 it can be seen that the minimum of the total annual network costs is determined with two core network locations. The differences in the total network costs for the range of up to seven core network locations and the costs in case of two core network locations are up to 23.89%. Note that an increase of the core network locations involves an increase of the number of controller locations, because the core network locations are always co-located with the controller locations[14]. Generally it can be concluded, that an increase of the number of network locations and corresponding network nodes always comes along with increased costs, which is quite straightforward.

(88) The control layer nodes MSC-S, HLR, SMSC and IN located on core network locations have enough capacity to compensate a complete failure (100%) of a core network location.

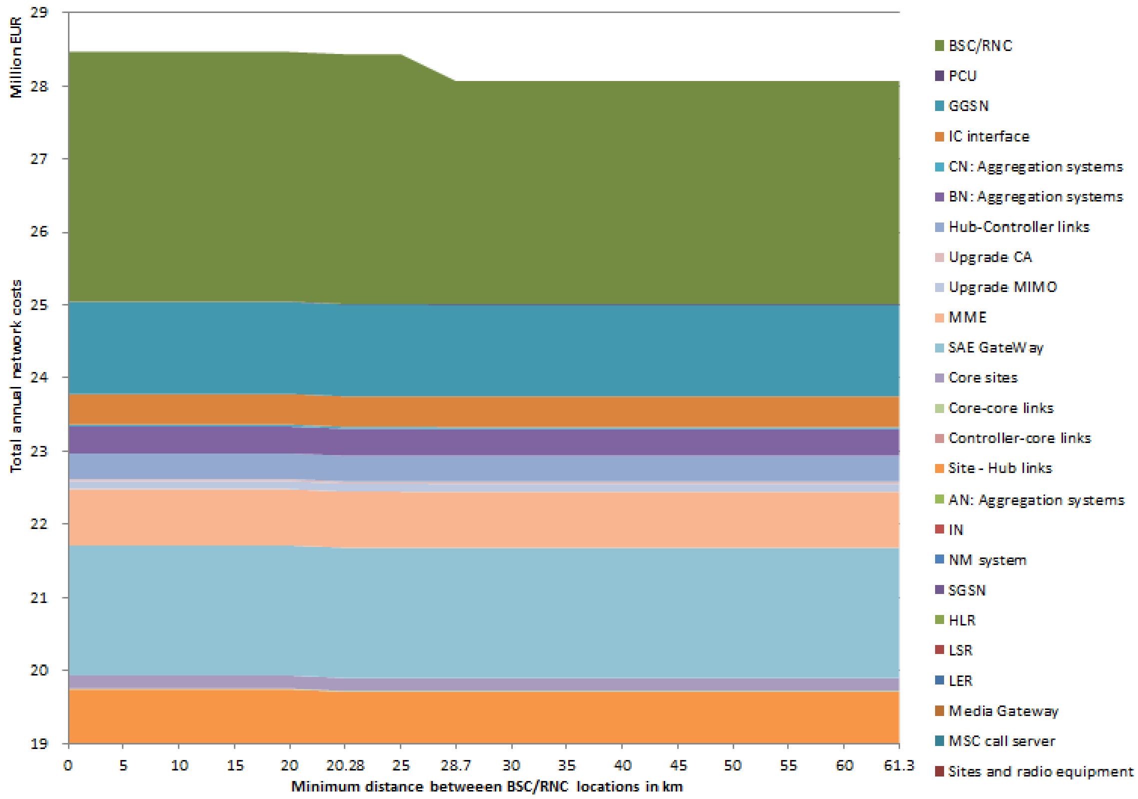
[14] This is necessary because the core network locations are selected from the set of controller locations by the model and thus cannot be greater than the number of controller locations.

(89) The model implements redundant connections between the controller sites and the core network locations. Hence, the complete traffic is doubled and the MGWs and their interconnection interfaces are dimensioned for the voice busy hour in a redundant manner. Similarly, the capacities of SGSN, GGSN, SAE-GW and LER nodes and switches are doubled due to these doubled connections. According to this redundancy approach, the network of the HEO includes two core network locations.

4.2.5 Minimum distances

(90) The final fine adjustment on the hypothetical efficient operator's mobile network relates to the determination of the minimum distances between the controller/core network locations. The minimum distances between the controller locations were varied between 0 km and 61.3[15] km, with the following results.

Figure 4-9: Total annual network costs depending on the minimum distance between controller locations [source: ILR, mobile cost model, 2016]



(91) The total network costs' minimum is determined when the controller locations are located at a distance of 28.7 km. For instance, this results in two controllers located in Luxembourg City (Gare) and in Diekirch. The differences in the total network costs for all minimum distances and the mentioned minimum distance are below 1.43%.

[15] For a minimum distance of more than 61.3 km, the model doesn't find a solution for the specified number of controller locations.

(92) Hence, the minimum distance between controller locations of the HEO is set to 28.7 km.

(93) Because the number of the core network locations is the same as the number of the controller locations, these locations are co-located. Hence the distance between the core network locations is the same as for the controller locations, so the core network locations are located in Luxembourg City (Gare) and in Diekirch as well.

(94) A 100% protected physical ring/link connects the two controller/core network sites. By means of this ring, a controller location is connected using doubled link connections with 100% protection to the other core network location.

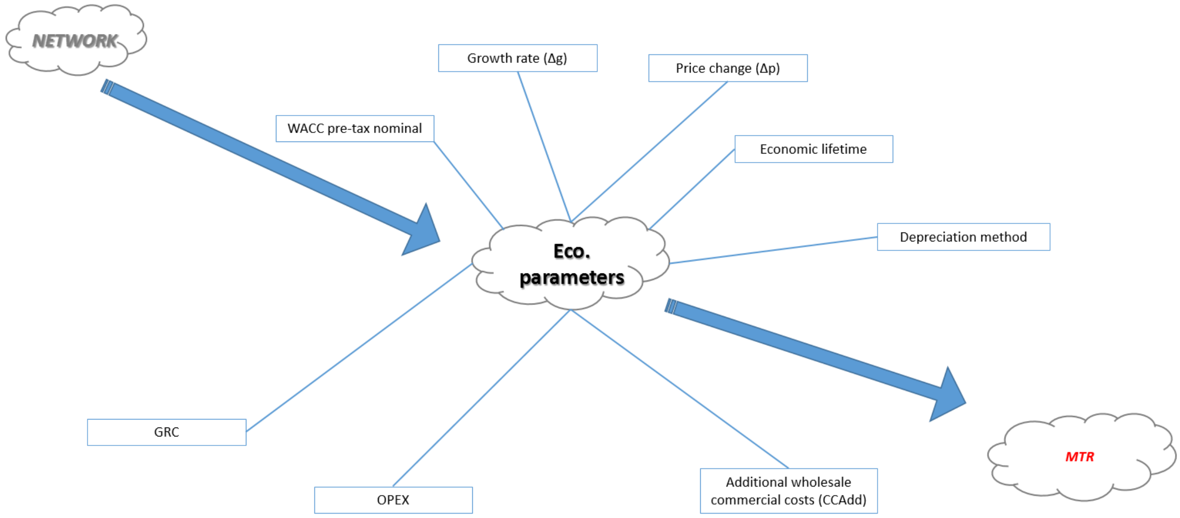
4.2.6 Interconnection locations for voice services

(95) The number of interconnection locations is set to two and these are collocated with the selected core network locations. More than two interconnection sites are, due to merely two core network locations, not efficient, whereas only one site represents from a redundancy and resilience point of view a single point of failure, which is not recommended.

4.3 Economic parameters

(96) The determination of the mobile termination costs requires as input the economic factors outlined in Figure 4-10.

Figure 4-10 : Economic parameters [Source: ILR, 2016]



4.3.1 Gross replacement cost

(97) For the determination of the gross replacement cost of the network (i.e. GRC), in accordance with the FTR-MTR Recommendation[6], ILR has opted for a valuation method using the current prices of the assets and as such the resulting values represent those of a new network (i.e. modern equivalent assets). In other words, the adopted conceptual approach considers that the cost of the network equals those incurred by a new entrant on the market.

(98) The total GRC of the hypothetical efficient operator's network equals 117.83 mio €. The investment related inputs used by the ILR in its model are based on operators' inputs as well as on international benchmarks.

4.3.2 Depreciation method

(99) The annual amortisation values of the network assets cover both the depreciation of and the interest on the capital resources employed. The ILR has opted for the annuity approach [i.e. a total annualised CAPEX of 16 584 475 €].

(100) For the determination of the economic depreciation, the ILR considers also the variation of the output (Δg) as well as the evolution of the assets' prices (Δp) in order to compensate for the asset's value loss over its economic lifetime.

4.3.3 Expected price change (Δp)

(101) The ILR considers an estimated yearly change in the prices of the specific assets (i.e. Δp) for the determination of the GRC. Thus, e.g. a negative price change represents a positive technological change in the domain of network assets as well as network support assets. The expected price changes of network assets taken into account by the ILR are shown in Table 4-12. The expected price changes of network support assets are illustrated in Table 4-13.

4.3.4 Expected growth rate (Δg)

(102) As referred supra, the ILR considers the estimated average variation of the utilisation rate of the installation during its economic lifetime (i.e. Δg). This expected growth rate is used in order to be able to react to changes on the demand side with regards to the depreciation as well as to allow a better approximation between the demand and the depreciation of the investment.

(103) The mobile market in Luxembourg is characterised by increasing capacities in voice traffic and strongly increasing capacities in data traffic. The ILR therefore considers in its bottom-up cost model:

- Δg = 0 for all active components used by voice and data as well as those which have a short lifetime and can therefore be adapted relatively quickly to changes;
- Δg > 0 for passive elements used by voice and data.

(104) The considered expected growth rates of the network assets, computed according to the historical usage pattern for voice and data, are shown in Table 4-12. The expected growth rates of the network support assets are represented in Table 4-13.

4.3.5 Economic lifetime

(105) The corresponding economic lifetimes of the different network assets considered for the determination of the annualised CAPEX are illustrated in Table 4-12. The corresponding economic lifetimes of network support assets used by the ILR are represented in Table 4-13.

Table 4-12: Expected price change, expected growth rate and economic lifetime of network assets [source: ILR, mobile cost model, 2016]

Network assets	Expected price change	Expected growth rate	Economic lifetime (years)
BTS / NodeB / HSPA /e-NodeB			
Sites	1.10%	17.48%	18
Equipment	-3.67%	0%	8
TRX / Carrier	-3.78%	0%	8
BSC/RNC			
BSC site	1.55%	17.48%	18
RNC site	1.55%	17.48%	18
BSC hardware	-1.50%	0%	8
BSC software	-4.75%	0%	5
RNC hardware	-1.50%	0%	8
RNC software	-4.75%	0%	5
BSC ports	-1.50%	0%	8
RNC ports	-1.50%	0%	8
PCU BSC	-1.50%	0%	8
MSC			
MSC call server	-3.20%	0%	8
MGW			
Media Gateway	-5.60%	0%	8
Ports	-5.60%	0%	8
Core sites	1.55%	17.48%	18
Other core location equipment			
HLR	-1.50%	0%	8
AUC	-1.50%	0%	8
EIR	-1.50%	0%	6
LER / LSR	-4.75%	0%	8
SMSC	-1.50%	0%	8
SGSN	-1.50%	0%	8
GGSN	-1.50%	0%	8
Other			
IC interface	-5.60%	0%	8
Network management system	-1.50%	0%	8
IN	-1.50%	0%	6
Aggregation systems	-4.45%	0%	8
Aggregation systems ports	-4.45%	0%	8
Radio links	-1.80%	0%	8

Table 4-13: Expected price change, expected growth rate and economic lifetime of network support assets [source: ILR, mobile cost model, 2016]

Network support assets	Expected price change	Expected growth rate	Economic lifetime (years)
Vehicles	2.00%	0%	5
Office equipment	2.00%	0%	6
Workshop Equipment	2.00%	0%	5
IT / general purpose computer	-4.75%	0%	5
Network management	2.00%	0%	6
Land and buildings	1.10%	0%	28

4.3.6 Weighted Average Cost of Capital (WACC)

(106) According to articles 28 (1) c) and 33 (2) of the "*Loi du 27 février 2011 sur les réseaux et les services de communications électroniques*", the ILR, when setting price caps of regulated wholesale products, should consider the investments realised by the SMP operators and allow them a reasonable remuneration of the capital employed, which should reflect the associated investment risk.

(107) The cost of capital equals the weighted average cost of capital (WACC). The ILR considers a pre-tax nominal WACC of 7.10% for the mobile network activities under review in accordance with the regulation 16/206/ILR[16].

4.3.7 Operational expenditure (OPEX)

(108) The considered operational expenditure of the hypothetical efficient operator is equal to the expenses required for the functioning/operation of the network.

(109) ILR determines the OPEX as a percentage mark-up on the GRC of the relevant facilities. The values of these percentage mark-ups are determined on the basis of values provided by the Luxembourgish operators as well as the WIK database (Table 4-14 and Table 4-15).

Table 4-14: OPEX mark-up [source: ILR, mobile cost model, 2016]

Network support assets	OPEX mark-up
Motor vehicles	11%
Office equipment	11%
Workshop Equipment	11%
IT / general purpose computer	11%
Network management	30%
Land and buildings	5%

[16] Règlement 16/206/ILR du 14 juin 2016 portant sur la fixation du coût moyen pondéré du capital pour les produits et services régulés d'un opérateur identifié comme puissant sur un marché pertinent
De plus amples informations relatives à ce règlement peuvent être consultées sur le site Internet de l'Institut à la page consacrée à l'encadrement tarifaire.

Table 4-15: OPEX mark-up on direct investment [source: ILR, mobile cost model, 2016]

Network segment	OPEX mark-up on direct investment
BTS / NodeB / HSPA / e-NodeB	
GSM/EDGE	12%
UMTS/HSPA	10%
LTE	10%
GSM/EDGE/UMTS/HSPA	11%
GSM/EDGE/LTE	10%
UMTS/HSPA/LTE	10%
GSM/EDGE/UMTS/HSPA/LTE	10%
BSC / RNC	
BSC/PCU	11%
RNC	12%
MSC call server, MGW and LER	
MSC call server	10%
Media Gateway	12%
LER / LSR	12%
Core sites	7%
Other core location equipment	
HLR	11%
AUC	11%
EIR	11%
SMSC	11%
SGSN	11%
GGSN	11%
Others	
IC interface	12%
Network management system	10%
IN	10%
Aggregation systems	10.50%
Radio links	10%

(110) The annual OPEX of the considered hypothetical efficient operator's network equals 12 734 477 €.

4.3.8 Additional wholesale commercial costs (CCAdd)

(111) Costs of the service of call termination is not only consisting of costs generated by the operator's network, but also of an additional wholesale commercial cost (hereafter "CCAdd"). This additional wholesale commercial cost represents the sale of termination provision namely the costs for human resources as well as the costs for the systems needed for the selling process of others operators' termination volume. This cost does neither cover retail nor wholesale commercial costs which have no direct link with the call termination service. In case the service of termination is neither offered nor billed, the additional wholesale commercial cost will not occur.

(112) During the previous process of setting the fixed and mobile call termination price caps, ILR decided to apply the value of 0.1013 €cents/min as CCAdd which was added to the results coming out of the models. This value for CCAdd has been determined based on data collected from the mobile and fixed operators. Moreover, ILR also retained that the CCAdd should not vary between the fixed and mobile call termination service, as it is considered as being an identical operation.

