MTR Model Specification Document for Ireland.

Final Report for ComReg

23 October 2015

Accompanies Final MTR Model

This report has been prepared on the basis of the limitations set out in the engagement letter and the matters noted in the Important Notice From Deloitte on page 1.

Contents

Important Notice from Deloitte

This Final Model Specification Document, supporting the financial model described herein, has been prepared by Deloitte (“Deloitte”) for the Commission for Communications Regulation (“ComReg”) in accordance with the contract between Deloitte and ComReg dated 26th June 2013 (the “Contract”), and the supplemental contract dated 7th October 2014.

The Final Model Specification Document is designed to support the determination of appropriate maximum wholesale mobile termination rates to be charged by mobile service providers who have been designated by ComReg with significant market power in the relevant mobile voice call termination markets in Ireland. It is not intended for use by any party other than ComReg or for any other purpose. If the Final Model Specification Document is updated or amended in any way by any party other than Deloitte, then Deloitte will accept no responsibility or liability or duty of care to any party for the Final Model Specification Document (as so updated or amended) or its associated outputs.

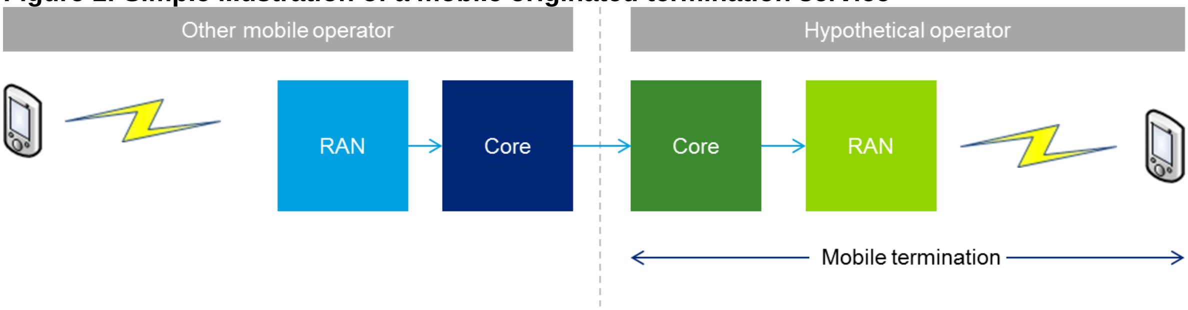
The Final Model Specification Document is provided exclusively for ComReg’s use under the terms of the Contract. No party other than ComReg is entitled to rely on the Final Model Specification Document or Model for any purpose whatsoever and Deloitte accepts no responsibility or liability or duty of care to any party other than ComReg in respect of the Final Model Specification Document and Model and/or any of its contents. If any party other than ComReg chooses to rely on the Final Model Specification Document, it does so at its own risk and without recourse to Deloitte. Any form of disclosure, distribution, copying, reference to, or use of this Final Model Specification Document or the information in it or in any attachments by any party other than ComReg is strictly prohibited and may be unlawful. If you have received this Final Model Specification Document in error, please notify ComReg, delete the Report and destroy any copies of it.

For the avoidance of doubt, in the absence of formal contractual agreement to the contrary, neither Deloitte, nor its partners, principals, members, owners, directors, staff and agents and in all cases any predecessor, successor or assignees shall be liable for losses, damages, costs or expenses arising from or in any way connected with the use of the Final Model Specification Document by any party other than ComReg.

1 Introduction

The Irish telecommunications regulator, the Commission for Communications Regulation ("ComReg") conducted in 2012 a market review of Markets 3 and 7 (fixed and mobile termination services) as defined by the European Commission (EC). As set out in the Decision D12/12, ComReg determined that fixed and mobile termination rates in Ireland should be set, going forward, on the basis of a bottom-up pure LRIC (BU-LRIC) model, consistent with the 2009 EC's Termination Rate Recommendation (2009 EC Recommendation).[1] ComReg has appointed Deloitte to develop the BU-LRIC model for the estimation of mobile termination pure LRIC per minute, to inform the setting of mobile termination rates (MTRs) going forward. Mobile termination is a wholesale service provided by the operator to the subscribers of other networks to terminate voice traffic on its network. A simple illustration is provided below. As presented in section 3.1.2 this terminating service may have originated form another national or international mobile operator or fixed network operator.

Figure 1: Simple illustration of a mobile originated termination service



Source: *Deloitte analysis.*

This document provides a description of the approach taken to construct a BU-LRIC model for estimating the efficient cost of mobile termination services in Ireland.

In particular, this document sets out:

- the approach and principles proposed for the development of the model;
- the inputs and parameters required in the model, and the options available when setting these parameters;
- the calculation steps; and
- the format of the output of the model.

1.1 The structure of this document

The remaining sections of this document are organised as follows:

---

[1] European Commission Recommendation 2009/396/EC.

- Section 2 includes a discussion of modelling principles to be considered when developing a BU-LRIC model and the options available;
- Section 3 presents the structure of the model, including sub-modules, the model calculation flow and the list of model entities;
- Section 4 describes the content of the load module;
- Section 5 describes the content of the network module;
- Section 6 describes the content of the cost module;
- Appendix A presents the route factor matrix used in the model;
- Appendix B presents the VBA code used to run the model;
- Appendix C presents a derivation and simple worked example of the economic depreciation methodology;
- Appendix D presents the definition of the coverage scenario; and
- Appendix E presents a glossary of abbreviations and acronyms used in this report.
- Appendix F presents the an analysis of the drivers of the increase in Pure LRIC since ComReg Supplementary Consultation 15/19

2 General Modelling Principles

This section outlines the general principles proposed for the specification of the final BU- LRIC model.

2.1 Form of the modelled operator

The form of the modelled operator is an important conceptual aspect of the model design, which can have a significant impact on the estimated cost profile.

In choosing the form of the operator to be modelled, there are four main choices:

- **Actual operator:** this would involve calculating the cost of the actual operators in the market;
- **Average operator:** under this approach, the volumes, costs and all other inputs of actual operators would be averaged together;
- **Hypothetical efficient new entrant:** this would involve calculating the cost of an operator entering the market in 2013, deploying a network using today's modern technology and network architecture; and
- **Hypothetical efficient existing operator:**[2] under this approach, the modelled operator is assumed to have fully deployed its network in 2003, and to have acquired its hypothetical market share in the same year (discussed below). The starting year of the model has been chosen given the context of the Irish market. This starting year reflects a period in which operators undertook initial network rollout or began major network upgrades. In particular this period also coincides with a time in which Irish network operators commenced 3G network deployment.

Modelling an actual operator is not considered appropriate as this would require separate calculations for each of the network operators, likely leading to asymmetric rates, unless all operators were considered to be efficient. It would also be difficult to ensure consistency in the modelling principles applied to each operator and would require that all operators submit complete datasets to be implemented effectively. This approach would not ensure that only efficiently incurred costs are included, again, unless all operators are considered to be efficient or necessary adjustments are made to reflect the efficient cost of service provision.

For similar reasons, the average operator approach is also not considered appropriate as, unless all operators are considered to be efficient, or sufficient adjustments can be made, the result would not reflect the efficient cost of provision. Furthermore, with regard to network element

---

[2] In previous drafts of the MTR Model Specification Document – specifically the Original MTR Consultation – this definition involved an operator deploying its network and services in 2003 and gradually attaining an efficient market share. Specifically, it involved a gradual increase in market share to 25% in 2007.

dimensioning, using an average of operator data on cost, network element capacity and utilisation may not lead to dimensioning rules that can be calibrated effectively against any operator inputs.

Modelling a hypothetical efficient new entrant would require an assumption about the most efficient technology that would be adopted by a new operator rolling out its network today (for example, it could be assumed that a new operator would not invest in 3G technology, but rather in 4G technology only). However, this might lead to network design and technology assumptions that are very different from those of the operators currently in the market. This would lead to costs being significantly different from those actually incurred by the operators and would limit the range of data that operators in Ireland would be able to contribute. Therefore, this approach has not been adopted in the final model.

For these reasons, the final model has been designed assuming a hypothetical efficient existing operator. This approach is consistent with most of the BU-LRIC models developed by other European NRAs[3] and allows the modelling of efficient costs and scale, whilst at the same time enabling costs and technology assumptions to be closely aligned with those actually faced by the operators currently in the Irish market.

2.2 Market share

The market share assumed for the hypothetical existing operator is an important design principle.

The 2009 EC Recommendation states that the minimum efficient scale that can be assumed in the BU-LRIC model is 20%. However, the Recommendation does not indicate a maximum market share.

As is customary in most BU-LRIC models developed in other jurisdictions[4] a “1/N” approach is used in the final model, where N is the number of operators actually operating in the market. Based on the 2013 Irish market, this approach implies a 25% market share.

Hutchison 3G Ireland’s (H3GI)’s acquisition of O_2 Ireland occurred in 2015, reducing the number of operators to 3, meaning that “1/N” approach would imply a market share of 33%.[5] Despite the acquisition, the revised final model assumes a constant market share throughout the modelled time period. Modelling a market share increase from 25% in 2014 to 33% in 2015 would impact the modelled network, whereby a significant network investment would occur in 2015. Such network investment is not considered a realistic representation of an actual operator’s investments. A constant market share is deemed more appropriate for the purposes of MTR modelling. Market shares of 25% and 33% are both considered for the hypothetical existing operator. ComReg considered the rationale for each and made a decision to assume a 25% market share throughout the modelled time period. This assumption should be reviewed in future decisions.

---

[3] Examples include ANACOM (Portugal), Netherlands (OPTA, now ACM) and Romania (ANCOM).

[4] Examples include Ofcom (UK) and Netherlands (OPTA, now ACM).

[5] As per European Commission’s decision regarding the merger (IP/14/607).

For the purposes of final model specification, N is assumed to equal 4 during the modelled time period between 2003 and 2032.

A hypothetical existing operator is assumed to be modelled in line with the 2009 EC Recommendation. Therefore, the assumed market share in the revised final model has been modified to be consistent with the "1/N" approach for every year that is modelled, i.e. the model is of an established operator that has already achieved minimum efficient scale by the first year of the time horizon of the model, 25% in 2003. The market share assumptions used in the final model are presented below.

Table 1: Market share assumptions

	2003	2004	…	2032
Market share	25%	25%	...	25%

2.3 Network technologies

The BU-LRIC model requires the specification of the modern technology on which the network needs to be designed and dimensioned. The hypothetical existing operator can in principle use a combination of 2G (GSM), 3G (UMTS) and 4G (LTE) technologies in its radio network and a legacy or NGN technology in its core network.

2.3.1 LTE is not explicitly modelled, but considered for data traffic migration

LTE network technology is at early stages of deployment in Ireland.[6] [7] [8] Based on discussions with operators, it is expected that LTE will be almost exclusively used, during the lifespan of this price control period, to carry data traffic and using Circuit Switched FallBack (CSFB) for voice and SMS. Given the focus on voice (and in particular on the increment of terminating voice traffic) for the BU-LRIC model, and the uncertainty of any future migration of voice traffic to LTE, the final model does not explicitly include LTE as a radio technology.

However, LTE is implicitly taken into account in the final model, by assuming migration of data traffic from 2G and 3G to LTE in future years. This is discussed in more detail in section 4.

---

[6] Eircom press release, http://pressroom.eircom.net/press_releases/article/eircom_Group_First_to_Launch_4G_Mobile_in_Ireland/, Retrieved 2014.

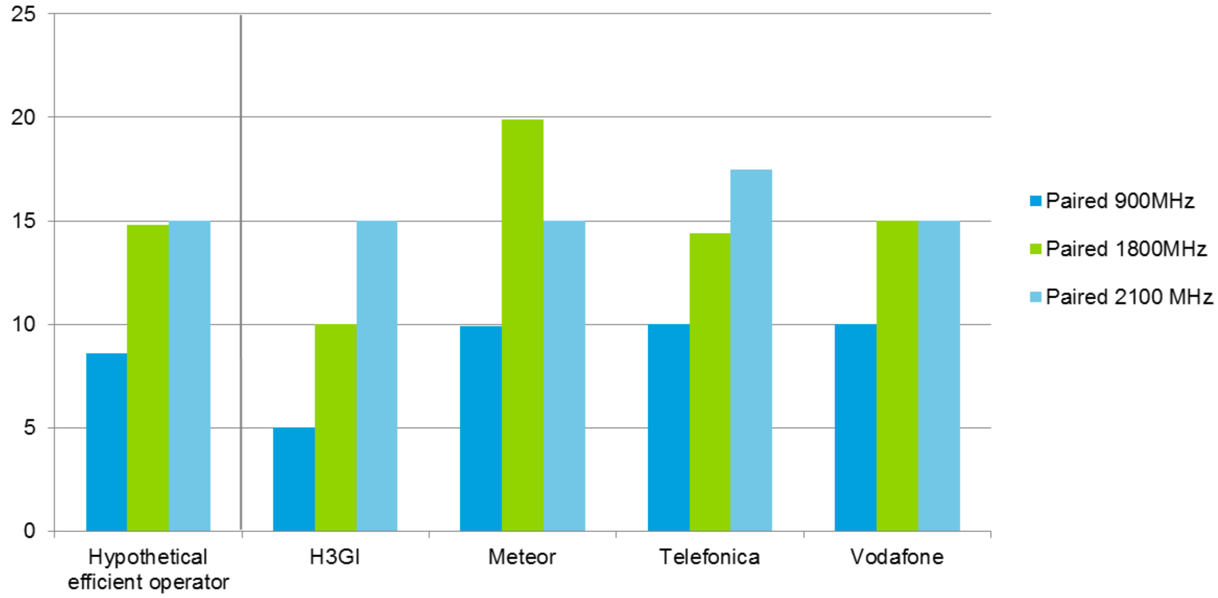
[7] Vodafone press release, http://www.vodafone.ie/aboutus/media/press/show/BAU022109.shtml, Retrieved 2014.

[8] H3GI press release, http://press.three.ie/press_releases/three-ireland-to-launch-comprehensive-4g-offers/, Retrieved 2014.

2.3.2 Spectrum holding

In line with the market share assumptions outlined in section 2.2, the hypothetical existing operator is assumed to hold 900MHz and 1800MHz frequency blocks for 2G (GSM) network provision as well as 900MHz and 2100MHz frequency blocks for 3G (UMTS) in the revised final model.

Figure 2: Paired spectrum holdings 900, 1800 and 2100MHz bands in 2013[9]



Source: *ComReg,*[10] *operators' data request returns and Deloitte analysis*

In 2013 and 2014, 35MHz of paired spectrum in the 900MHz band is available to the Irish operators.[11] Assuming a “1/N” approach (see section 5.1.1 for more information), this implies that 8.6MHz is available to an operator with a 25% market share.[12] 5MHz of paired 900MHz spectrum is assumed to be used for 2G (GSM) until 2013 and will be used for 3G (UMTS) in 2013 until the end of the modelled time horizon.[13] Thus, 3.6MHz of paired spectrum in the 900MHz band remains in 2G use in 2013 and 2014. The revised final model assumes that an operator with 5MHz of paired UMTS spectrum has one UMTS channel available. Similarly, it is assumed that an operator with 0.2MHz of paired GSM spectrum has one channel available. Thus, the spectrum holdings do not

---

[9] Telefonica holds 5MHz of unpaired spectrum in the 2100 band. It is included as 2.5MHz in the chart. In 2014 the hypothetical operator is assumed to clear 2x5MHz of its 1800MHz holding for LTE usage.

[10] ComReg, www.comreg.ie/radio_spectrum/search.541.874.10003.0.rslicensing.html, retrieved 2013, and ComReg 12/123.

[11] *Ibid.*

[12] A further assumption is made that increments of 0.2MHz are available for 2G channel use.

[13] The process of reallocation to another service is also sometimes referred to as “refarming”.

reflect “1/N” linear assignment of spectrum but closely resemble it, given operators’ comments on this point.

The revised final model assumes that 7.2MHz of paired spectrum in the 900MHz band is available from 2003-2012.[14] During this period, 7.2MHz of paired spectrum was held by Vodafone, Telefonica and Meteor each, while 2x13.4MHz (including guard-bands) of spectrum was unassigned. These assignments expired on 31 January 2013 for Vodafone and Telefonica, and on 12 July 2015 for Meteor.

The values discussed above have been amended to more explicitly reflect the “1/N” methodology in the updated final model.

Although the hypothetical existing operator is assumed to deploy and operate an LTE network within the time horizon of the final model, as LTE network elements are not dimensioned, spectrum holdings for LTE are also not included in this analysis, as discussed in section 2.3.1.

2.3.3 Radio network technology

Based on the spectrum holding assumptions discussed above, it is assumed that the hypothetical existing operator deploys both 2G and 3G technologies in its radio network. In particular, the final model assumes that 2G and 3G technology costs are introduced in the first year of the model.

The design assumptions and parameters used to dimension the 2G and 3G radio networks are discussed in detail in Section 5.

2.3.4 NGN core

The 2009 EC Recommendation stipulates that the core network should be specified as NGN-based for the purpose of BU-LRIC modelling of MTRs.[15]

As Irish operators have modern networks, an NGN core is considered to be a reasonable assumption for the hypothetical existing operator to deploy. Existing operators may have followed one of a number of potential strategies to implement IP transmission in the core network. These include:

- maintaining a separate legacy core switching architecture and deploying a new switching network for its 3G network, including the necessary interworking capabilities;
- upgrading the existing legacy switching equipment and transmission for IP-core support; or
- deploying a single integrated NGN core switching and transmission system, with equipment and architecture designed to carry both 2G and 3G traffic, and including separate circuit and packet switched layers.

---

[14] According to ComReg Document 12/25.

[15] 2009 EC Recommendation, page 3.

As the hypothetical existing operator is assumed to begin rolling out both 2G and 3G networks simultaneously in 2003, it is considered most appropriate to assume that the latter option is deployed in the final model. Consequently, in the final model, the hypothetical existing operator is assumed to deploy NGN core switches and transmission that are fully integrated and specified as being capable of switching both voice and data traffic.