(113) During the international consultation phases which ran in 2014 and 2015[17], the European Commission issued comments related to the CCAdd. More precisely, the Commission stated the following during the international consultation phase relative to the setting of the mobile termination price cap[18] : "*The Commission considers that wholesale commercial costs should be derived from the costing model itself rather than being calculated outside the model based on data provided by the active operators in the market. The Commission does not consider that the specificities of the Luxembourgish market (such as lower traffic volume or higher wage levels than the European average) are sufficient justification to derive wholesale commercial costs outside of the BU-LRIC model. This is because the cost model can be designed to account for these particular features when deriving the commercial costs incurred by an efficient operator in Luxembourg. The Commission therefore invites the ILR in the context of the next update and/or review of the costing model to amend it accordingly. Furthermore, against the background of differing practices by various NRAs in this respect, the Commission invites the ILR to cooperate more closely with other NRAs and BEREC to redress inconsistencies in its modelling approach.*"

(114) In order to completely take into account all of the comments issued by the Commission, ILR has adapted its method for determining the CCAdd for the new call termination price caps. ILR has therefore followed up the comments issued by the Commission by collecting and analysing more precise and more disaggregated operators' data as well as by adapting its models to calculate automatically the CCAdd as described in the following paragraphs.

(115) For the determination of the additional wholesale commercial cost of the hypothetical efficient operator in Luxembourg, ILR inquired for values among the Luxembourgish fixed and mobile network operators. The operators were asked to quantify their cost relative to the sale process of the termination provision separately for their fixed and mobile activities, as well as to split into costs related to billing (i.e. management of information used for invoicing) and invoicing (e.g. issuing, management, defaults) as well as others ("Operations, administration and maintenance"). Furthermore, the first two cost positions should be split into human resources costs, equipment costs ("hardware one-off and recurring") and licence fees ("one-off and recurring").

(116) The analysis of the information provided by the operators has shown that it is impossible to determine the equipment costs and licence fees incurred separately by the termination provision, as the cost of this type of service is generally considered part of all voice services provided by the operator. For this reason, only the costs for the human resources necessary for the provision of termination services were considered by ILR.

[17] Case LU/2014/1682, LU/2014/1683 and LU/2015/1712

[18] Case LU/2015/1712

(117) The following Figure 4-11 and Figure 4-12 show the values kept by ILR for every operator. It should be noted that the operators providing mobile and fixed services are shown by two separate points as a function of their volume and cost born on the respective markets.

Figure 4-11 : CCAdd by operator as a function of off-net termination traffic [Source: ILR, 2016]

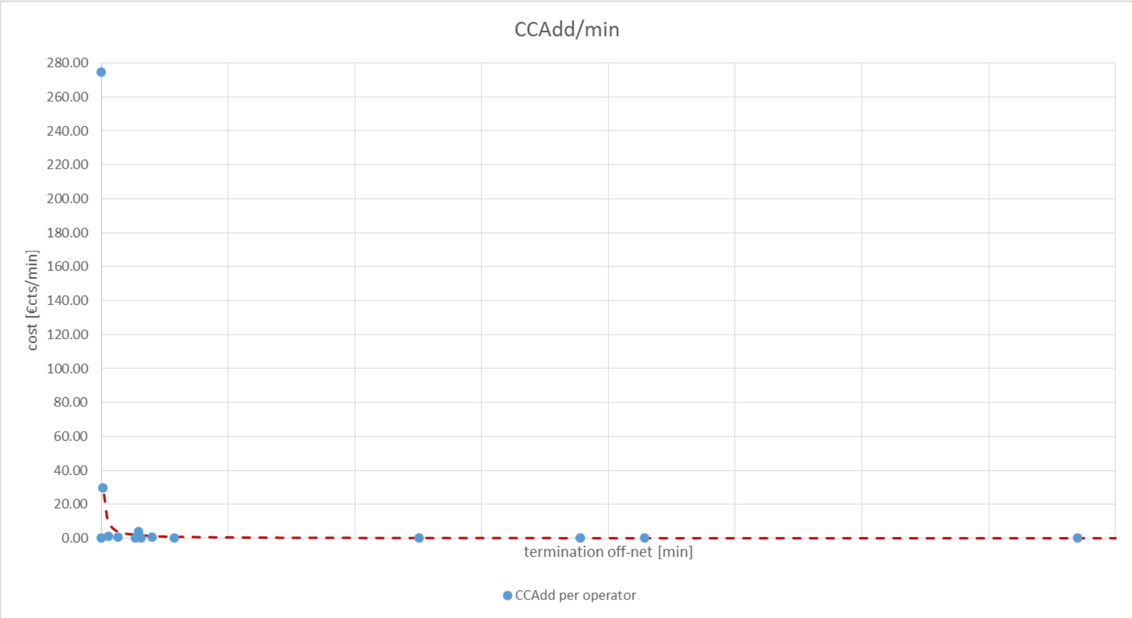
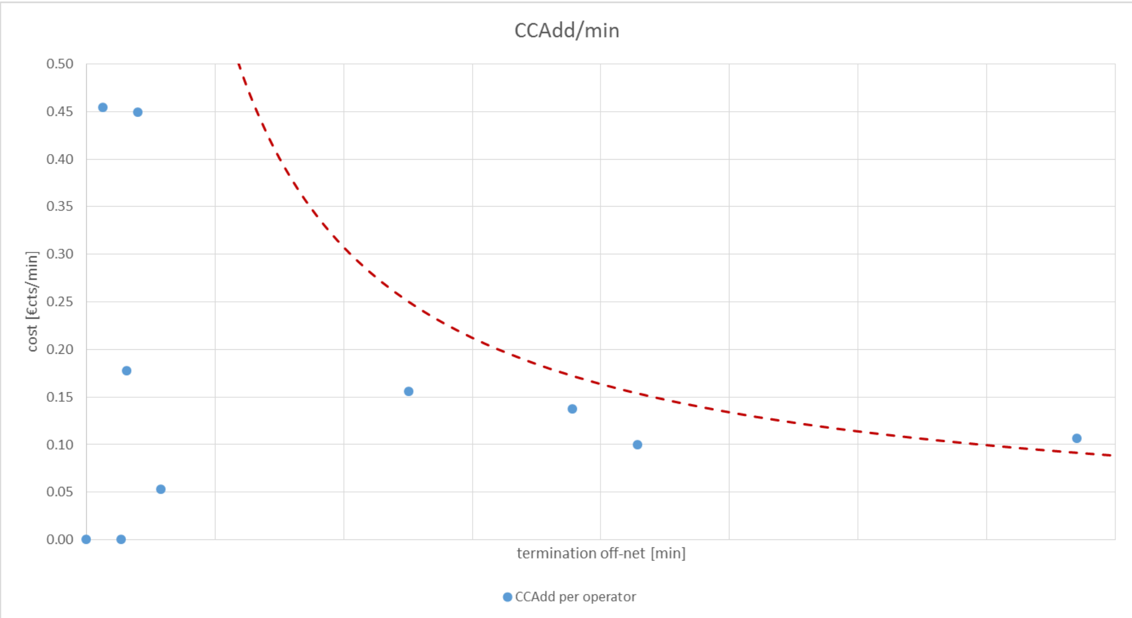


Figure 4-12 : CCAdd by operator as a function of off-net termination traffic - zoom [Source: ILR, 2016]



(118) Figure 4-11 shows that the CCAdd per termination minute decreases with increasing termination volume and converges towards 0. On the other hand, the CCAdd per minute is very important for the operators with smaller termination volumes. This observation confirms that the CCAdd per termination minute is non-negligible and crucial to be considered in an efficient network with a size comparable to those deployed in Luxembourg.

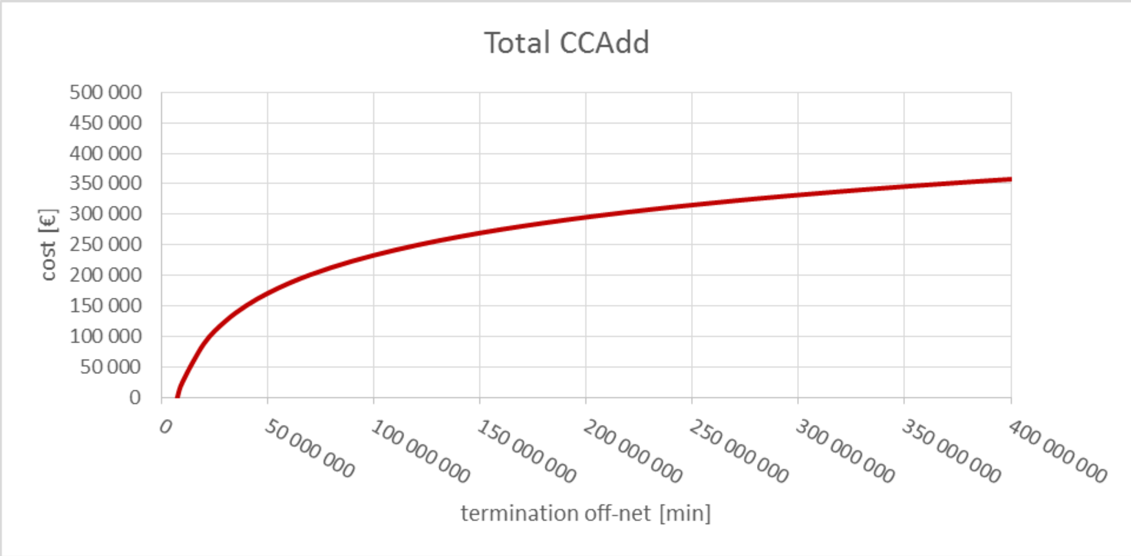
(119) From the Figure 4-12, it can be derived, that the CCAdd per minute from the operators having the four largest volumes can be estimated with the function shown as a dotted line. ILR is of the opinion that this function is well suited for the determination of the CCAdd born by a hypothetical efficient operator in Luxembourg.

(120) The following function, which is plotted in the Figure 4-13, is incorporated in the ILR's cost models:

Formula 14

$$CCAdd\ (€) = 90\ 000\ \cdot ln(termination\ offnet) - 1\ 425\ 000$$

Figure 4-13 : Total CCAdd total as a function of off-net termination traffic [Source: ILR, 2016]



(121) This natural logarithmic function, which determines the CCAdd incurred by a hypothetical efficient operator in Luxembourg, as a function of its incoming minutes on its fixed or mobile network, is implemented in the cost models after the determination of the total pure LRIC costs onto which they are added. The cost per termination minute is then calculated by dividing all the considered costs by the termination volume taken into account.

(122) ILR considers that it is justified to include the CCAdd in the cost of the termination services as the interconnection volumes in Luxembourg are small compared to those in other European countries and, as a consequence, the additional wholesale commercial costs cannot be neglected.

5 Determination of the price cap

(123) In this section the process for determining the mobile termination rates (MTR) based on a pure LRIC method for a hypothetical efficient operator using a cost model is explained. Therefore the corresponding inputs needed by the cost model as well as the generated outputs are identified in the following paragraphs.

(124) The figures regarding the various steps contain the different inputs [green background] that lead to intermediate results [orange background] and final results [orange background, red border]. The corresponding values are also illustrated later in this section or a reference is made to the corresponding appendix.

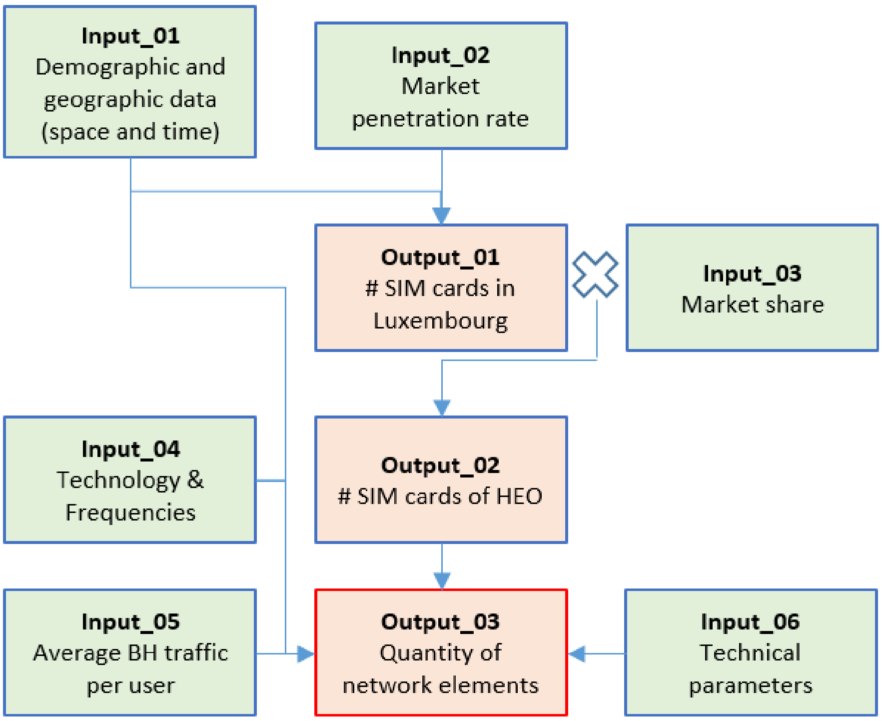
(125) As already mentioned, ILR uses a BU pure LRIC approach for determining the costs of mobile call termination in order to set a price cap on the service of wholesale voice call termination on individual mobile networks (market 2/2014) [Output_11: 0.89 €cts/min.]

(126) The process is divided into five steps:

1. Determination of the HEO's number of SIM cards;
2. Determination of the quantity of the network elements;
3. Calculation of the total annual network costs;
4. Calculation of the total cost of provisioning mobile call termination;
5. Determination of the MTR price cap.

(127) The first two steps, i.e. determination of the HEO's number of SIM cards and the determination of the quantity of the network elements, are outlined in Figure 5-1.

Figure 5-1 : Determination of network equipment volume [source: ILR, 2016]



(128) Figure 5-1 shows that the number of total SIM cards in Luxembourg [Output_01] is determined by considering the demographic data and the average penetration rate. Then the number of the HEO's SIM cards [Output_02] is determined by considering the total SIM cards in Luxembourg multiplied with the market share.

(129) The information of the HEO's SIM cards, the technical parameters, the frequencies the HEO has obtained, the technology (i.e. GSM/EDGE, UMTS/HSPA, VoLTE/LTE) to be applied as well as the average BH traffic per user are considered for dimensioning the HEO's network. This needs to be done in order to define the type and quantity of elements required to satisfy the demand of the network busy hour and to guarantee a 100% coverage of Luxembourg. This is done once for a network with termination and for a network without termination, which is needed for the next step. An overview of the different input values and the generated outputs for these two steps are illustrated in Table 5-1 and Table 5-2.

Table 5-1: Values of the inputs outlined in Figure 5-1 [source: ILR, 2016]

Input_01	Demographic and geographic input data (Described in chapter 4.1.1)
Input_02	1.11
Input_03	0.3333
Input_04	GSM/EDGE/UMTS/HSPA/LTE (see Table 4-11 Frequency spectrum)
Input_05	Table 4-10: Input values into the bottom-up cost model for different services
Input_06	Technical parameters are specified in the reference document[7]

Table 5-2: Values of the outputs outlined in Figure 5-1 [source: ILR, 2016]

Output_01	# of SIM cards	906 033	
Output_02	# of SIM cards	302 011	
Output_03	**Unit#**	**With termination**	**Without termination**
BTS / NodeB / e-NodeB			
Sites	#	358	351
Equipment	#	1 740	1 664
TRX / Carrier	#	2 271	2 138
BSC/RNC			
BSC site	#	2	2
RNC site	#	2	2
BSC hardware	#	2	2
BSC software	#	2	2
RNC hardware	#	5	4
RNC software	#	5	4
BSC ports	#	636	558
RNC ports	#	762	742
PCU BSC	#	2	2
MSC call server	#	2	2
MGW			
Media Gateway	#	2	2
Ports	#	102	56
Core sites	#	2	2
Other equipment			
HLR	#	2	2
HSS / EIR	#	4	4
LER	#	2	2
LER Ports	#	8	7
LSR	#	2	2
LSR Ports	#	10	10
SMSC	#	0	0
SGSN	#	2	2
SGSN Ports	#	10	6
GGSN	#	2	2
GGSN ports	#	6	6
SAE-GW	#	4	4
IC interface	#	2	2
Network management system	#	1	1
IN	#	2	2
Aggregation systems	#	32	32
Aggregation systems ports	#	1 100	1 080
Radio links	#	568	548

(130) In the next step, the total annual network costs are determined as illustrated in Figure 5-2.