2.3.5 Node layout

The Radio Access Network (RAN) dimensioning algorithm within the model determines, amongst other outputs, the number of nodes in the RAN. This is designed to respond to variations in factors such as market share, coverage area, network design parameters and traffic load. Therefore, the RAN dimensioning is recalculated dynamically after the new network load is computed when removing the increment of interest. A variety of options exist as part of bottom-up cost modelling to determine how the RAN characteristics of the hypothetical existing operator responds to the removal of the increment. Examples include the following:

Scorched earth: The model designs the network layout, configuration and technologies in the most efficient way that is feasible for a given traffic profile and any changes in what it is required to carry. This is based on the technical constraints of available technologies without any regard to the actual network configuration. If the network load or other characteristics change, the network would be designed in an alternative way based on the characteristics of the scenario.

Scorched node: The model maintains a static nodal layout directly informed by returns from operators, but the configuration of the nodes (e.g. the capacity, band configurations etc.), is optimised for the traffic scenario.

Modified scorched node: Similar to the scorched node methodology, the modified scorched node approach takes information provided by operators as the basis for network dimensioning, but allows the assumed network to be changed to reflect reasonable improvements in efficiency, if appropriate, and to respond dynamically to the scenarios on traffic load and market share, within the constraints of network parameters and input data provided by operators.

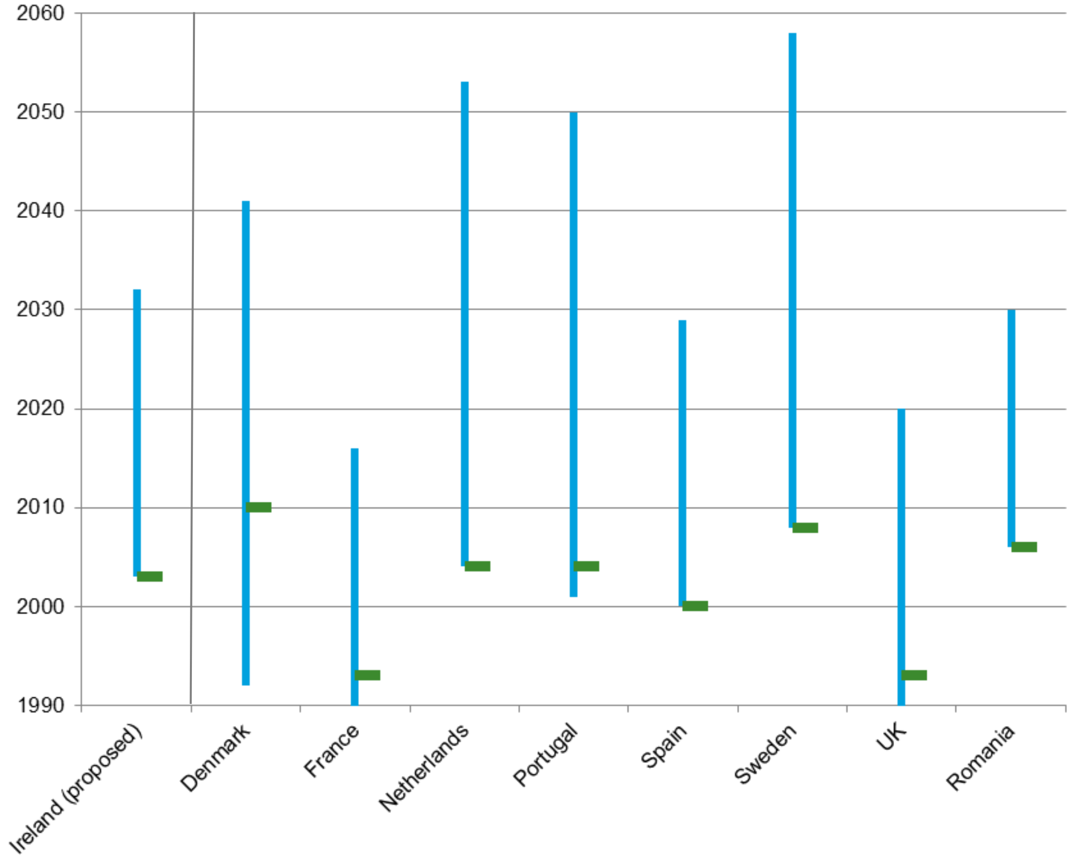
The scorched earth approach typically does not reflect accurately the practical constraints on operators in terms of network deployment and design and therefore may provide an over-efficient representation of the cost base that mobile operators incur. Further, with the range of technology solutions available, a scorched earth algorithm may imply the use of technologies or configurations that are not consistent with those seen in the Irish market. Modelling methodologies and adjustments used to counteract this potential over-efficiency typically add significant complexity to the modelling process. Furthermore, these methodologies may reduce transparency of the model outputs as they are more significantly impacted by assumed inputs or network parameters that are not observable in Irish operator networks.

The final model is based on a modified scorched node methodology, aligning the hypothetical existing operator to the network design parameters provided by operators whilst ensuring the hypothetical existing operator network design is modern and efficient. This is in line with ERG recommendations on LRIC network modelling.[16]

2.4 Time period covered by the model

The model covers a 30-year time period from 2003 until 2032. This includes two spectrum fee renewal periods. The chosen time period of the model is in line with other European NRA models which consider a similar time frame, as shown in the figure below.

Figure 3: Examples of time periods modelled in other European NRA models compared to proposed Irish time period



Source: *Analysys Mason report for ComReg and Deloitte analysis.*
Note: *Green bar indicates when the hypothetical operator is modelled to be active from.*

The time period of the model is sufficiently long that by discounting the future years' costs and traffic, extending the time horizon further would have a negligible effect on current costs. The

---

[16] ERG Common Position, ERG(05) 29. http://www.irg.eu/streaming/erg_05_29_erg_cp_rec_as_and_cas_final.pdf?contentId=543322&field=ATTACHED_FILE, page 22.

model does not include a terminal value, to incorporate costs associated with a network that is active in perpetuity. Adding a terminal value results in a negligible impact on current costs, in the same way that extending the time horizon does. Specifying a finite year in the model ensures that costs associated with deploying and running the network within the time period of the model are recovered from revenues generated within the model time horizon.

2.5 Use of economic depreciation

The 2009 EC Recommendation indicates a preference for the use of economic depreciation in MTR models:

"*A depreciation method that reflects the economic value of an asset is the preferred approach.*"

Economic depreciation seeks to align the recovery of the cost of an asset, with the exhaustion of its economic value over a period of time. This method is in contrast to accounting depreciation methodologies, such as straight-line, where these approaches do not attempt to provide this alignment. The economic value of an asset is modelled as the present value of expected income associated with the use of that asset over its useful life and therefore the change in present value of the asset over a year represents the exhaustion of economic value over that period. The economic depreciation algorithm assumes that the present value of expenditures equates to the present value of revenues over the time horizon of the model. This means that the algorithm distributes the cost recovery profile in line with the profile of discounted[17] outputs of the asset and the price trend of the underlying asset over its useful life.

Economic depreciation of network costs in the model should match the profile of utilisation of the assets in the provision of services, i.e. the exhaustion of value. In effect, this means that costs are depreciated more when the network and its elements are used more intensively and vice versa. This methodology therefore better aligns the attribution of cost over time in line with the usage of the network, in comparison to typical accounting depreciation methodologies, particularly in the presence of investment in anticipation of future capacity needs.

The calculation of economic depreciation is described in section 6.2 and a mathematical derivation of the approach used, as well as simplified worked example, is provided in Appendix C.

2.6 Cost of capital

The pre-tax nominal Weighted Average Cost of Capital (WACC) has been provided by ComReg. In the updated model this is proposed to be set at 8.63%, as per ComReg Decision 15/14 (Cost of Capital),[18] compared to 8.66% previously based on ComReg Consultation 14/28 (Review of Cost of Capital). The WACC is held constant throughout the time horizon of the final model.

---

[17] The pre-tax WACC serves as the discount factor for the purposes of calculating economic depreciation.

[18] http://www.comreg.ie/_fileupload/publications/ComReg14136.pdf

2.7 Pure LRIC, LRAIC+ calculation and relevant increment

The 2009 EC Recommendation states that for the calculation of the cost of a mobile termination service:

"*the relevant increment is the wholesale call termination service and which includes only avoidable costs*."

The final model follows this Recommendation by calculating the pure LRIC of the voice termination increment. In addition, the final model calculates the long-run average incremental cost plus (LRAIC+) of the voice termination increment.

The services included in the relevant increment of voice termination are:

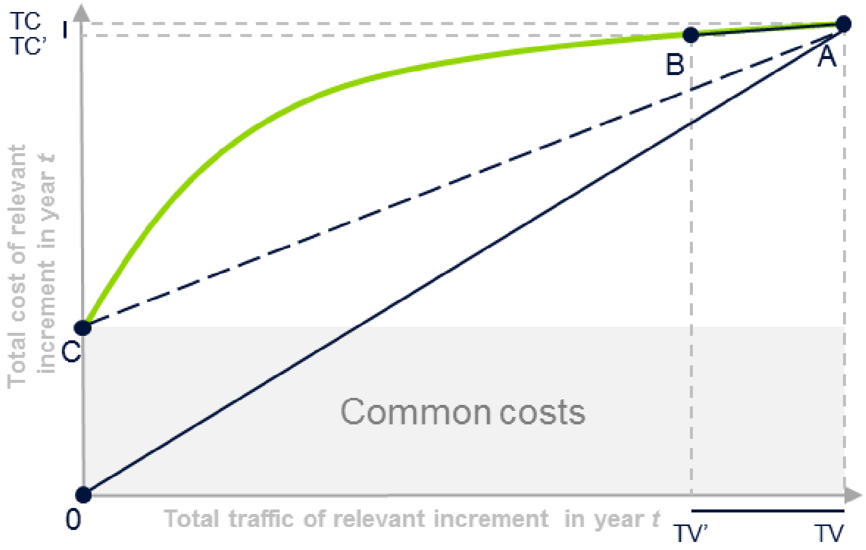
- **2G and 3G off-net to mobile**: calls from a subscriber of another Irish mobile network operator, terminating on the hypothetical existing operator's network;
- **2G and 3G fixed to mobile:** calls from a subscriber of an Irish fixed network operator, terminating on the hypothetical existing operator's network;
- **2G and 3G international to mobile:** calls from a subscriber located outside of Ireland, terminating on the hypothetical existing operator's network; and
- **2G and 3G inbound roaming:** calls to a subscriber, who is roaming onto the hypothetical existing operator's network.

Pure LRIC allows the recovery of the costs incurred solely due to provision of the services in the increment but does not allow the recovery of common costs. Pure LRIC can be considered to correspond to a measure of avoidable costs. Figure 4 portrays the definition of pure LRIC on a diagram of total cost and volumes. The difference between TV and TV' and between TC and TC' is due to the marginal traffic of a relevant increment. The gradient (slope of the line) between points B and A represents the value of pure LRIC for year *t* as it quantifies the cost-volume relationship of the increment. Pure LRIC is the cost of providing the additional increment, divided by the traffic associated with the additional increment. The chart in Figure 4 also portrays the concave shape of the cost-volume relationship.

LRAIC+ allows for the recovery of the costs incurred due to provision of the services in the increment as well as proportional common costs. Figure 4 depicts LRAIC+ as a gradient between points 0 and A, where common costs are equi-proportional to the traffic volume of the relevant increment compared to overall network traffic. LRAIC measures the average incremental cost of the increment of services and the "+" represents the inclusion of common costs. For instance, the group of services below can represent voice traffic, where the common cost is the share of total common costs associated with voice traffic. Via route factor attribution of element costs to respective services, LRAIC represents the average cost of voice services.

It should be noted that under the LRAIC+ methodology, the sum of all possible increments will add up to the overall cost of the network operation. The same is not true for pure LRIC as it does not include the common costs and is affected by the concavity of the cost-volume relationship.

Figure 4: Illustrative cost-volume relationship and pure LRIC for a group of services

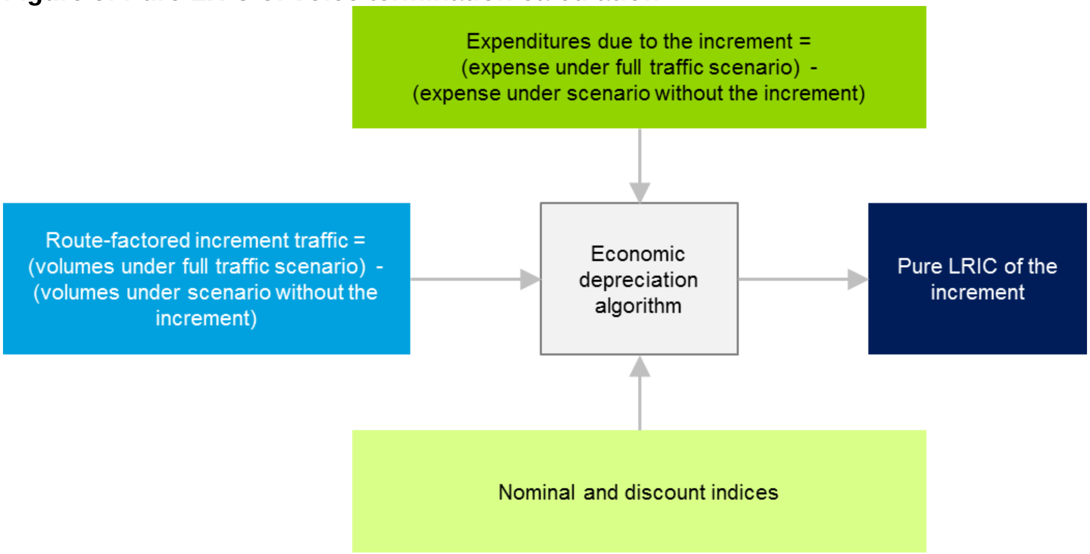


Source: *Deloitte analysis.*

The final model estimates the cost per unit of the increment of interest under the pure LRIC and LRAIC+ methodologies. To do so, the model estimates the volumes of all modelled services over the time period. The model then dimensions the appropriate network to support these volumes and attributes the costs of the resulting network to the underlying services that are supported. This calculation effectively corresponds to point A in the illustration in Figure 4. To determine the pure LRIC and LRAIC+, the model is then re-run, without the increment of interest, corresponding to points B and 0 of Figure 4. The difference in resulting costs is considered purely incremental to the increment of interest.

After the costs and volumes attributable to the increment are obtained, the economic depreciation algorithm is applied to obtain the pure LRIC and LRAIC+ of the increment over the time horizon of the model. Dividing this value by the incremental volume yields the pure LRIC/LRAIC+ per unit of traffic (i.e. minutes in the case of the voice termination). This calculation is summarised for voice termination in the figure that follows. LRAIC+ uses the same inputs, but also includes the relevant proportion of common costs. The calculation of route factored volumes and the application of discount factors are discussed in section 4.3.3 and section 6.2 respectively.

Figure 5: Pure LRIC of voice termination calculation



Source: *Deloitte analysis.*

3 Model Structure

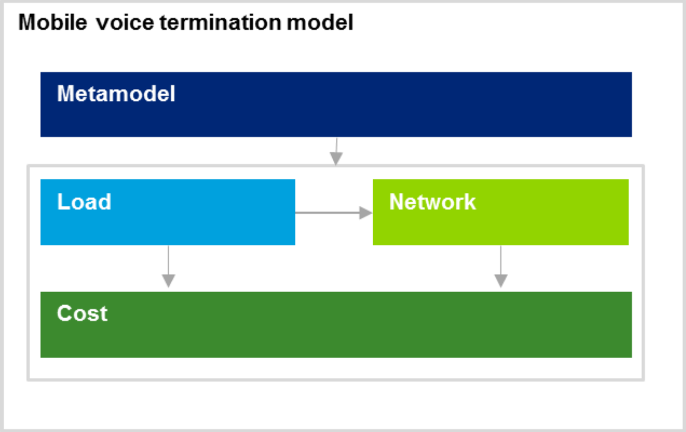
The model is composed of three distinct, but interlinked, calculation modules. Each module has a distinct set of inputs and the outputs from preceding modules serve as inputs to other modules.

- **Load:** This module determines the relevant network load, on the basis of the operator market share, per subscriber traffic usage and the busy hour (BH) profile of traffic.
- **Network:** This module dimensions the number of logical network elements required to cater for the calculated network load and determines the replacement cycle of these elements, given the asset lives applied.
- **Cost:** This module calculates an annual capital and operating cost associated with the dimensioned number of elements required and the purchasing profile of assets. These costs are marked-up to reflect associated supporting costs that are required to facilitate their use and the provision of mobile services. These costs are profiled over the time horizon of the model using an economic depreciation algorithm and then apportioned between services. This module also contains the controls for the modelling functionality to run the model with and without the termination increment, to determine the pure LRIC.

Objects[19] used in the calculation modules are defined in the metamodel, on worksheet a3.Meta in the model, which presents codes, descriptions and metadata for these objects. The calculation modules of the model are operated by a VBA macro to determine the pure LRIC.

A high-level representation of the flow of data between the modules that make up the final model is presented in the figure below.

Figure 6: High-level model logical flow



Source: *Deloitte analysis.*

---

[19] Objects in the model are entities that may be assigned a cost, a service volume or other value. Examples of objects include services and network elements.

3.1 Model objects

The tables that follow summarise the objects specified in the metamodel and used throughout the calculation modules.

3.1.1 List of modelled services

The list of services contained in the final model is presented below, along with their classification by traffic type and the default unit of measure for service traffic (before any conversion of units that may be applied within the model).