Figure 5-2: Determination of total annual network costs [source: ILR, 2016]

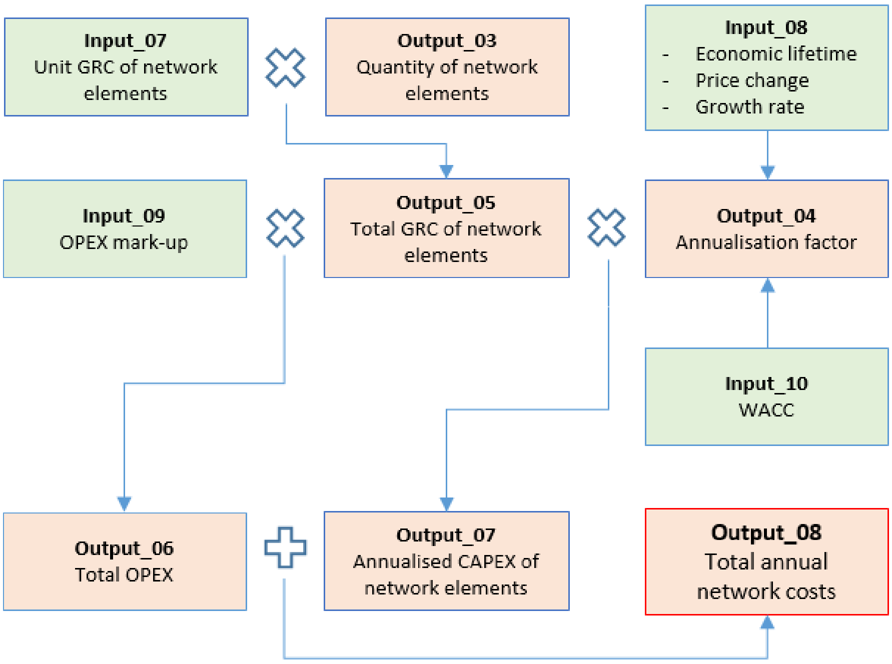


Table 5-3 : Values corresponding to the inputs outlined in Figure 5-2 [source: ILR, 2016]

Input_07	Table 7-1 Gross replacement costs considered as input in the model
Input_08	Table 4-12: Expected price change, expected growth rate and economic lifetime of network assets [source: ILR, mobile cost model, 2016] Table 4-13: Expected price change, expected growth rate and economic lifetime of network support assets [source: ILR, mobile cost model, 2016]
Input_09	Table 4-14: OPEX mark-up [source: ILR, mobile cost model, 2016] Table 4-15: OPEX mark-up on direct investment [source: ILR, mobile cost model, 2016]
Input_10	7.10%

Table 5-4 : Values corresponding to the outputs outlined in Figure 5-2 [source: ILR, 2016]

	Unit	With termination	Without termination
Output_03	#	7 225	6 845
Output_05	€	117 825 234	113 498 344
Output_06	€/year	12 734 477	12 239 143
Output_07	€/year	16 548 475	15 945 762
Output_08	€/year	29 282 952	28 184 904

(131) In this step, the annualised CAPEX of the network equipment [Output_07] is calculated considering the sum of unit gross replacement costs [Output_05] as well as economic parameters [Output_04].

(132) The total annual network costs [Output_08] are determined by the sum of the annualised CAPEX [Output_07] and the total operational expenditure [Output_06].

(133) According to the BU pure LRIC approach, ILR determines the total annual network costs with total volume of termination [Output_08A] and without voice call termination [Output_08B], as outlined in Figure 5-2.

(134) Figure 5-3 outlines the step for the determination process of the BU pure LRIC cost, considered for the price cap of the provision of call termination [Output_11].

Figure 5-3: Determination of the price cap for mobile voice call termination [source: ILR, 2016]

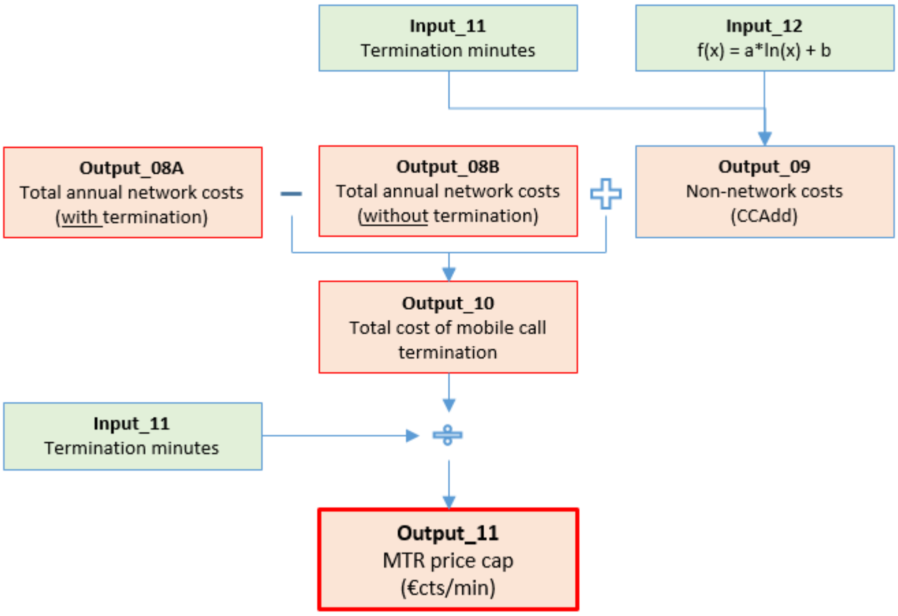


Table 5-5: Values of the inputs and outputs outlined in Figure 5-3 [source: ILR, 2016]

	Unit	2017
Input_11[19]	Minutes	153 456 358
Input_12	n/a	CCAdd(min. TA off-net) = 90 000 * ln(min. TA off-net) – 1 425 000
Output_08A	€/year	29 406 696
Output_08B	€/year	28 308 648
Output_09	€/year	271 403
Output_10	€	1 369 451
Output_11	€cts/min	0.8924

(135) The difference between Output_08A and Output_08B refers to the network costs effectively incurred for mobile call termination.

(136) The non-network costs ("CCAdd") directly related to the provision of mobile call termination [Output_09] are determined based on a natural logarithmic function [Input_12] as well as on the volume of call termination minutes [Input_11] (see chapter 4.3.8).

[19] Input_11 corresponds to 33.33% [Input_03] of the traffic values indicated in Table 4-3.

(137) The sum of the network [Output_08A-Output_08B] and non-network [Output_09] costs represents the total annual cost of providing mobile call termination [Output_10].

(138) The price cap [Output_11] determined by ILR consists of the total cost for mobile call termination [Output_10] divided by the termination minutes [Input_11].

6 Sensitivity analyses

(139) Sensitivity analyses are performed in order to check the correct functioning of the cost model used by ILR for the current price caps setting. These analyses allow to identify the key factors affecting the cost of the provision of mobile wholesale call termination.

(140) In this context, the sensitivity of different input assumptions corresponding to the properties of the hypothetical efficient operator (i.e. the base case corresponding to 100% of voice traffic and 100% of data traffic) is examined. The following input parameters are considered:

- Demand (section 6.1)
  - Demand per service (section 6.1.1)
  - Traffic distribution between on-net, origination and off-net (section 6.1.2)
  - Market share (section 6.1.3)
- Network characteristics (section 6.2)
  - Technology (section 6.2.1)
  - Consideration of Voice over LTE (section 6.2.2)
- Economic parameters (section 6.3)
  - Gross replacement costs (section 6.3.1)
  - Cost of capital (section 6.3.2)
  - Operational expenditure (section 6.3.3)

(141) The results of the analyses performed with regard to the demand and the network characteristics are outlined in three dimensional graphics allowing a meaningful presentation of the behaviour of the costs of call termination. The corresponding analyses consider different scenarios for the demand of voice services and of data services. For this purpose, the voice traffic is sampled between 95% and 105% while the data traffic is varied from 100% to 120%, based on the traffic defined in chapter 4.1.4.

(142) By means of these analyses, the impact on the costs resulting of the model due to variations of one particular input assumption, all other input data being equal, could be explored. ILR assesses the variations of the cost of the provision of mobile off-net call termination for the year 2017.

6.1 Sensitivity to the demand

6.1.1 Sensitivity to the demand per services

(143) Pure LRIC costs for termination are calculated based on a hypothetical mobile operator with a market share of 33.33% as described in chapter 4. The network with optimum costs for this operator was determined in a bottom-up cost accounting model. The traffic demand for services included in the calculation was estimated with 100%. This equals 33.33% of total market demand from 2015. Due to the design of the bottom-up cost accounting model, different demand situations lead to different quantity structures for network dimensioning. This again leads to different values for pure LRIC costs of termination. Therefore calculations were not based on a pure static view of 100% demand for all services, but on various demand settings.

(144) The services referred to in chapter 4.1.4 are treated as follows:

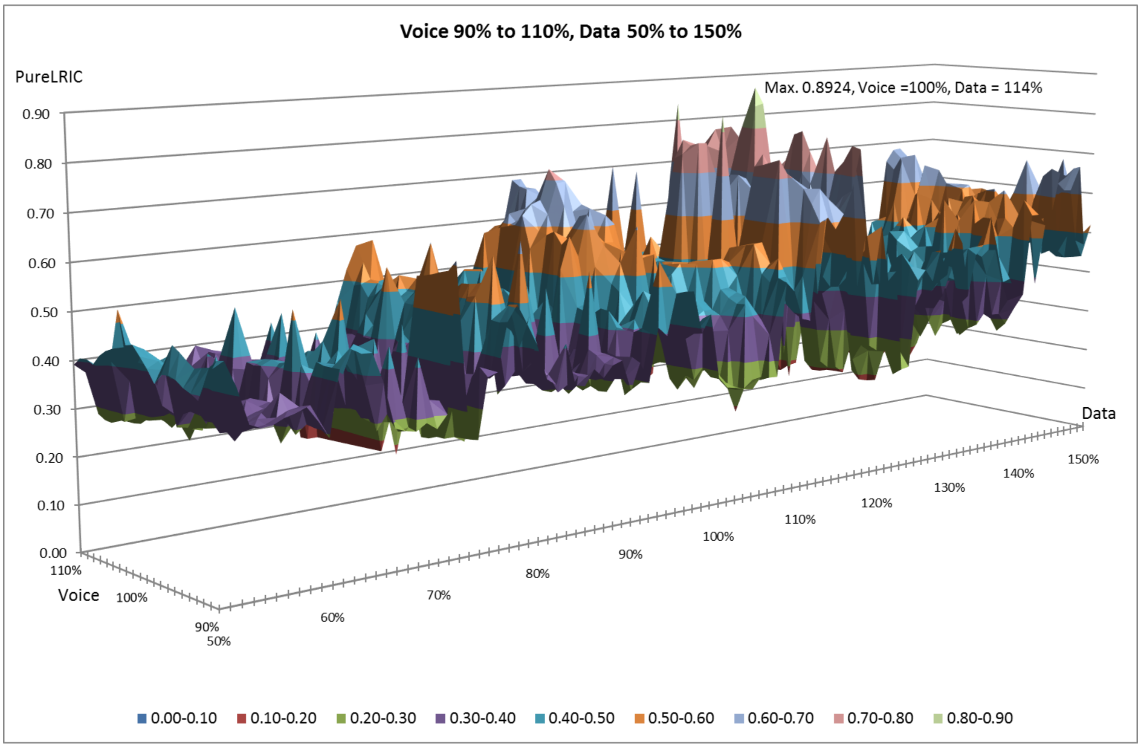
- Demand for voice service has risen by approximately 5% during the last year, but there might equally be a decrease in voice service demand in the future. Therefore range of demand is set with 90% to 110%.
- Demand for broadband services (best effort, mobile and LTE broadband) is expected to increase further in the future. Last year the increase was approximately 50%. So demand for broadband services was set with 50% to 150% (simultaneously for the three data services).

Table 6-1: Change of demand per service [source: ILR, 2016]

service	change of demand
VOICE	90% to 110%
BEST_EFFORT	50% to 150%
SMS	no change
MMS	no change
MOBILE_BROADBAND	50% to 150%
LTE_MBAS	50% to 150%

(145) In the course of this variation, demand for voice was changed in steps of 1% and demand for best effort, mobile and LTE broadband were changed jointly in steps of 1% in a combinatorial way. This results in 2 121 possible combinations. Figure 6-7 shows the sample space of these calculations.

Figure 6-1: Pure LRIC range [source: ILR, mobile cost model, 2016]



(146) The maximum value of 0.8924 €cents/minute corresponds to the calculated costs for 114% of data traffic and 100% of voice traffic.

(147) As clarified in chapter 3, pure LRIC costs represent the absolute minimum for the determination of termination fees. In order to avoid that the operator has to recover the costs for the termination service from revenues of other services (i.e. cross-subsidising), termination fees have to be determined at the upper limit of the calculated range. If the arithmetic mean or any other statistical method (median, x%-quantile etc.) were used, the terminating operator would not even recover incremental costs with a probability of 50% (or 1 minus x% at an x%-quantile). To determine a termination fee lower than costs seems inadequate.

6.1.2 Sensitivity to the traffic distribution between on-net, origination and off-net

(148) The total voice traffic consists of on-net, origination as well as off-net minutes. As the costs of call termination are determined, ILR investigates the potential impact of an increase and a decrease in termination ("off-net") traffic.

(149) The following scenarios are considered:

- on-net = 40%, origination = 40% and off-net = 20% ;
- on-net = 32.3%, origination = 34.2% and off-net = 33.5% (i.e. base case) ;
- on-net = 25%, origination = 25% and off-net = 50% ;
- on-net = 15%, origination = 15% and off-net = 70%.

(150) The respective results are illustrated in Figure 6-1 to Figure 6-4.