Table 2: List of modelled services

Service code	Service name	Unit of Measure	Traffic type flag[20]
S02_001	2G to 2G Mobile on-net minutes	Annual mins	V
S02_002	2G to 3G Mobile on-net minutes	Annual mins	V
S02_003	2G Mobile off-net minutes (outgoing)	Annual mins	V
S02_004	2G Mobile to fixed minutes (outgoing)	Annual mins	V
S02_005	2G Mobile to international minutes (outgoing)	Annual mins	V
S02_006	2G Outbound roaming	Annual mins	V
S02_007	2G Off-net minutes to mobile (incoming)	Annual mins	V
S02_008	2G Fixed to mobile minutes (incoming)	Annual mins	V
S02_009	2G International to mobile minutes (incoming)	Annual mins	V
S02_010	2G Inbound roaming	Annual mins	V
S02_011	2G to 2G SMS on-net	Annual messages sent	SM
S02_012	2G to 3G SMS on-net	Annual messages sent	SM
S02_013	2G SMS off-net (outgoing)	Annual messages sent	SM
S02_014	2G SMS off-net (incoming)	Annual messages sent	SM
S02_018	2G Data traffic	Annual MB transferred	D
S03_001	3G to 2G Mobile on-net minutes	Annual mins	V
S03_002	3G to 3G Mobile on-net minutes	Annual mins	V
S03_003	3G Mobile off-net minutes (outgoing)	Annual mins	V
S03_004	3G Mobile to fixed minutes (outgoing)	Annual mins	V
S03_005	3G Mobile to international minutes (outgoing)	Annual mins	V
S03_006	3G Outbound roaming	Annual mins	V
S03_007	3G Off-net minutes to mobile (incoming)	Annual mins	V
S03_008	3G Fixed to mobile minutes (incoming)	Annual mins	V
S03_009	3G International to mobile minutes (incoming)	Annual mins	V
S03_010	3G Inbound roaming	Annual mins	V
S03_011	3G to 2G SMS on-net	Annual messages sent	SM
S03_012	3G to 3G SMS on-net	Annual messages sent	SM
S03_013	3G SMS off-net (outgoing)	Annual messages sent	SM
S03_014	3G SMS off-net (incoming)	Annual messages sent	SM
S03_015	3G MMS on-net	Annual messages sent	MM
S03_016	3G MMS off-net (outgoing)	Annual messages sent	MM

---

[20] Traffic type flags the service as Voice, Data, Short Message or Media Message.

Service code	Service name	Unit of Measure	Traffic type flag[20]
S03_017	3G MMS off-net (incoming)	Annual messages sent	MM
S03_019	3G Data traffic	Annual MB transferred	D
S04_020	LTE Data traffic	Annual MB transferred	D

3.1.2 List of defined increments

The binary traffic scenario markers are defined in the table below. The traffic scenarios define the increments considered as part of this analysis. Two scenarios are defined in the table below. Traffic scenario 1 is used in the calculation of voice termination cost.

- Traffic scenario 0 – full traffic – includes all services.
- Traffic scenario 1 – traffic without voice termination – defines, by exclusion, the termination increment.

The use of these binary markers is explained further in section 2.7.

Table 3: Traffic scenarios to define the relevant service increments

Service code	Service name	TS_0	TS_1
S02_001	2G to 2G Mobile on-net minutes	1	1
S02_002	2G to 3G Mobile on-net minutes	1	1
S02_003	2G Mobile off-net minutes (outgoing)	1	1
S02_004	2G Mobile to fixed minutes (outgoing)	1	1
S02_005	2G Mobile to international minutes (outgoing)	1	1
S02_006	2G Outbound roaming	1	1
S02_007	2G Off-net minutes to mobile (incoming)	1	0
S02_008	2G Fixed to mobile minutes (incoming)	1	0
S02_009	2G International to mobile minutes (incoming)	1	0
S02_010	2G Inbound roaming	1	0
S02_011	2G to 2G SMS on-net	1	1
S02_012	2G to 3G SMS on-net	1	1
S02_013	2G SMS off-net (outgoing)	1	1
S02_014	2G SMS off-net (incoming)	1	1
S02_018	2G Data traffic	1	1
S03_001	3G to 2G Mobile on-net minutes	1	1
S03_002	3G to 3G Mobile on-net minutes	1	1
S03_003	3G Mobile off-net minutes (outgoing)	1	1
S03_004	3G Mobile to fixed minutes (outgoing)	1	1
S03_005	3G Mobile to international minutes (outgoing)	1	1
S03_006	3G Outbound roaming	1	1

Service code	Service name	TS_0	TS_1
S03_007	3G Off-net minutes to mobile (incoming)	1	0
S03_008	3G Fixed to mobile minutes (incoming)	1	0
S03_009	3G International to mobile minutes (incoming)	1	0
S03_010	3G Inbound roaming	1	0
S03_011	3G to 2G SMS on-net	1	1
S03_012	3G to 3G SMS on-net	1	1
S03_013	3G SMS off-net (outgoing)	1	1
S03_014	3G SMS off-net (incoming)	1	1
S03_015	3G MMS on-net	1	1
S03_016	3G MMS off-net (outgoing)	1	1
S03_017	3G MMS off-net (incoming)	1	1
S03_019	3G Data traffic	1	1
S04_020	LTE Data traffic	1	1

3.1.3 List of modelled elements

The list of elements contained in the final model is presented below, with their corresponding classification into element groups and the classification of elements into cost apportionment groups. Table 4 is a reproduction of data held within the model.

Table 4: List of modelled elements

Element code	Element name	Element group name
E01_001	Site	RAN
E01_002	BTS	RAN
E01_003	TRX	RAN
E01_004	BSC	RAN
E01_005	Node B	RAN
E01_006	3G radio	RAN
E01_007	RNC	RAN
E02_001	MSC-S	Core
E02_002	GMSC	Core
E02_003	MGW	Core
E02_004	HLR	Core
E02_005	EIR	Core
E02_006	AuC	Core
E02_007	SMSC	Core
E02_008	MMSC	Core
E02_009	IN	Core
E02_010	NMC	Core

Element code	Element name	Element group name
E02_011	Signalling platform	Core
E02_012	Number portability platform	Core
E03_001	Abis (BTS_BSC)	Tx
E03_002	IuCS (RNC_MGW)	Tx
E03_003	IuCS (RNC_MSC/VLR)	Tx
E03_004	Iur (RNC_RNC)	Tx
E03_005	Iub (NB_RNC)	Tx
E03_006	Nb (MGW_MGW)	Tx
E03_007	E (MSC/VLR_GMSC)	Tx
E03_008	A (BSC_MGW)	Tx
E03_009	Mc (MSS/VLR_MGW)	Tx
E04_002	900MHz 2G spectrum fees	Other
E04_003	1800MHz spectrum fees	Other
E04_004	900MHz 3G spectrum fees	Other
E04_005	2100MHz spectrum fees	Other
E04_006	Wholesale billing platform	Other
E04_007	VMS	Other

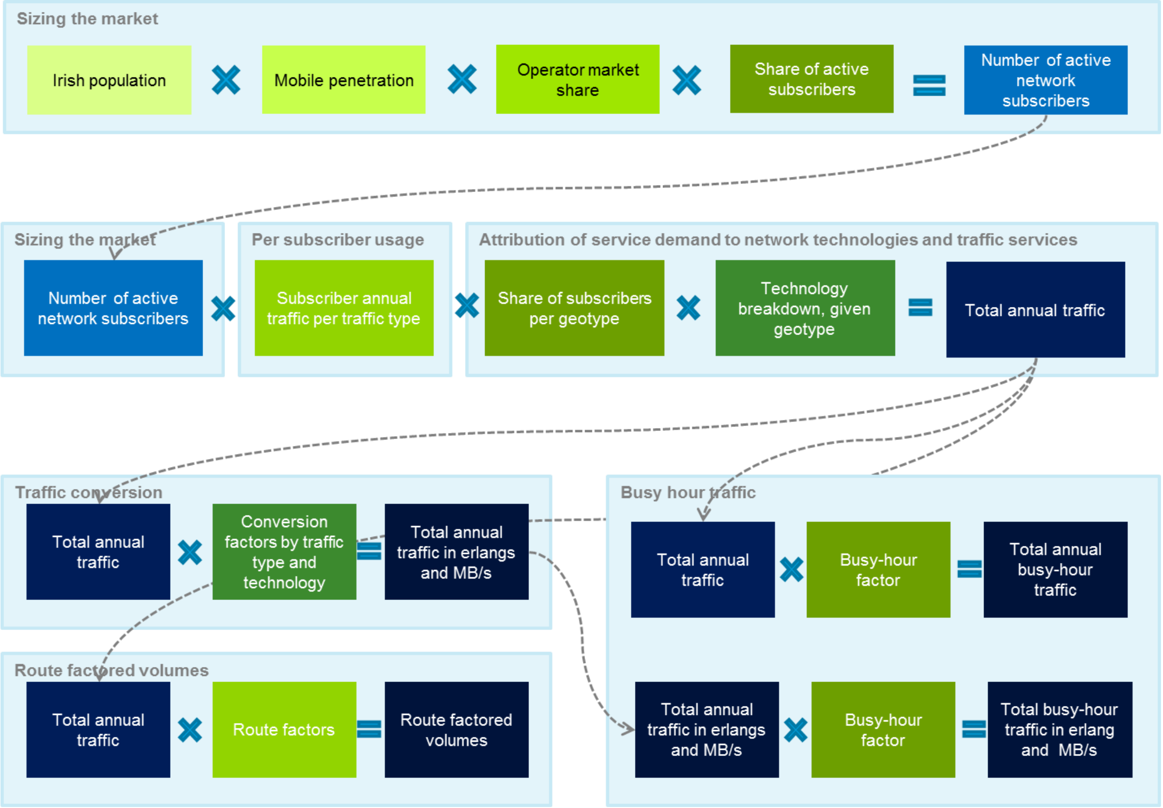
4 Load Module

The first step in calculating the pure LRIC of the increment of interest is to estimate the volume of service traffic that the hypothetical existing operator's network is required to carry, based on the projected volume of traffic in Ireland and the hypothetical existing operator's assumed market share. To determine the network required to carry this traffic, it is also necessary to consider the fact that service traffic is not uniformly distributed across each hour of the year and that individual services may use network equipment more intensively than other services, for a given unit of traffic. Both of these factors are therefore also taken into account in the initial stages of the modelling.

As a consequence, the load module determines the size of the market, the scale of the operator and the level of network load for each relevant traffic service that the hypothetical existing operator provides.

The figure below presents a logical summary of calculation flow and the outputs of the Load Module, the sections that follow discuss each of these calculation steps in turn.

Figure 7: Load module logical flow



Source: *Deloitte analysis.*

4.1 Sizing the market, the operator and per subscriber usage over time

This section describes the calculation steps required to calculate the estimated service traffic volumes that the hypothetical existing operator's network would be required to carry, given the aggregate historic and projected traffic in the Irish market and the hypothetical existing operator's assumed market share.

4.1.1 Sizing the market

Sizing the market is based on three inputs: population, mobile penetration, and operator market share. Each of these input sources and forecasts are explained below. The number of subscribers is obtained from the following equation:

$$\begin{aligned} &\mathit{number\ of\ subscribers}_t \\ &\qquad = (\mathit{population})_t \times (\mathit{mobile\ penetration})_t \times (\mathit{operator\ market\ share})_t \end{aligned} \qquad (1)$$

where *t* denotes the year of service (between 2003 and 2032).

4.1.1.1 Population

Historical population figures and forecasts are available from the Central Statistics Office (CSO). These projections are shown in Table 5.

The CSO provides projection figures for the five-year intervals shown in Table 5. Those values are taken as inputs and polynomial smoothing is employed for the intermediate years to provide a smooth population growth profile.

Table 5: Projected population from 2011 (in thousands) by criteria for projection and year

Projection method	2011	2016	2021	2026	2031	2036	2041	2046
Method - M1F1	4,574.90	4,704.10	4,986.80	5,308.90	5,636.70	5,988.10	6,357.60	6,729.30
Method - M1F2	4,574.90	4,699.40	4,960.60	5,244.90	5,522.20	5,816.70	6,121.80	6,421.20
Method - M2F1	4,574.90	4,691.20	4,901.00	5,103.30	5,293.40	5,492.50	5,701.20	5,907.30
Method - M2F2	4,574.90	4,686.50	4,875.10	5,042.10	5,187.40	5,337.40	5,491.00	5,635.20
Method - M3F1	4,574.90	4,673.70	4,803.40	4,910.30	4,991.70	5,072.80	5,159.10	5,239.60
Method - M3F2	4,574.90	4,669.00	4,778.00	4,852.10	4,893.70	4,932.30	4,970.80	4,997.40

***Source:** Central Statistics Office, Current Population and Labour Force Projections (2011 Based), table PEC08.*

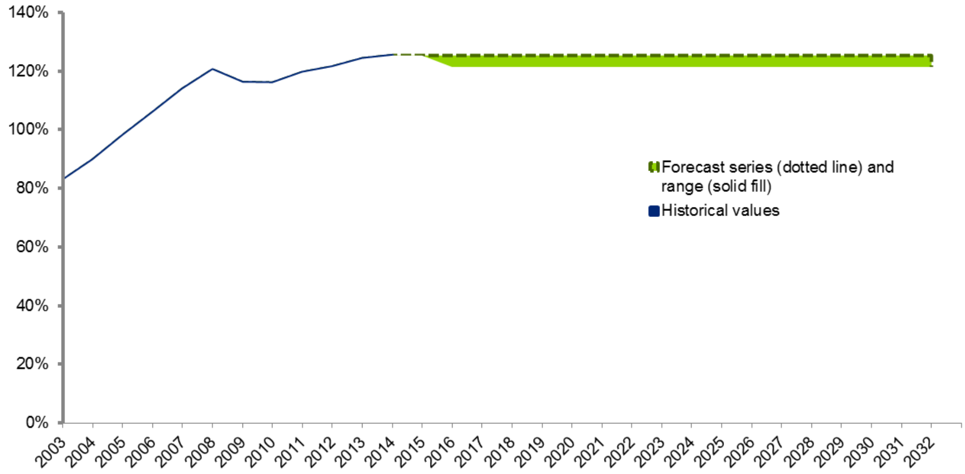
Since several forecast projections are available, the midpoint projection method M2F1 is used in the final model, to minimise the risk of over or under estimation of the size of the Irish market. As the divergence in estimates occurs primarily beyond the time horizon of the model, the results of the model are not materially sensitive to the projection selected.

4.1.1.2 Mobile penetration

The historical figures for number of mobile subscribers are sourced from ComReg's Quarterly Key Data Reports, which are based on submissions by operators. [21] Mobile penetration is calculated by dividing the total number of mobile subscriptions by population. This series is plotted in blue in Figure 8, below. A range of potential profiles may be applied within the model. A conservative range for the long-term peak penetration is anticipated to fall between 121% and 125.3%. The lower bound takes 121%, similar to the penetration rate in 2012, as the long-term peak (or saturation rate) and the 125.3% upper bound is based on the penetration rate of 2014.[22] The penetration rate is assumed to stay fixed after 2018 at 125.3% (plotted in green in Figure 8).

Forecasts between 2015 and 2032 are kept constant at the updated Q4 2014 value of 125.3%. This value is within the range of saturation points used by other European NRAs. For instance, Ofcom's[23] (UK) model uses 132%, ARCEP's[24] (France) uses 103% and ANACOM's[25] (Portugal) uses 170% as their respective saturation rates.

Figure 8: Mobile penetration historical values and forecast range



Source: ComReg, Quarterly Key Data Questionnaire for historical values (2003-2014). IMF and Deloitte analysis for forecasts.

4.1.1.3 Market share

The hypothetical existing operator is modelled with network investment and the provision of services between 2003 and 2032. It is assumed that the operator has an established market share

---

[21] Latest data is available from ComReg Document 15/27.

[22] *Ibid*.

[23] http://www.ofcom.org.uk/static/wmvct-model/model-2011.html, Retrieved 2013.

[24] http://www.arcep.fr/index.php?id=8080&L=1, Retrieved 2013.

[25] http://www.anacom.pt/text/render.jsp?contentId=1125693&showMetadata=0&contentStatistics=0&showTags=1&channel=graphic, Retrieved 2013.

of 25% in 2003 in the revised final model, as presented in the table below and discussed in section 2.2. Market share reflect the number of operators in the Irish market in 2013.

Table 6: Market share (proportion of subscribers)

	2003	2004	…	2032
Market share	25%	25%	...	25%

4.1.2 Per subscriber usage

Per subscriber usage is broken down into voice, message and data traffic services. Traffic load is defined on the basis of Irish population and market share; together these services describe total Irish market traffic demand. This leads to traffic volumes from, for example, machine-to-machine communications (M2M), MVNO traffic and international roaming traffic, being ascribed to domestic subscribers of the hypothetical operator. Historical demand and forecast demand is populated with the network operators' data weighted by traffic volumes and with ComReg's Quarterly Key Data (QKD) where available. The per subscriber usage volumes for voice calculations for historic years are now derived in the first instance from aggregate market volume for voice and data traffic information as presented in QKD rather than, as was the case in the previous version of the model, estimates derived from Irish mobile operator input data on a per subscriber basis obtained in response to a 13D Information Request from ComReg.

Along with the voice and SMS per-subscriber traffic volumes, the per-subscriber data traffic has been revised, in agreement with ComReg, and is informed by the QKD reports, covering Q2 2011 through Q3 2014. Unlike voice services where all operators report a relatively consistent traffic profile, it is notable with regard to data traffic that the profile is highly influenced by dongles and differs across the operators. Considering the high contribution of data traffic caused by dongles as opposed to handsets, two alternative approaches for per-subscriber data traffic were considered by ComReg. The first approach is to treat dongle traffic as an outlier in terms of mobile data traffic and exclude a significant element of dongle traffic from informing the model inputs. The second is to include dongle traffic in full as part of the Irish mobile data traffic market. The first approach would result in a significant element of dongle traffic not being included in the analysis. The second means that per-subscriber data traffic in the model would reflect the average of the Irish market, reconciling with QKD, however the model inputs would not closely resemble input data provided by any of the operators.[26] In modelling the average subscriber usage for data services, the inclusion of all dongle traffic would result in an average subscriber load that would not reflect a typical Irish mobile operator and for this reason an element of dongle traffic is excluded.

In order to avoid potential distortions caused by the high contribution to data traffic from dongles as opposed to handsets, the modelling excludes a portion of dongle traffic that is not deemed to be representative of the data traffic that would likely be carried by a hypothetical efficient Irish mobile operator. This is based on an assessment of handset and dongle traffic carried by Irish operators.

---

[26] According to the operator reported data traffic per-subscriber in in response to a Section 13D Information Request that was sent on 9 July 2013 to all mobile service providers designated with SMP in mobile voice termination in the Irish market.

The mobile-fixed incoming/outgoing traffic ratio is implied by QKD and reflected in the modelled mobile-to-fixed minutes and fixed-to-mobile minutes per subscriber. The ratio is then held constant at 0.5 from 2014 onwards.