Figure 6-1 : Sensitivity of the pure LRIC costs to the traffic distribution between on-net (40%), origination (40%) and off-net (20%) [source: ILR, 2016]

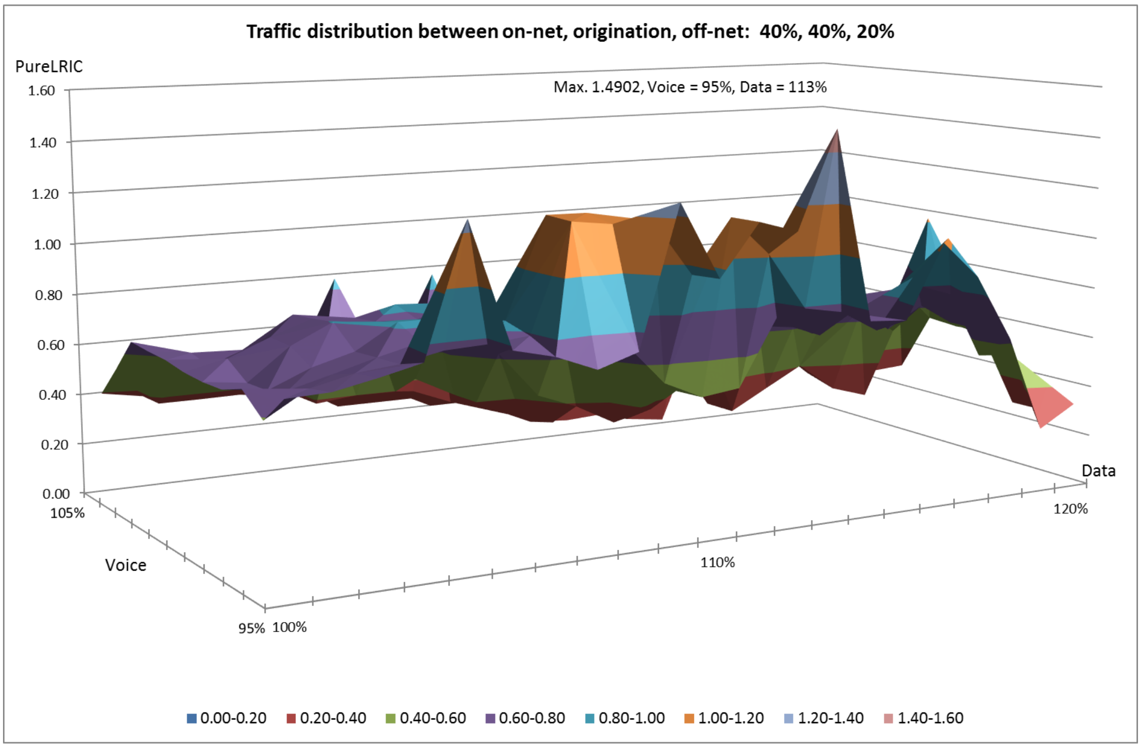


Figure 6-2 : Sensitivity of the pure LRIC costs to the traffic distribution between on-net (32.3%), origination (34.2%) and off-net (33.5%), i.e. base case [source: ILR, 2016]

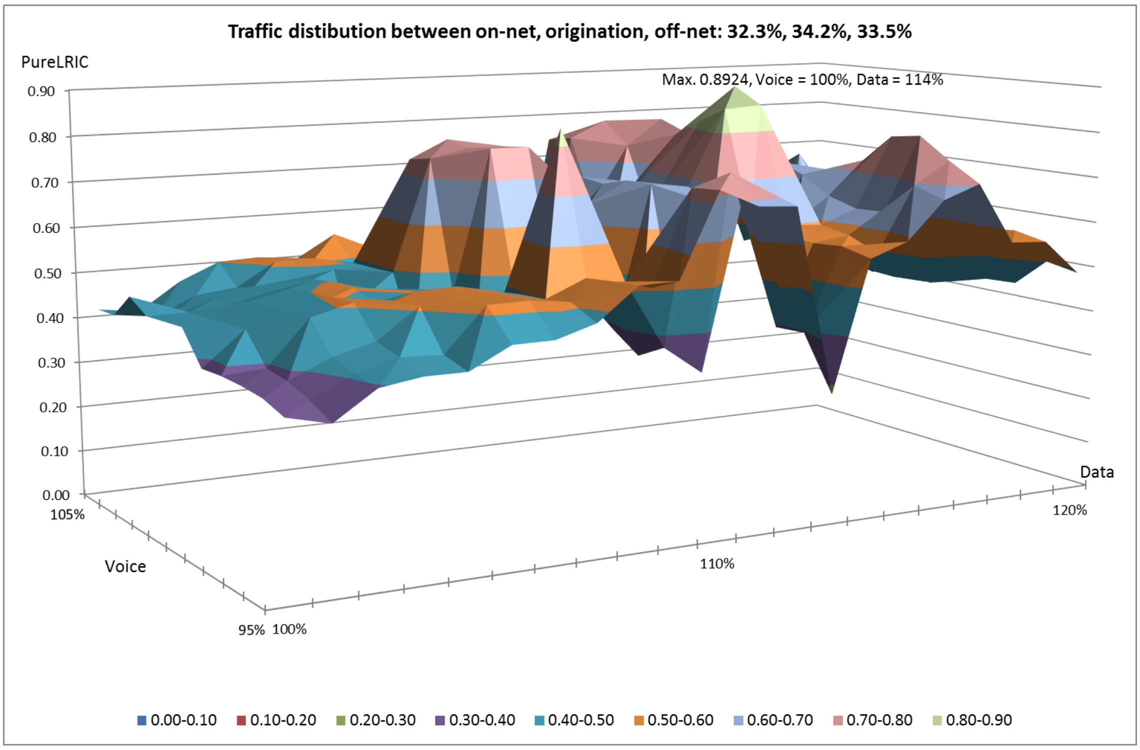


Figure 6-3 : Sensitivity of the pure LRIC costs to the traffic distribution between on-net (25%), origination (25%) and off-net (50%) [source: ILR, 2016]

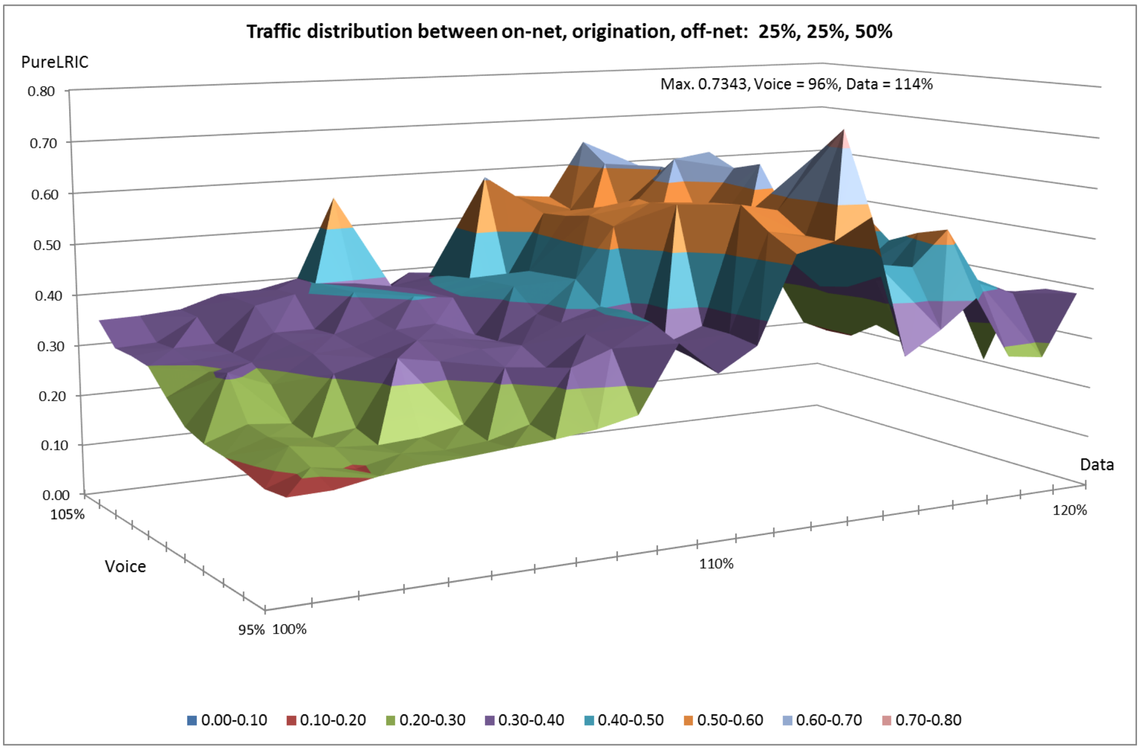


Figure 6-4 : Sensitivity of the pure LRIC costs to the traffic distribution between on-net (15%), origination (15%) and off-net (70%) [source: ILR, 2016]

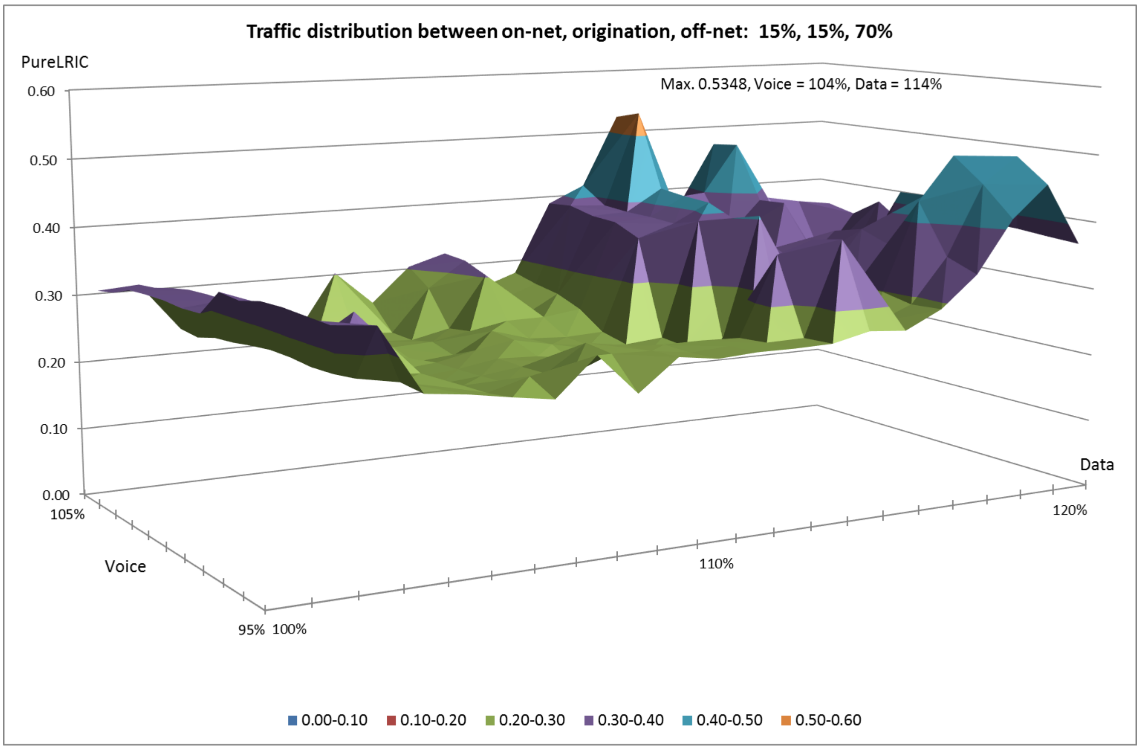


Table 6-1 : Sensitivity of the pure LRIC costs to the traffic distribution between on-net, origination and off-net [source: ILR, 2016]

Distribution of total voice traffic (%)		Maximum value		Value resulting of voice = 100% and data = 114%	
		Cost (€cts/min)	Variation (%)	Cost (€cts/min)	Variation (%)
On Net rate of the service traffic : **Off Net Outgoing rate of the service traffic :** **Off Net Incoming rate of the service traffic :**	**40.0** **40.0** **20.0**	1.4902	66.99	0.2457	-72.47
On Net rate of the service traffic : **Off Net Outgoing rate of the service traffic :** **Off Net Incoming rate of the service traffic :**	**32.3** **34.2** **33.5**	0.8924	-	0.8924	-
On Net rate of the service traffic : **Off Net Outgoing rate of the service traffic :** **Off Net Incoming rate of the service traffic :**	**25.0** **25.0** **50.0**	0.7343	-17.72	0.6280	-29.63
On Net rate of the service traffic : **Off Net Outgoing rate of the service traffic :** **Off Net Incoming rate of the service traffic :**	**15.0** **15.0** **70.0**	0.5348	-40.07	0.3937	-55.88

(151) Due to different demand settings in voice call services, the network dimensioning is adjusted in order to satisfy an increase/decrease in termination traffic volumes. Thus, the resulting network costs as well as the costs of provisioning the service of mobile call termination are also affected.

6.1.3 Sensitivity to the market share

(152) Changes in the market shares could be the result of the evolution of the competitive environment. Therefore, ILR analyses the effect on the pure LRIC costs of the provision of mobile call termination by the entry of new operators in the corresponding market.

(153) For this purpose, ILR assesses whether the presence of 4 and 5 market players in the mobile call termination market affects the costs of the provision of mobile call termination. The corresponding effects are outlined in Figure 6-5, Figure 6-6 and Figure 6-7.

Figure 6-5 : Sensitivity of the pure LRIC costs to a 33% market share, i.e. base case [source: ILR, 2016]

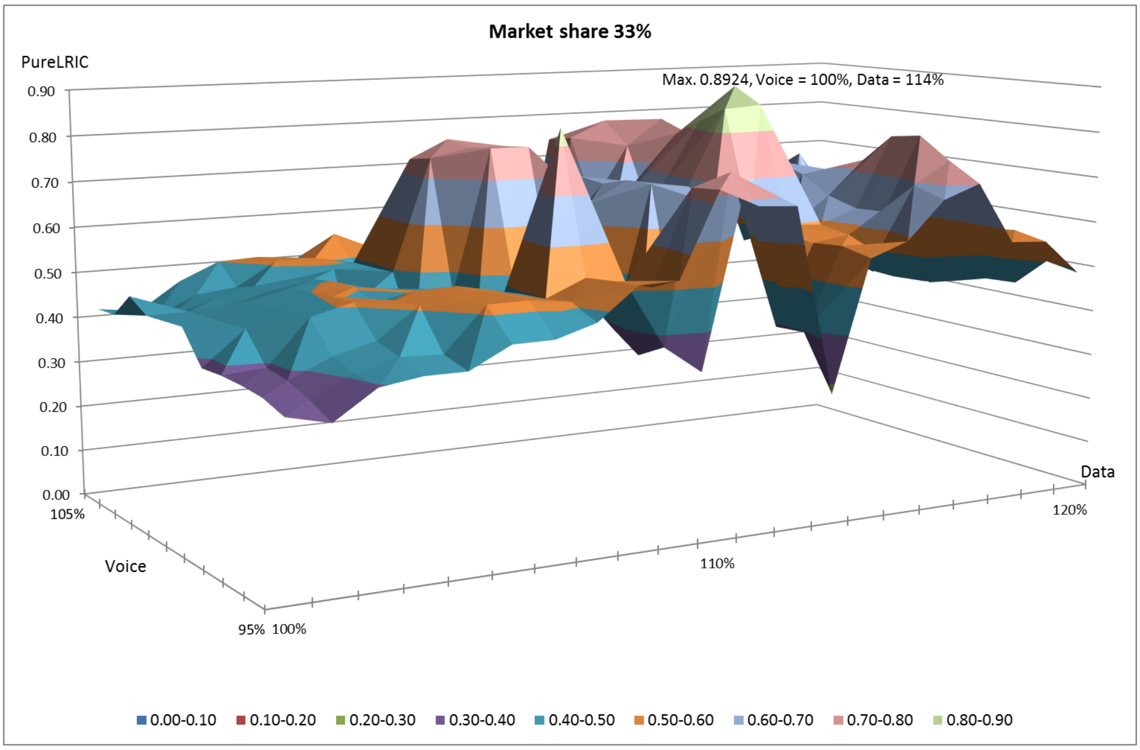


Figure 6-6 : Sensitivity of the pure LRIC costs to a 25% market share [source: ILR, 2016]