The on-net and off-net mobile minutes traffic are also adjusted to reflect the fact that an operator with a higher market share would typically have a higher proportion of on-net traffic. The relationship, as observed in Ireland, is obtained from a simple linear regression from QKD. In the revised final model, a larger dataset has been used, covering Q3 2012 – Q3 2014 on mobile minutes and number of subscribers.[27] The output of the regression analysis is:

$$\left(\frac{onnet}{offnet}\right)_i = 6.1658 \times (market\ share)_i + u_i, \text{ with } R^2 = 0.70 \qquad (2)$$

A fitted line (Ordinary Least Squares - OLS) is used to obtain the coefficient estimate. The data plot supports the OLS estimate, for changes in market share in the range of 10% to 35%. A non-linear relationship may need to be explored for market shares close to 100%. No intercept is assumed, so that setting the market share close to 0% would result in trivial on-net traffic volumes. The u_i term of the regression represents the error term. The market share coefficient is statistically significant at 1% level. [28]

This relationship is applied to network operators' overall originating and terminating mobile minutes to obtain the breakdown of on-net and off-net originating minutes. A clear correlation between market share and on-net vs. off net traffic ratio is observed in QKD data. This is consistent with correlations observed in other jurisdictions and models.

The revised final model includes the assumption that off-net to mobile calls are based on a closed system containing N equal and stable operators. This means that the total volume of off-net minutes originated to other operators is now modelled to equal the total volume of off-net minutes terminated from other operators.

Although not reflected in the table below, the forecast of SMS per-subscriber traffic has been revised to decline from 2014, as opposed to remaining constant, following comments from the operators. A logarithmic decay is assumed throughout 2014-2032, so that the decrease is steepest in early years. Nevertheless, the SMS traffic remains significant throughout the modelled time horizon.

Table 7: Per subscriber annual usage

Service	2013 value
Outgoing annual minutes	
Mobile on-net minutes (outgoing)	1,006

---

[27] Number of subscribers excluding MVNOs is used as a proxy for market share, while mobile minutes (on-net and off-net) are used to calculate the ratio. Data on the four Mobile Network Operators is used throughout the period.

[28] Given equation coefficient above, the implied ratio of on-net to off-net mobile minutes is 1.54 for a 25% market share.

Service	2013 value
Mobile off-net minutes (outgoing)	701
Mobile to fixed minutes (outgoing)	225
Mobile to international minutes (outgoing)	118
Outbound roaming (outgoing)	67
Outgoing voice total	**2,117**
Incoming annual minutes	
Off-net minutes to mobile (incoming)	701
Fixed to mobile minutes (incoming)	126
International to mobile minutes (incoming)	118
Inbound roaming (incoming)	67
Incoming voice total	**1,012**
Annual message traffic (messages)	
SMS per subscriber – on-net	1,681
SMS per subscriber - incoming	1,081
SMS per subscriber - outgoing	1,081
MMS per subscriber – on-net	12
MMS per subscriber - incoming	8
MMS per subscriber - outgoing	8
Annual data traffic (MB)	
2G hypothetical data usage	400
3G hypothetical data usage	6,300
LTE hypothetical data usage	-

***Source:** Operator data returns and Deloitte analysis.*

4.1.3 Traffic profile across network technologies

The voice traffic migration profile between 2G and 3G is assumed to lie in a range of potential values as shown in the figure below.

This range is informed by data returns from operators on historic and expected forecast migration as well as the migration profiles as observed in other NRA models. [29] In particular, one Irish operator provided forecast volumes for a substantial portion of the time horizon of the model. The extent of 2G to 3G voice traffic migration can be varied across geo-types, and the migration path shows a progressive increase in voice traffic carried on 3G, reaching a peak of approximately 60%, after which it is held constant for the remainder of the time horizon of the model. This assumes that there is an incremental migration of voice to 3G, and that the extreme cases of either intensive usage of existing 2G assets, or rapid and complete migration from 2G, are not assumed. The

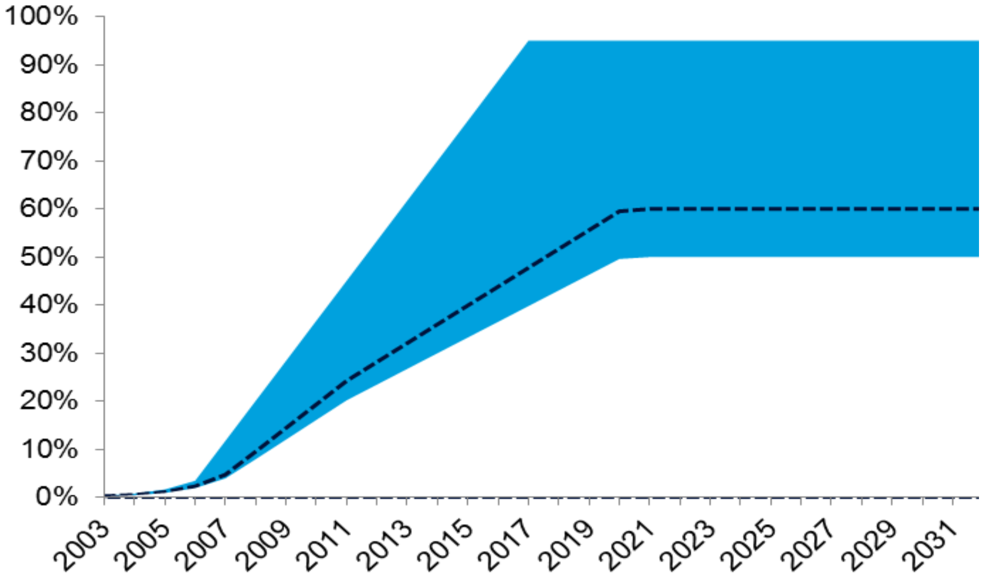
---

[29] See for instance ANACOM (Portugal) and ANCOM (Romania).
http://www.anacom.pt/text/render.jsp?contentId=1125693&showMetadata=0&contentStatistics=0&showTags=1&channel=graphic, Retrieved 2013
http://www.ancom.org.ro/en/uploads/links_files/documentatia_modelului_operatorului_mobil.pdf

remaining voice traffic is carried over the 2G network, and currently no voice is assumed to be carried on LTE. Figure 9 displays the series (as a dotted line) and the considered range.

In the revised final model, the proportion of traffic carried across 2G and 3G networks in rural areas has been amended, so that rural areas no longer have the same profile as that observed in denser geo-types. The migration profile remains in line with the figure below.

Figure 9: Share of voice traffic on 3G: migration profile range



Source: *Deloitte analysis.*

The geographic breakdown of traffic differs between data traffic and voice and message traffic, since data traffic is dependent on the availability of 2G, 3G and LTE technologies. The implied per-subscriber data usage by technology is based on ComReg's QKD as of Q3 2014 and operator reported returns on data traffic breakdown by 2G, 3G and LTE which were obtained in response to Section 13D Information Request. This is estimated in the description provided in equation (3). The QKD Reports, excluding a significant element of dongle traffic, inform the mobile traffic data for 2013 at 5,950MB per subscriber.

The values included in the final model presented in the load module imply the annual traffic that a subscriber would generate, by network technology, were they to only have access to one of the three technologies. In practice, a subscriber has access to a mix of technologies and this mix varies by geo-type and over the time horizon of the model. In the model the propensity of traffic by network technology is also specified to determine how likely a subscriber is to use a given network technology for data transfer. The more likely a subscriber is to use LTE, the more data the subscriber will have transferred and conversely, the more likely a subscriber is to use 2G, the less data the subscriber will have transferred. This yields an overall data traffic profile shown in Figure 12. Geo-type traffic breakdown is discussed further in section 4.2 and the underlying geo-type area breakdowns are reported in section 5.1.1.2.

Equation (3) below demonstrates the calculation of data traffic. The split by geo-type is the same as for voice and message traffic. The propensity of data traffic usage by technology is estimated from the operators' demand series on data traffic per subscriber. The profile of data traffic usage, by network technology and geo-type, are approximated by assuming that the geo-type breakdown of subscribers is represented by the voice and messages traffic breakdown by geo-type, as reported in network operator data request returns. The profile also assumes a hypothetical data usage by technology such that the per subscriber data traffic by technology is in line with the operators' values. The equation is shown below. This approach is in line with that adopted by other European NRAs, such as, for example, PTS in Sweden, for modelling data traffic calculation per subscriber.

$$\begin{aligned}&(data\ usage\ by\ geotype\ and\ technology)_t\\&\qquad = (hypothetical\ data\ usage\ by\ technology)_t \times (subscribers)_t\\&\qquad \times (split\ by\ geo\text{-}type)_t \times (propensity\ of\ traffic\ by\ technology)_t\end{aligned} \tag{3}$$

Figure 10 through Figure 12 show the traffic profiles of the input data. The historical data is in blue and forecasts are in green. Forecast trends are informed by inputs provided by operators. The overall trend is one of slow, but positive, growth in voice traffic, and continued rapid growth in mobile data usage. One network operator, which provided forecast inputs through to 2020, implied continued growth in per-subscriber SMS volumes throughout the time period to 2020. Other operators, which provided a one-year forecast, anticipated a decline in per subscriber SMS usage.