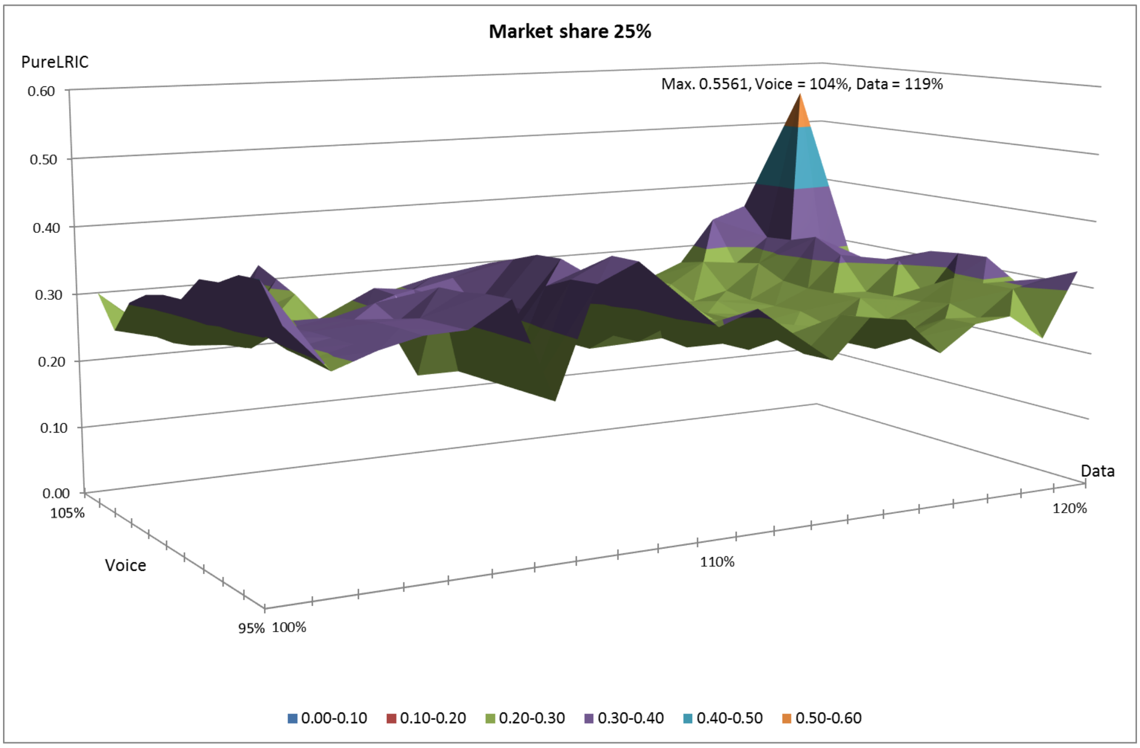
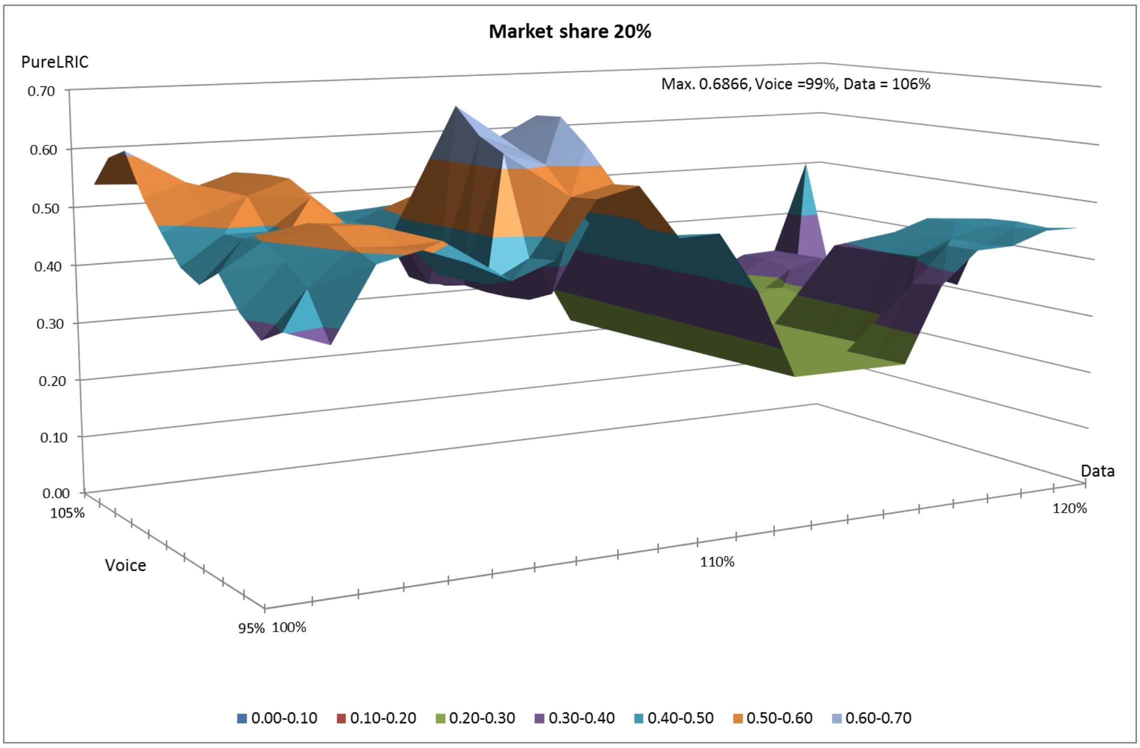


Figure 6-7 : Sensitivity of the pure LRIC costs to a 20% market share [source: ILR, 2016]



(154) In Table 6-2, it could be observed that the highest pure LRIC costs for the provision of mobile call termination correspond to 0.6866 €cts/min. for an operator holding a 20% market share, and to 0.5561 €cts/min. for a 25%-operator. However, these maximum values are related to demand settings varying from the base case. In particular, the maximum value in the case of an operator having a 20% market share is the result of the demand setting of voice traffic = 100% and data traffic = 113%. With regard to a market with 4 players, the demand setting is as follows: voice traffic = 104% and data traffic = 119%.

(155) Furthermore, the results of considering the demand setting of the maximum value for the HEO, i.e. voice traffic = 100% and data traffic = 114%, as well as a variation of the market share are represented in Table 6-2.

Table 6-2 : Sensitivity of the pure LRIC costs to the market share [source: ILR, 2016]

Market share (%)	Mobile call termination (minutes)	Maximum value		Value resulting of voice = 100% and data = 114%	
		Cost (€cts/min)	Variation (%)	Cost (€cts/min)	Variation (%)
33%	153 456 358	0.8924	-	0.8924	-
25%	115 092 268	0.5561	-37.68	0.2377	-73.36
20%	92 073 815	0.6866	-23.06	0.0791	-91.14

(156) By changing the market share, the whole demand of the HEO is also modified. Thus, the resulting costs significantly vary from the initial maximum value of 0.8924 €cts/min.

6.2 Sensitivity to the network characteristics

6.2.1 Sensitivity to the technology

(157) The Long Term Evolution (LTE) technology, a 4G radio access technology, has evolved over the last years and has been partially deployed by the mobile network operators in Luxembourg. Thus, it is appropriate to check the sensitivity of the cost of call termination with respect to a network without LTE technology. The corresponding results are shown in Figure 6-8 and Figure 6-9.

Figure 6-8 : Sensitivity of pure LRIC costs to the presence of LTE technology, i.e. base case [source: ILR, 2016]

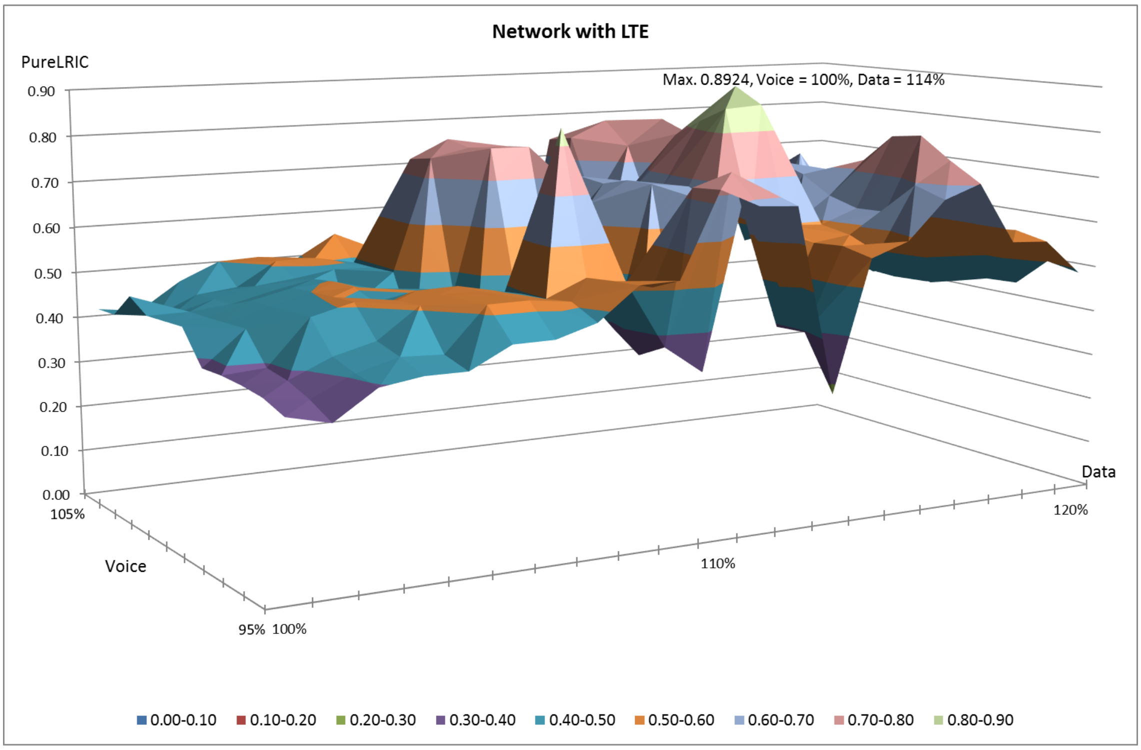
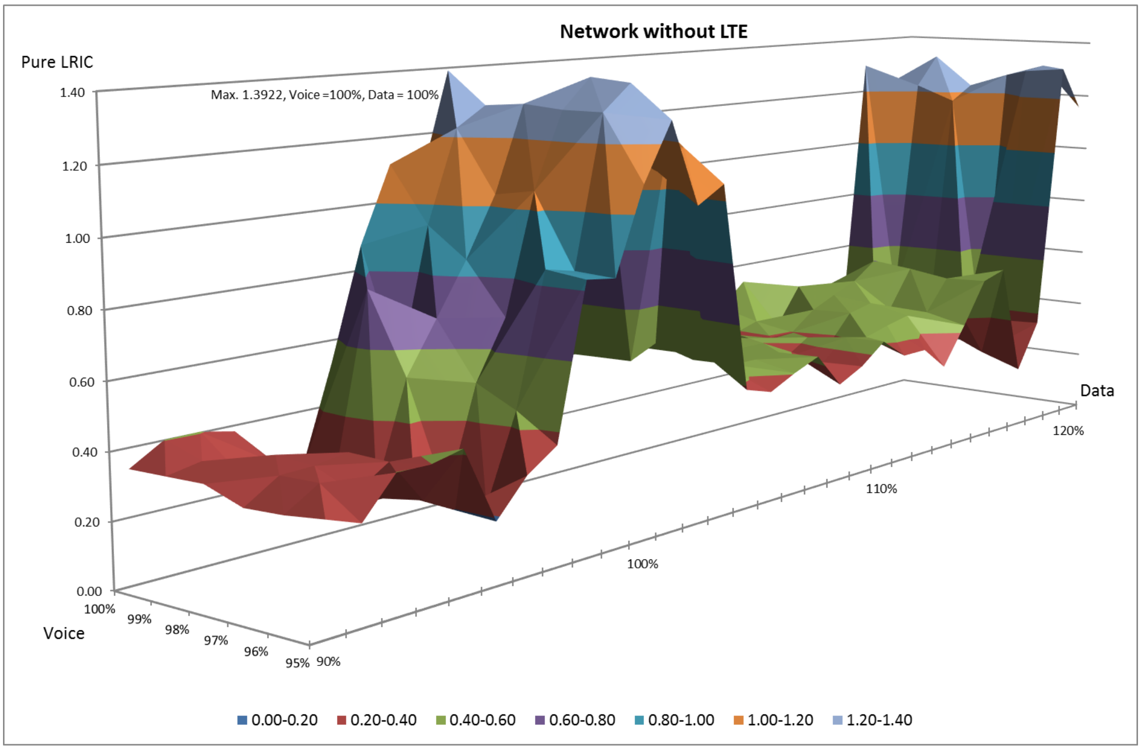


Figure 6-9 : Sensitivity of pure LRIC costs to the absence of LTE technology [source: ILR, 2016]



(158) It could be observed, in Table 6-3, that the highest pure LRIC cost for the provision of mobile call termination equals 1.3922 €cts/min. by considering a radio access network without LTE technology. However, this maximum value is related to a demand setting varying from the base case. In particular, the maximum value is the result of the demand setting voice traffic = 100% and data traffic = 100%.

(159) Moreover, the results of considering the demand setting of the highest value for the HEO, i.e. voice traffic = 100% and data traffic = 114%, as well as a network without LTE technology are represented in Table 6-3.

Table 6-3 : Sensitivity of pure LRIC costs to the absence of LTE [source: ILR, 2016]

Technology	Maximum value		Value resulting of voice = 100% and data = 114%	
	Cost (€cts/min)	Variation (%)	Cost (€cts/min)	Variation (%)
Network with LTE	0.8924	0.00	0.8924	-
Network without LTE	1.3922	56.01	0.2721	-69.51

(160) As the network elements are technology-dependent, a completely different network is dimensioned and the related network costs significantly vary. Furthermore, the effect of the demand assumptions on pure LRIC costs is different as in the base case.

6.2.2 Sensitivity to the consideration of VoLTE

(161) By considering the technological evolution in mobile networks, it is appropriate to assess the potential effect of considering a part of voice traffic handled over LTE. Thus, besides of the base case, ILR also considers three different scenarios how voice traffic is distributed with regard to VoLTE:

- 100% over 2G+3G and 0% over VoLTE, i.e. base case ;
- 90% over 2G+3G and 10% over VoLTE ;
- 80% over 2G+3G and 20% over VoLTE ;
- 70% over 2G+3G and 30% over VoLTE.

(162) The corresponding results are plotted in Figure 6-10 to Figure 6-13.

Figure 6-10 : Sensitivity of the cost of the pure LRIC costs to the distribution of voice traffic, 100% over 2G+3G and 0% over VoLTE, i.e. base case [source: ILR, 2016]

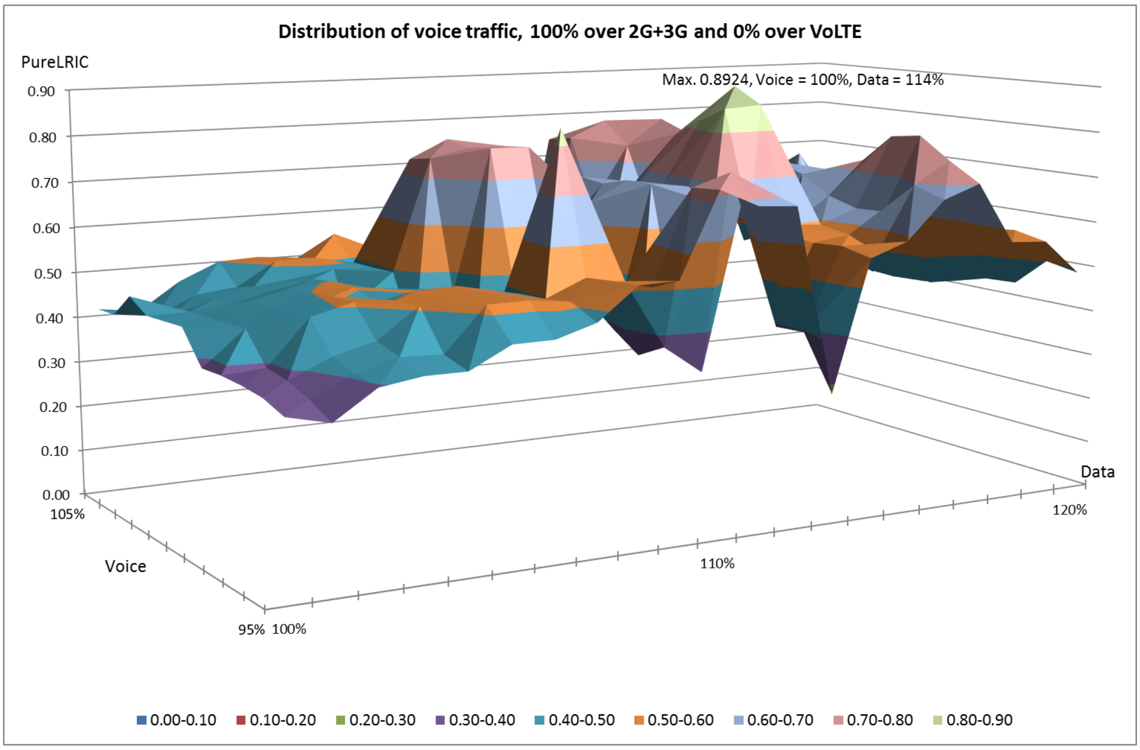


Figure 6-11 : Sensitivity of the cost of the pure LRIC costs to the distribution of voice traffic, 90% over 2G+3G and 10% over VoLTE [source: ILR, 2016]

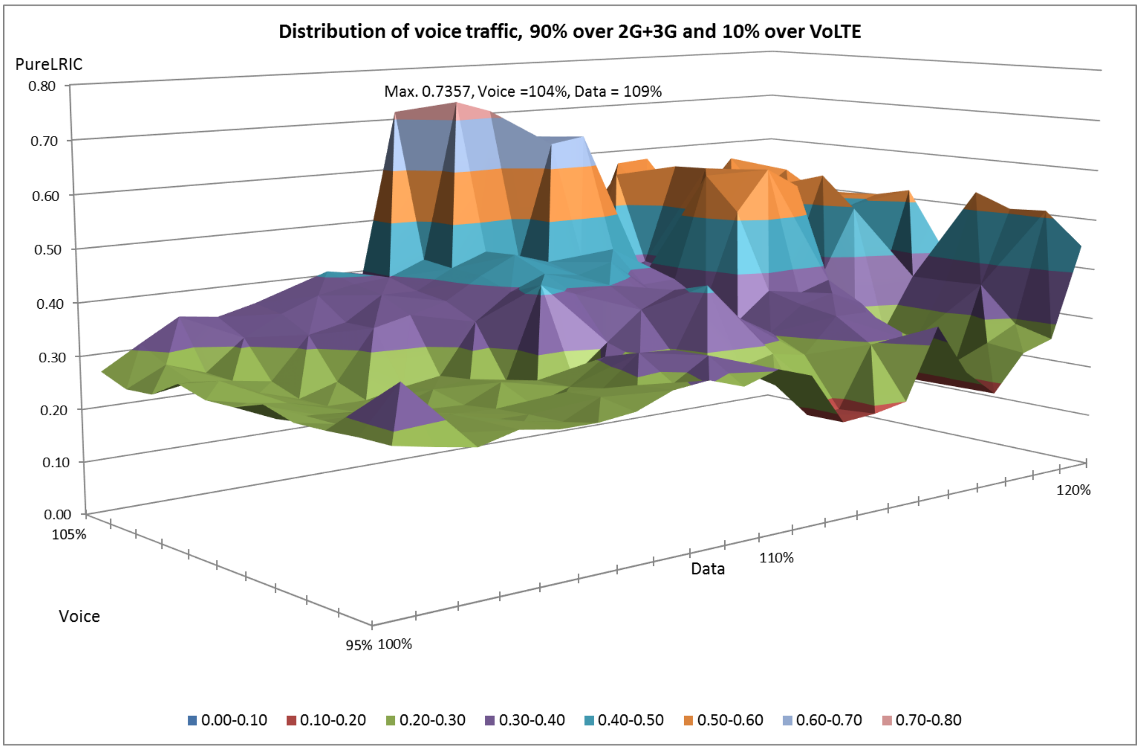


Figure 6-12 : Sensitivity of the cost of the pure LRIC costs to the distribution of voice traffic, 80% over 2G+3G and 20% over VoLTE [source: ILR, 2016]

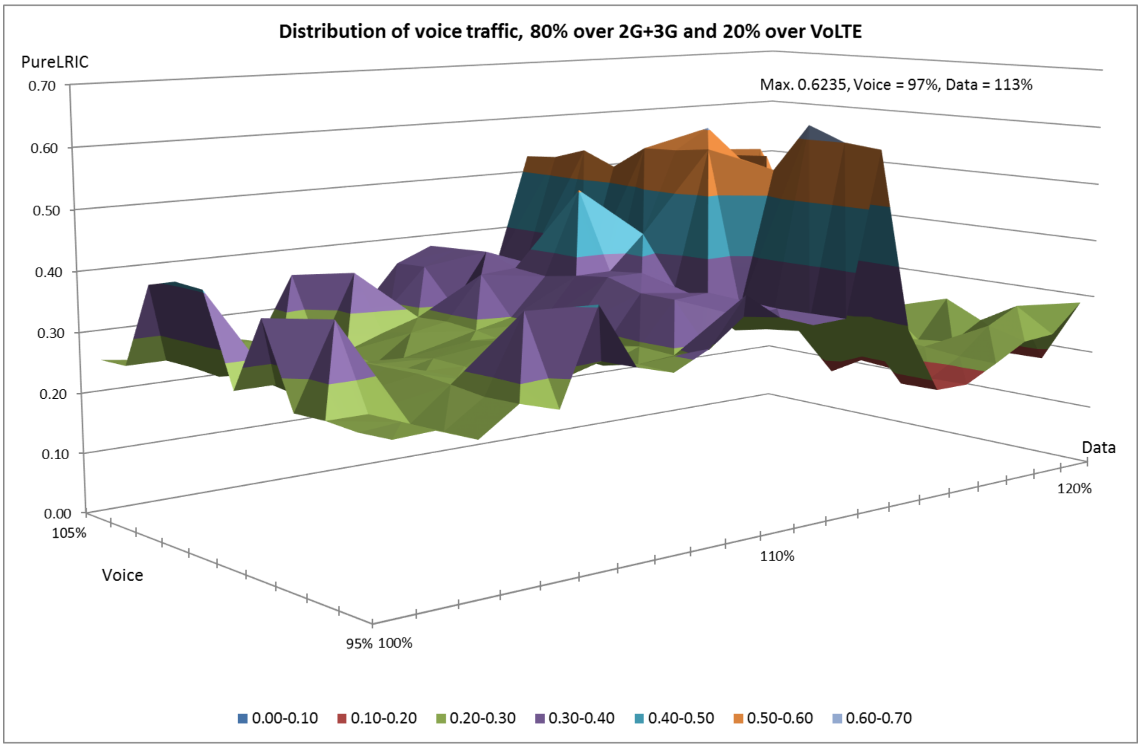


Figure 6-13 : Sensitivity of the pure LRIC costs to the distribution of voice traffic, 70% over 2G+3G and 30% over VoLTE [source: ILR, 2016]

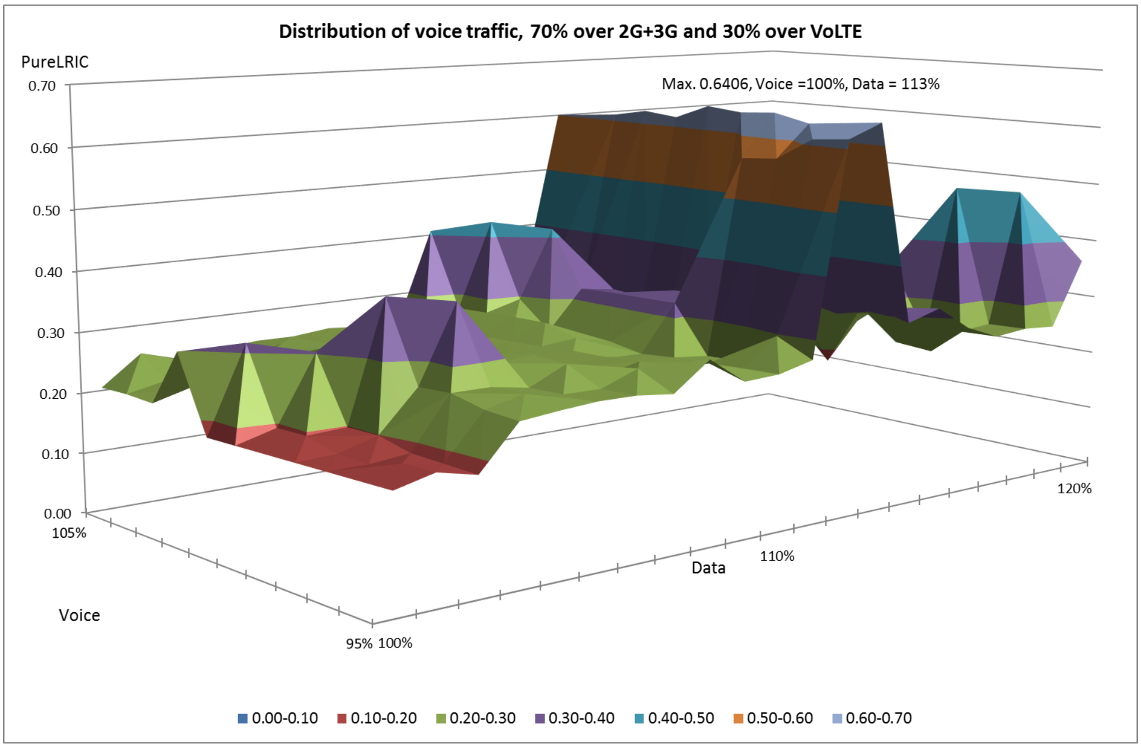


Table 6-4 : Sensitivity of the pure LRIC costs to the distribution of voice traffic [source: ILR, 2016]

Distribution of total voice traffic	Maximum value		Value resulting of voice = 100% and data = 114%	
	Cost (€cts/min)	Variation (%)	Cost (€cts/min)	Variation (%)
100% over 2G+3G - 0% over VoLTE	0.8924	0.00	0.8924	-
90% over 2G+3G - 10% over VoLTE	0.7357	-17.56	0.5163	-42.14
80% over 2G+3G - 20% over VoLTE	0.6235	-30.13	0.2698	-69.77
70% over 2G+3G - 30% over VoLTE	0.6406	-28.22	0.2827	-68.32

(163) The distribution of total voice traffic between different technologies, in particular 2G and 3G as well as VoLTE, with respect to the HEO's demand setting, results in a significant decrease of the costs of mobile call termination (Table 6-4). This is due to the fact that the VoLTE technology is more efficient than the 2G and 3G technologies.

6.3 Sensitivity to economic parameters

6.3.1 Sensitivity to the gross replacement costs

(164) The gross replacement costs (GRC) are considered as important input data in the model used by ILR. Therefore, it is appropriate to analyse the impact on the model results by changing these costs.

(165) Changes in gross replacement costs could be related to the consideration of different network elements, such as less or more powerful elements.

(166) Figure 6-14 outlines the impact on the pure LRIC costs of mobile call termination by varying the unit GRC from -50% to +50%.

Figure 6-14 : Sensitivity of the pure LRIC costs to the gross replacement costs [source: ILR, 2016]

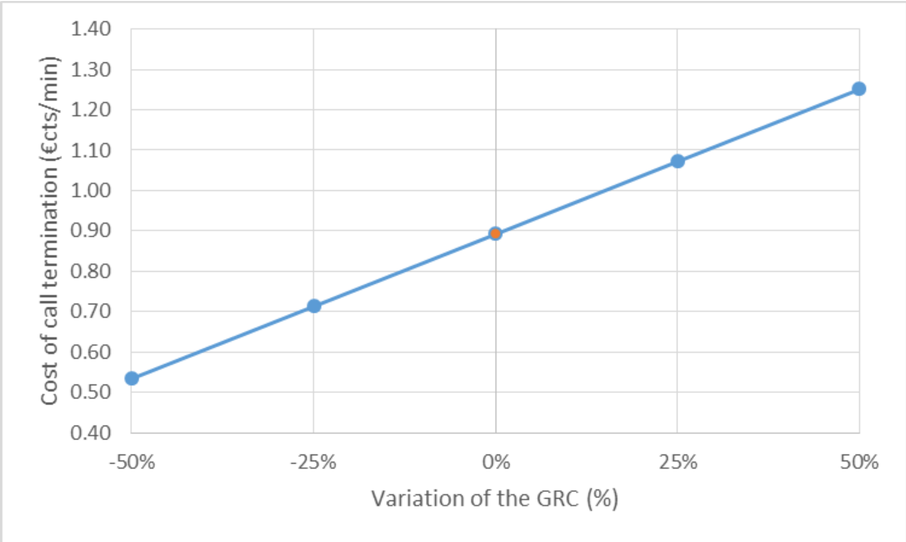


Table 6-5 : Sensitivity of the pure LRIC costs to the gross replacement costs - Extracts [source: ILR, 2016]

Variation of the gross replacement costs (%)	Cost of mobile call termination (€cts/min)	Variation of the cost of mobile call termination (%)
-50	0.5338	-40
0	0.8924	-
50	1.2510	40

(167) A positive linear relationship between the pure LRIC costs and the unit GRC of the network elements could be observed. Indeed, the network becomes more expensive by considering equipment with higher investment costs, and vice versa. Hence, the correct functioning of the model is confirmed.

6.3.2 Sensitivity to the cost of capital (WACC)

(168) In order to take into account the return an operator gets by investing in its network, ILR considers in its model a pre-tax nominal WACC set to 7.10%.

(169) The impact on the pure LRIC costs of mobile call termination due to a variation of the WACC from -50% to +75% is outlined in Figure 6-15.

Figure 6-15 : Sensitivity of the pure LRIC costs to the cost of capital [source: ILR, 2016]

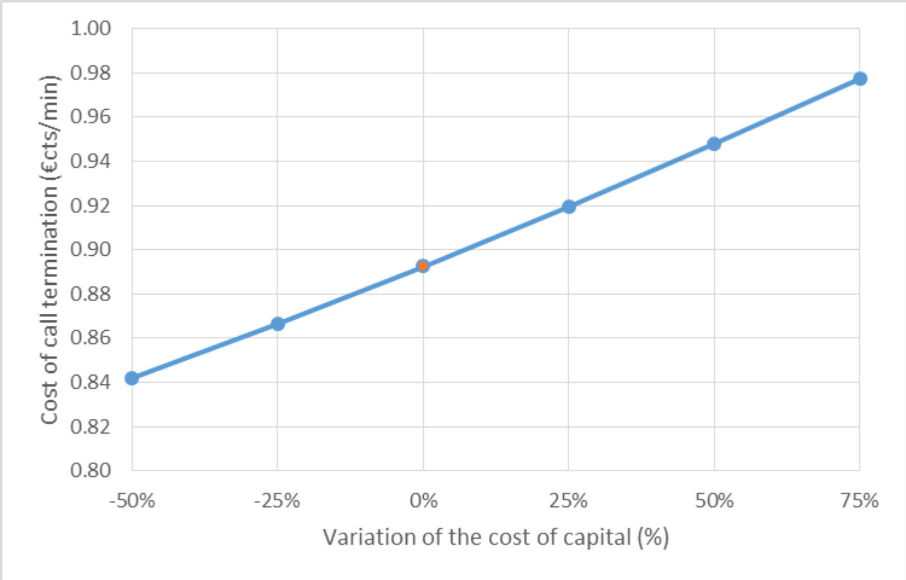


Table 6-6 : Sensitivity of the pure LRIC costs to the cost of capital [source: ILR, 2016]

Variation of the cost of capital (%)	WACC value (%)	Cost of mobile call termination (€cts/min)	Variation of the cost of mobile call termination (%)
-50	3.55	0.8420	-5.65
-25	5.33	0.8667	-2.88
0	7.10	0.8924	-
25	8.88	0.9195	3.04
50	10.65	0.9477	6.20
75	12.43	0.9774	9.52

(170) This analysis shows a positive relationship between the cost of capital and the cost of call termination. The correct functioning of the model is confirmed, as the WACC affects the level of expected return and thus the costs to be recovered by the operator.

6.3.3 Sensitivity to the operational expenditure (OPEX)

(171) This sensitivity analysis is performed with regard to the network related OPEX as well as non-network related OPEX.

(172) Figure 6-16 and Table 6-7 outline the impact of a variation of operational expenditure (from -50% to +50%) on the cost of mobile call termination.

Figure 6-16 : Sensitivity of the pure LRIC costs to the operational expenditure [source: ILR, 2016]

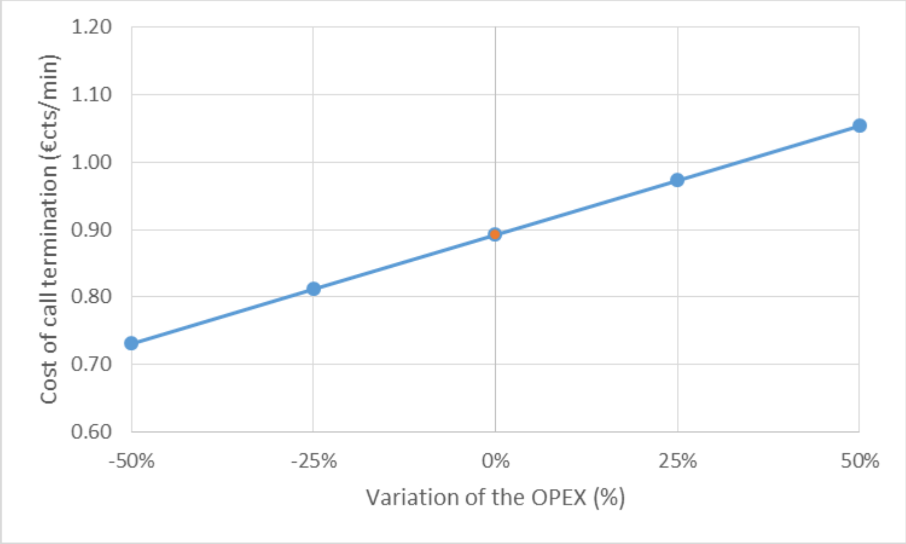


Table 6-7 : Sensitivity of the pure LRIC costs to the operational expenditure - Extracts [source: ILR, 2016]

Variation of the operational expenditure (%)	Cost of mobile call termination (€cts/min)	Variation of the cost of mobile call termination (%)
-50	0.7310	-18
0	0.8924	-
50	1.0538	18

(173) This analysis shows a positive linear relationship between the operational expenditure and the cost of mobile call termination. Indeed, the total costs of the network and thus the cost per minute of call termination raise due to an increase in operational expenditure, and vice versa. Hence, the correct functioning of the model is confirmed.

6.4 Conclusion

(174) By performing these sensitivity analyses, ILR identified the key factors affecting the costs of the provision of mobile wholesale call termination incurred by the hypothetical efficient operator.

(175) With regard to the input assumptions significantly impacting the network dimensioning and thus the corresponding costs, it is worth mentioning the demand of the services, the distribution of voice traffic over LTE, the market share of the operator, as well as the network technology (absence of LTE). Furthermore, the investment costs of the network elements have a considerable effect on the costs of call termination.

(176) Finally, the reliability of the input data as well as the correct functioning of the model are confirmed by the respective sensitivity checks.

7 Appendix A

7.1 Population density, zones and cell hubs

(177) For the radio access network modelling process, the national territory of Luxembourg is divided into zones. Within each of these zones, homogeneous conditions are assumed to apply so that a corresponding cell deployment can be performed. In addition, the resulting zones form the first level of aggregation regarding the whole network, over which the incoming and the outgoing traffic from the base stations are carried. The process of determining the zones is described in the reference document[4]. The aggregation network connects the base stations with the controllers. With regard to the physical network, it is useful to divide the aggregation network into two separate parts: (a) connections from the individual cell sites of a zone to a central location, cell hub, which represents the first concentration point of the mobile radio network, and (b) the connections of the cell hubs to a corresponding controller location (BSC in 2G and RNC in 3G). In addition, controller locations are considered as part of the aggregation network in the dimensioning process.

Figure 7-1 : Zones and cell hubs of the hypothetical efficient mobile operator in Luxembourg [source: ILR, 2016]

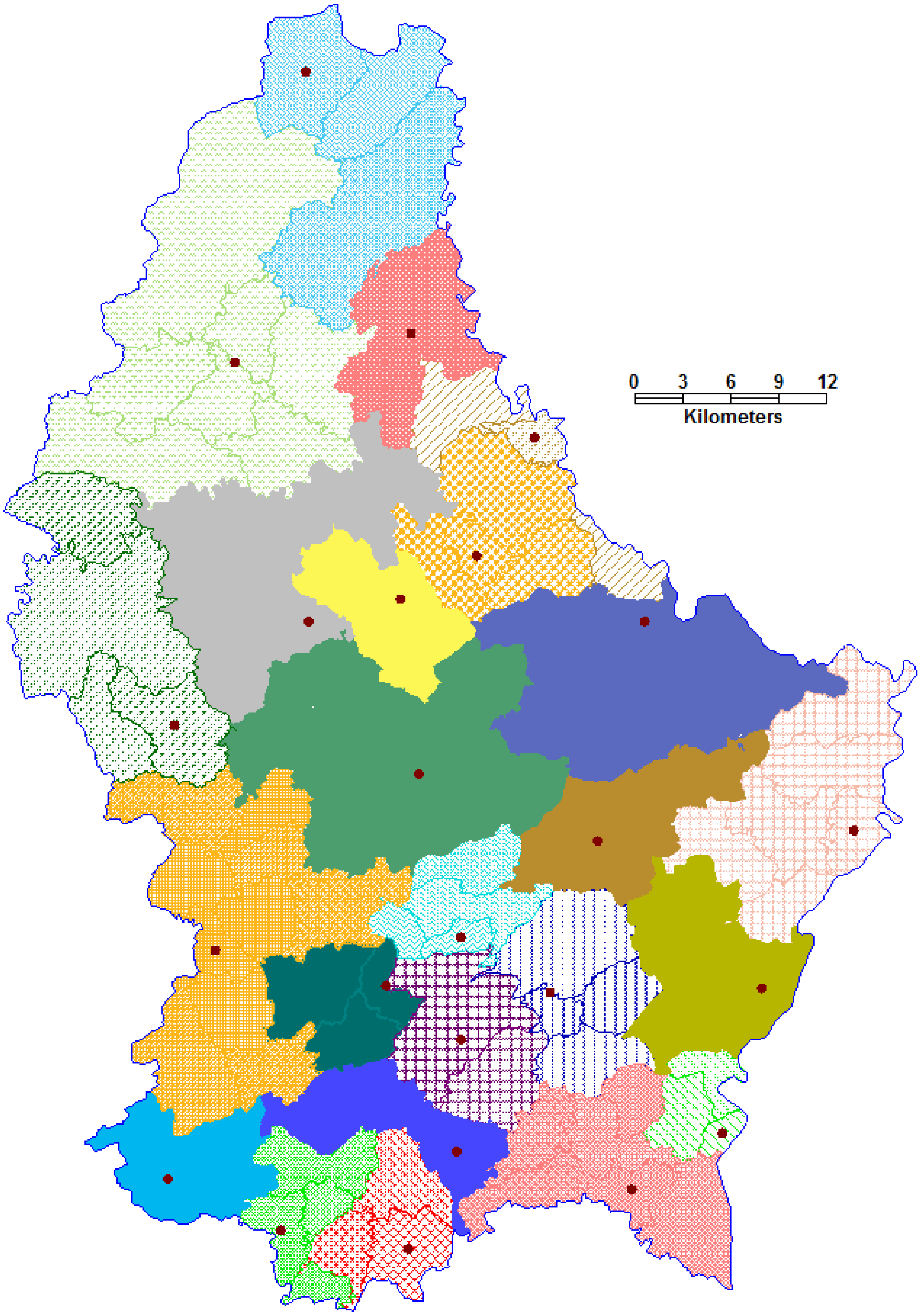
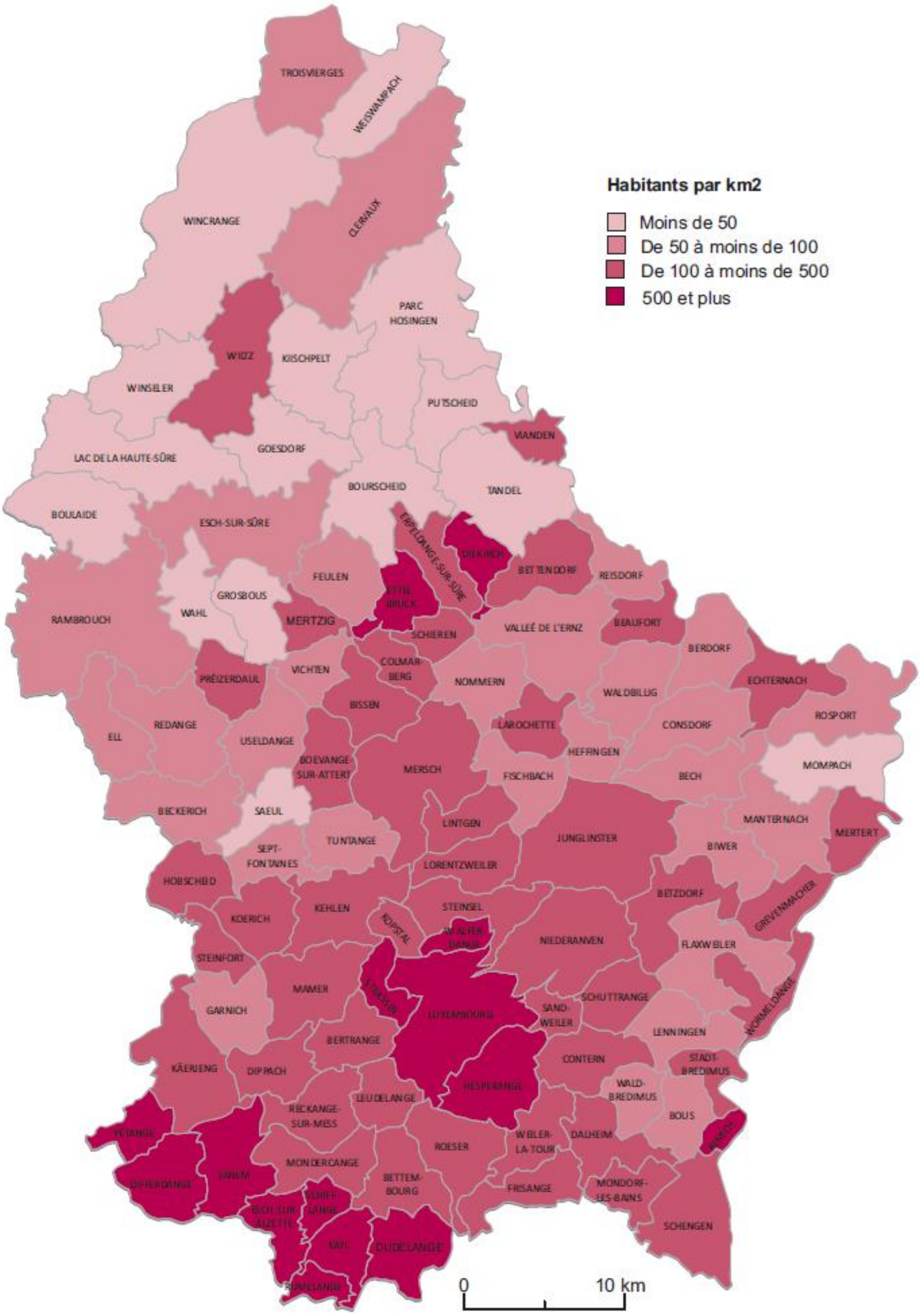


Figure 7-2 : Population density in Luxembourg on 1st January 2016 [source: Statec, 2016]



Source: Statec

7.2 Input Parameters

Table 7-1 Gross replacement costs considered as input in the model (in EUR) [source: ILR, mobile cost model, 2016]

BTS / NodeB / e-NodeB	Average investment
Macrocell – Construction per site	103 036
Macrocell – Hybrid site upgrade	41 088
Microcell – Construction per site	79 568
Microcell – Hybrid site upgrade	32 311
Picocell – Construction per site	72 570
Picocell – Hybrid site upgrade	29 518
GSM/EDGE equipment	**Average investment per unit**
Macrocell 1-sector BTS equipment	13 226
Macrocell 2-sector BTS equipment	16 961
Macrocell 3-sector BTS equipment	20 952
Microcell 1-sector BTS equipment	13 191
Microcell 2-sector BTS equipment	14 963
Microcell 3-sector BTS equipment	20 431
Picocell 1-sector BTS equipment	12 754
Picocell 2-sector BTS equipment	14 468
Picocell 3-sector BTS equipment	19 755
Pure 2G repeaters for highway and railway tunnels	15 612
Overlay of BTS equipment (2-Band)	18 644
Overlay of BTS equipment (3-Band)	17 523
UMTS/HSPA equipment	**Average investment per unit**
Macrocell NodeB equipment without carriers	16 602
Microcell NodeB equipment without carriers	17 061
Picocell NodeB equipment without carriers	17 049
Macrocell sector	5 287
Microcell sector	4 664
Picocell sector	4 204
Pure 3G repeaters for highway and railway tunnels	8 882
LTE equipment	**Average investment per unit**
Macrocell eNodeB equipment without carriers	22 129
Microcell eNodeB equipment without carriers	23 126
Picocell eNodeB equipment without carriers	24 082
Macrocell sector	8 446
Microcell sector	8 398
Picocell sector	8 454

GSM/EDGE/UMTS/HSPA equipment	
Macrocell NodeB equipment without carriers	
Macrocell 1-sector BTS equipment	23 067
Macrocell 2-sector BTS equipment	25 955
Macrocell 3-sector BTS equipment	29 041
Microcell 1-sector BTS equipment	23 039
Microcell 2-sector BTS equipment	24 410
Microcell 3-sector BTS equipment	28 639
Picocell 1-sector BTS equipment	22 702
Picocell 2-sector BTS equipment	24 027
Picocell 3-sector BTS equipment	28 116
Microcell NodeB equipment without carriers	
Macrocell 1-sector BTS equipment	23 422
Macrocell 2-sector BTS equipment	26 310
Macrocell 3-sector BTS equipment	29 397
Microcell 1-sector BTS equipment	23 395
Microcell 2-sector BTS equipment	24 765
Microcell 3-sector BTS equipment	28 994
Picocell 1-sector BTS equipment	23 057
Picocell 2-sector BTS equipment	24 382
Picocell 3-sector BTS equipment	28 471
Picocell NodeB equipment without carriers	
Macrocell 1-sector BTS equipment	23 413
Macrocell 2-sector BTS equipment	26 301
Macrocell 3-sector BTS equipment	29 387
Microcell 1-sector BTS equipment	23 385
Microcell 2-sector BTS equipment	24 756
Microcell 3-sector BTS equipment	28 985
Picocell 1-sector BTS equipment	23 047
Picocell 2-sector BTS equipment	24 373
Picocell 3-sector BTS equipment	28 461
GSM/EDGE/UMTS/HSPA/LTE equipment	
Macrocell e-NodeB equipment without carriers	
Macrocell 1-sector BTS equipment + Macrocell NodeB equipment without carriers	40 180
Macrocell 1-sector BTS equipment + Microcell NodeB equipment without carriers	40 535
Macrocell 1-sector BTS equipment + Picocell NodeB equipment without carriers	40 526
Macrocell 2-sector BTS equipment + Macrocell NodeB equipment without carriers	43 068
Macrocell 2-sector BTS equipment + Microcell NodeB equipment without carriers	43 423
Macrocell 2-sector BTS equipment + Picocell NodeB equipment without carriers	43 414
Macrocell 3-sector BTS equipment + Macrocell NodeB equipment without carriers	46 155

Macrocell 3-sector BTS equipment + Microcell NodeB equipment without carriers	46 510
Macrocell 3-sector BTS equipment + Picocell NodeB equipment without carriers	46 500
Microcell 3-sector BTS equipment + Macrocell NodeB equipment without carriers	45 752
Microcell 3-sector BTS equipment + Microcell NodeB equipment without carriers	46 107
Microcell 3-sector BTS equipment + Picocell NodeB equipment without carriers	46 098
Picocell 3-sector BTS equipment + Macrocell NodeB equipment without carriers	45 229
Picocell 3-sector BTS equipment + Microcell NodeB equipment without carriers	45 584
Picocell 3-sector BTS equipment + Picocell NodeB equipment without carriers	45 575
Microcell e-NodeB equipment without carriers	
Macrocell 1-sector BTS equipment + Macrocell NodeB equipment without carriers	40 951
Macrocell 1-sector BTS equipment + Microcell NodeB equipment without carriers	41 306
Macrocell 1-sector BTS equipment + Picocell NodeB equipment without carriers	41 297
Macrocell 2-sector BTS equipment + Macrocell NodeB equipment without carriers	43 839
Macrocell 2-sector BTS equipment + Microcell NodeB equipment without carriers	44 194
Macrocell 2-sector BTS equipment + Picocell NodeB equipment without carriers	44 185
Macrocell 3-sector BTS equipment + Macrocell NodeB equipment without carriers	46 925
Macrocell 3-sector BTS equipment + Microcell NodeB equipment without carriers	47 281
Macrocell 3-sector BTS equipment + Picocell NodeB equipment without carriers	47 271
Microcell 3-sector BTS equipment + Macrocell NodeB equipment without carriers	46 523
Microcell 3-sector BTS equipment + Microcell NodeB equipment without carriers	46 878
Microcell 3-sector BTS equipment + Picocell NodeB equipment without carriers	46 869
Picocell 3-sector BTS equipment + Macrocell NodeB equipment without carriers	46 000
Picocell 3-sector BTS equipment + Microcell NodeB equipment without carriers	46 355
Picocell 3-sector BTS equipment + Picocell NodeB equipment without carriers	46 346
Picocell e-NodeB equipment without carriers	
Macrocell 1-sector BTS equipment + Macrocell NodeB equipment without carriers	41 690
Macrocell 1-sector BTS equipment + Microcell NodeB equipment without carriers	42 045
Macrocell 1-sector BTS equipment + Picocell NodeB equipment without carriers	42 036
Macrocell 2-sector BTS equipment + Macrocell NodeB equipment without carriers	44 578
Macrocell 2-sector BTS equipment + Microcell NodeB equipment without carriers	44 933
Macrocell 2-sector BTS equipment + Picocell NodeB equipment without carriers	44 924
Macrocell 3-sector BTS equipment + Macrocell NodeB equipment without carriers	47 665
Macrocell 3-sector BTS equipment + Microcell NodeB equipment without carriers	48 020
Macrocell 3-sector BTS equipment + Picocell NodeB equipment without carriers	48 010
Microcell 3-sector BTS equipment + Macrocell NodeB equipment without carriers	47 262
Microcell 3-sector BTS equipment + Microcell NodeB equipment without carriers	47 617
Microcell 3-sector BTS equipment + Picocell NodeB equipment without carriers	47 608
Picocell 3-sector BTS equipment + Macrocell NodeB equipment without carriers	46 739
Picocell 3-sector BTS equipment + Microcell NodeB equipment without carriers	47 094
Picocell 3-sector BTS equipment + Picocell NodeB equipment without carriers	47 085

TRX and carrier	Average investmentt
TRX (2G)	1 886
Carrier (3G)	2 220
License cost	
License cost per year (800 MHz), in 2.5 MHz blocks	93 750
License cost per year (900 MHz), in 2.5 MHz blocks	93 750
License cost per year (1800 MHz), in 2.5 MHz blocks	93 750
License cost per year (2100 MHz), in 5 MHz blocks	120 000
License cost per year (2600 MHz), in 5 MHz blocks	120 000
Administrative licences cost per year	0
BSC / RNC	
Average investment for site construction (BSC), in €	86 437
Average investment for site construction (RNC), in €	86 437
Hardware investment per BSC unit of type	191 972
Software investment per BSC unit of type	173 811
Hardware investment per RNC unit of type	362 907
Software investment per RNC unit of type	681 781

BSC/RNC Ports	1	2
Average investment per E1 port installed at the BSC	2 190	2 190
Average investment per type 1 port installed at the RNC i (i=1 to 2)	935	1 775
Average investment per type 2 port installed at the RNC I (i=1 to 2)	3 150	4 025
Average investment per type 3 port installed at the RNC i (i=1 to 2)	3 200	4 025
Average investment per type 4 port installed at the RNC i (i=1 to 2)	3 200	4 025
PCU (only for BSC)	**1**	**2**
Average investment per packet control unit installed at BSC unit of type i: (i=1 to 2)	11 250	13 200
Core Site		
Average investment per core site	763 633	
MSC call server		
Average investment for MSC call server unit	1 363 704	
MediaGateway with integrated SBC		
Investment in material and installation per MediaGateway	558 333	
Average investment per type 1 port	2 274	
Average investment per type 2 port	7 449	
Investment per E1 port, facing interconnection at Media Gateway	707	
Investment per Ethernet based type 1 port, facing interconnection	2 074	
Investment per Ethernet based type 2 port, facing interconnection	6 949	
Label Edge Router		
Investment in material and installation per LER unit of type i	125 556	
Average investment per type 1 port	1 178	
Average investment per type 2 port	9 411	
Average investment per type 3 port	21 248	
Average investment per type 4 port	40 987	

Label Switch Router		
Investment in material and installation per LSR unit of type i	146 333	
Average investment per type 1 port	1 611	
Average investment per type 2 port	27 111	
Average investment per type 3 port	38 915	
Average investment per type 4 port	55 653	
HLR		
Investment in material and installation per HLR functionality	2 395 633	
Authentication centre	**included in the HLR**	
EIR	**included in the HLR**	
SMSC		
Investment in material and installation per SMSC unit	2 104 772	
SGSN		
Investment in material and installation, per SGSN unit	1 165 578	
Average investment per type 1 port	4 500	
Average investment per type 2 port	5 000	
GGSN		
Investment in material and installation per GGSN unit	1 462 222	
Average investment per type 1 port	1 325	
Average investment per type 2 port	6 650	
IC Interface		
Investment in interconnection interface	562 500	
Network management system		
Investment in Network management system	1 903 285	
Intelligent network (IN)		
Investment in Intelligent network	2 662 957	
Aggregation systems	**1**	**2**
Investment in Aggregation systems of type i (i=1 to 2)	21 023	39 542
Average investment per type 1 port	215	265
Average investment per type 2 port	825	1 000
Average investment per type 3 port	5 425	6 200
Average investment per type 4 port	5 425	6 200
Radio links (i=1 to 2)	**1**	**2**
Licence charge per radio link (one off investment)	99.50	
Annual price per 25 MHz (frequency cost for radio links)	800.00	
Investment per radio link of type i (cell site - hub)	9 350	9 600
Investment per radio link of type i (hub - controller)	10 325	10 950
Investment per radio link of type i (controller - core)	9 100	9 100
Investment per repeater for radio link of type i	7 475	7 975
Leased lines (i=1 to 2)	**1**	**2**
Annual charge for the provision of a local link of type i	2 385	6 675
Annual charge for the provision of a regional link of type i	2 884	6 600
Annual charge for the provision of a long distance link of type i	3 586	6 550

8 Appendix B – Network costs with and without mobile call termination

Table 8-1 : Difference between network costs with and without mobile call termination [source: ILR, 2016]

Network element	Total cost per element with termination (€)	Total cost per element without termination (€)	Difference (€)
Sites and radio equipment	12 530 253	11 891 910	638 344
BSC/RNC	3 487 157	3 041 610	445 547
PCU	7 664	7 664	-
MSC call server	853 611	853 611	-
Media Gateway	394 296	390 704	3 592
LER	403 539	369 340	34 198
LSR	105 596	105 596	-
HLR	1 501 900	1 501 900	-
AUC	-	-	-
EIR	-	-	-
SMSC	-	-	-
SGSN	737 792	777 972	-40 181
GGSN	1 262 254	1 262 254	-
IC interface	414 959	403 190	11 769
NM system	577 583	577 583	-
IN	1 837 947	1 837 947	-
AN: Aggregation systems	371 713	383 707	-11 994
BN: Aggregation systems	391 975	377 796	14 179
CN: Aggregation systems	26 828	25 333	1 496
Site - Hub links	1 228 036	1 238 734	-10 697
Hub-Controller links	385 132	377 095	8 036
Controller-core links	-	-	-
Core-core links	11 528	11 528	-
Core sites	179 769	179 769	-
SAE GateWay	1 784 104	1 780 346	3 758
MME	772 800	772 800	-
IMS GateWay	-	-	-
IMS	-	-	-
Upgrade MIMO	109 997	109 997	-
Upgrade CA	30 263	30 263	-
Total	**29 406 696**	**28 308 648**	**1 098 048**
Non-network costs			**271 403**

Note: It is possible to get negative costs for different network elements. This is due to the fact that the capacity of these network elements depends on the demand of the network and then the most cost efficient solution is taken into account. Thus, by considering even more minutes, some network elements could cost less in some cases.

9 Appendix C – List of Abbreviations

2G	2nd Generation of mobile network technology, collective name for GSM, GPRS and EDGE
3G	3rd Generation of mobile network technology, collective name for UMTS und HSPA
3GPP	3rd Generation Partnership Project
4G	4th Generation of mobile network technology
AMR	Adaptive Multi Rate
AMR-WB	Wide-Band Adaptive Multi Rate (Codec)
AN	Access Network
ATM	Asynchronous Transfer Mode
AuC	Authentication Centre
BH	Busy Hour
BN	Backhaul Network
bps	bits per second, abbreviation of the standard bit rate unit bit/s
BS	Base Station
BSC	Base Station Controller
BSS	Base Station System
BTS	Base Transceiver Station
CA	Carrier Aggregation
CDR	Call Data Record
CN	Core Network
CS	Circuit Switched
DL	Downlink
E1	Primary Rate Interface with a gross data rate of 2048 kbit/s, subdivided into 32 channels of 64 kbit/s
EDGE	Enhanced Data Rates for GSM Evolution
EIR	Equipment Identity Register
eNodeB	(evolved NodeB) Base station in 4G LTE
ETSI	European Telecommunication Standards Institute
G-MSC	Gateway-MSC
GB (also GByte)	Gigabyte, equals 10^9 or 1.000.000.000 Byte
GGSN	Gateway GPRS Support Node
GiB	Gibibyte, equals 1024^3 or 1.073.741.824 Byte
GMSK	Gaussian Minimum Shift Keying
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communication
GW	Gateway
HLR	Home Location Register
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access, collective name for HSDPA and HSUPA
HSUPA	High Speed Uplink Packet Access
IC	Interconnection
IM	Instant Messaging

IMS	IP Multimedia Subsystem
IN	Intelligent Network
IP	Internet Protocol
ISDN	Integrated Services Digital Network
Iu-Interface	Interface in UMTS between RNC and core network
kbit/s	Kilobit per Second
LER	Label Edge Router
LSR	Label Switch Router
LTE	Long Term Evolution, a 4G radio access technology
MGW	Media Gateway
MIMO	Multiple Input Multiple Output
MME	Mobility Management Entity
MMS	Multimedia Messaging Service
MSC	Mobile Switching Center
MSC-S	MSC (Call) Server
MTR	Mobile Termination Rate
NGN	Next Generation Network
NM	Network Management
Node B	Base station in UMTS
PCU	Packet Control Unit
PSTN	Public Switched Telephone Network
QoS	Quality of Service
SAE	System Architecture Evolution
SAE-GW	System Architecture Evolution Gateway
RNC	Radio Network Controller
SGSN	Serving GPRS Support Node
SMS	Short Message Service
SMSC	Short Message Service Center
TDM	Time Division Multiplex
TRX	Transceiver, from “transmitter” and “receiver”
UL	Uplink
UMTS	Universal Mobile Telecommunications System
UTRAN	Universal Terrestrial Radio Access Network
VLR	Visitor Location Register
VoLTE	Voice over LTE
WACC	Weighted Average Cost of Capital
WLAN	Wireless Local Area Network

10 Appendix D – Impact assessment

(178) The ILR has executed an impact analysis with regard to the proposed MTR ceiling adaptation.

(179) The method used was on the one hand, to first compare the provided estimation of minutes on their respective networks by the various operators for the period 2016 with the realised figures of the first half of 2016. The ILR has doubled the realised figures of the first half in order to account for a full year.

(180) In order to take account of the potential bias of the provided estimated volumes, the ILR has also analysed the impact of an adapted volume estimation. For this exercise, the ILR has weighted the volumes by the realised bias regarding the 2016 values.

(181) On the other hand, the ILR has compared the impact of the proposed adaption on the estimated minutes terminated for the whole period 2017-2018 provided by the operators in the process of the determination of the price cap for the provision of mobile call termination.

(182) What is more, the ILR has analysed the potential financial impact of the proposed adaptation of the MTR ceiling for the operator. The analysis was based on the provided estimations of incoming minutes for the two-year period 2017-2018 and an extrapolation of the actual outgoing minutes for the first half of 2016 to the 2017 and 2018 estimations.

(183) The potential financial impact (i.e. the balance between the mobile termination amounts paid to and received from other operators) for the whole period of 2017-2018 varies between a negative balance of EUR 243k to an excess of EUR 1k.

10.1 EPT (confidential)

10.2 JOIN (confidential)

10.3 Orange (confidential)

10.4 Tango (confidential)