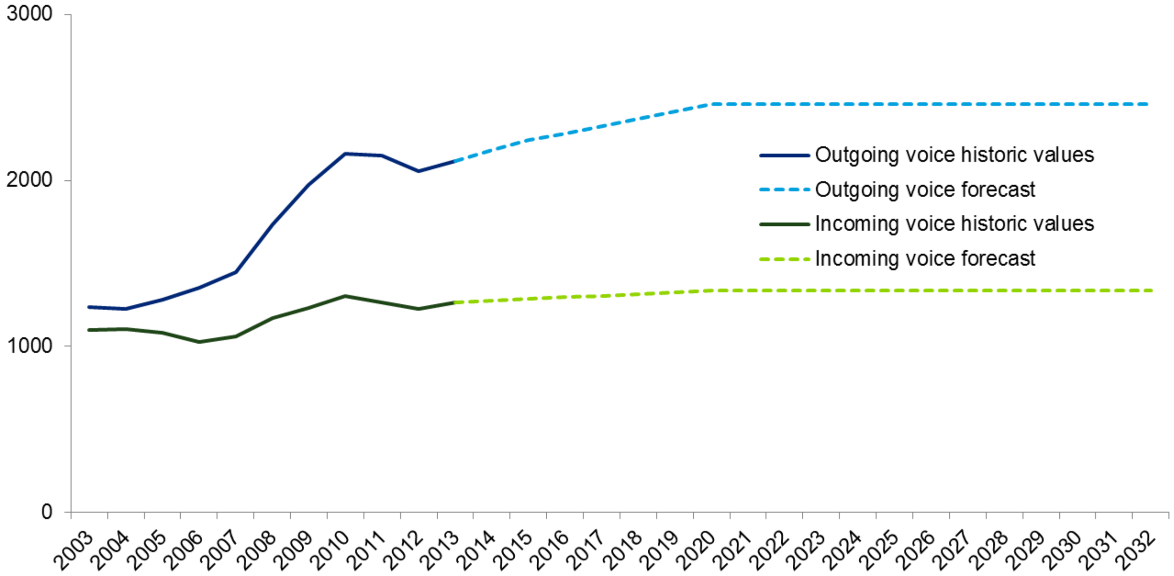
The per-subscriber usage is held constant in the time period post 2020, for all traffic types except for SMS, due to uncertainty in forecasting, as is typically observed in NRA models. Figure 12 shows overall traffic on the network. The decline in SMS traffic from 2020 in the Final MTR Model is discussed above.

In the updated final model, the on-net vs off-net traffic ratio has been revised to reflect the constant market share of the hypothetical existing operator.[30]

---

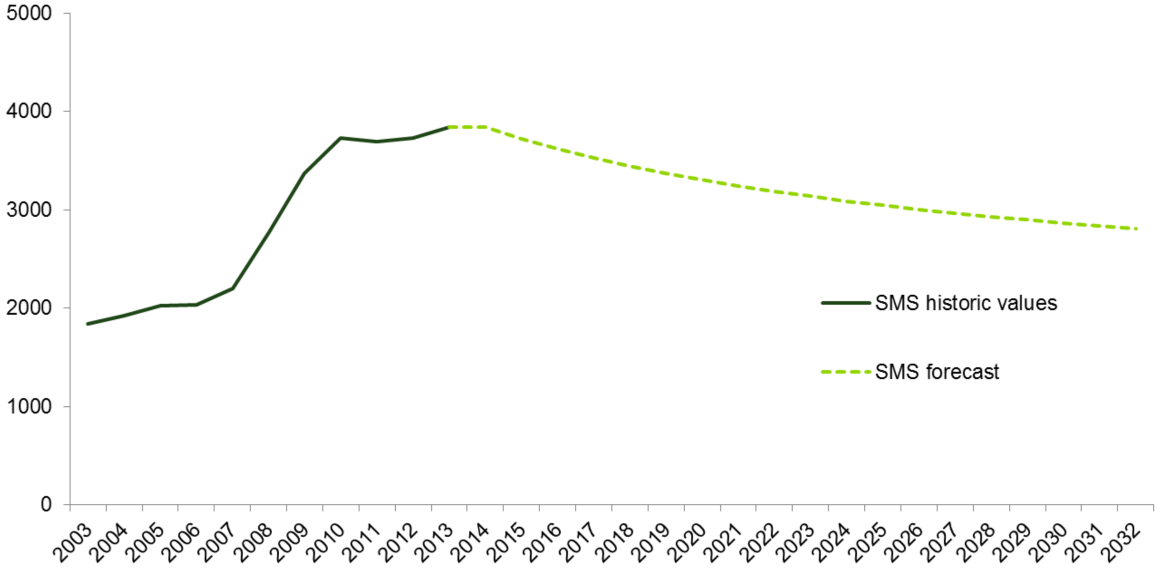
[30] See sections 2.2 and 4.1.2 for a discussion on market shares and per-subscriber voice traffic updates.

Figure 10: Outgoing and incoming annual minutes per subscriber



Source: *Deloitte analysis.*

Figure 11: Annual total SMS, per average subscriber

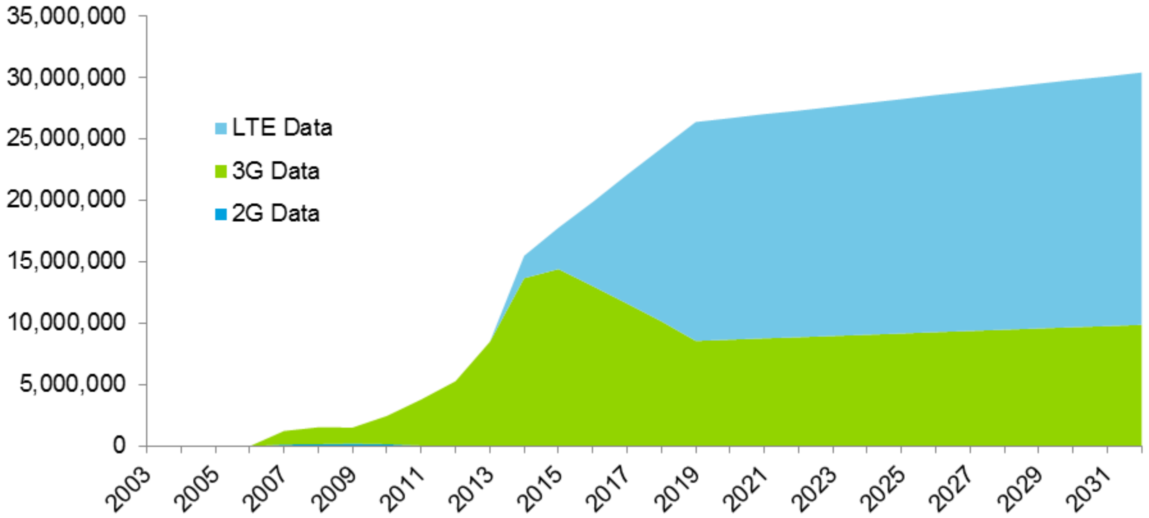


Source: *Deloitte analysis.*

The total network data traffic presented in Figure 12 below and incorporated into the model is guided by QKD Reports on a per subscriber data traffic basis. Crucially, for the purposes of designing a mobile network for a hypothetical efficient mobile operator with 25% market share in the model, Figure 12 excludes a significant element of dongle traffic, and therefore does not fully reconcile with the information presented in ComReg's QKD Reports. Consequently, forecasts presented in Figure 12 are not representative of the Irish market as a whole but rather are consistent with Irish mobile operator data, excluding a significant element of dongle traffic, in the context of the approach adopted by the model.

The model is guided by Irish mobile operator data received by ComReg and includes operator forecasts which extend to 2020. Beyond this timeframe, subsequent forecasts within the model and in Figure 12 have been estimated by Deloitte based on population forecasts from CSO (see section 4.1.1.1). These forecasts post-2020 are held constant on a per-subscriber basis[31] and the aggregate network traffic is increasing during this period, due to growth in population projections. Given that per-subscriber forecasts represent a continuation of 2020 figures within the model, it follows that all forecasts out to 2032 are based on Irish mobile operator data and the CSO but exclude a significant element of dongle traffic within the market for the purposes of the model.

Figure 12: Total network data traffic by technology (in GB per year)



Source: *Deloitte analysis and QKD as of December 2014 excluding a significant element of dongle data traffic.*

4.2 Attribution of service demand to network technologies and traffic services

In the model, the total demand is broken down by geo-type and technology in order to model the three geo-types separately. The model has the functionality to allow traffic, network technology and therefore cost to vary across geo-type.

The breakdown by geo-type apportions total demand between urban, suburban or rural subscribers. Geo-type breakdown is defined for data and all other traffic separately; as data profiles are dependent on LTE rollout and take-up. One operator provided geo-type disaggregated data based on a mapping of urban, suburban and rural geo-types, which has been adopted for the geo-type disaggregation of traffic across services.

The technology breakdown describes the proportion of traffic on 2G, 3G, or LTE. 2G and 3G services are assumed to launch in 2003 and LTE data services in 2014 as no LTE services traffic

---

[31] Except for the SMS traffic per subscriber, which is forecasted to decrease, as suggested by a consultation response from one of the operators.

was reported in network operator data returns in 2013. A proportion of data traffic is assumed to migrate to LTE. The migration of voice from 2G to 3G is assumed to have begun in 2003 and to stabilise in 2020. The 2G proportion of voice is assumed to be 40% of total voice traffic in 2020, given the operator forecasts. It is likely that the 2G network will remain operational after 2020, for instance due to M2M communication, and therefore will be operational throughout the time period of the model. As discussed elsewhere, this and other modelling principles may be reviewed and reassessed by ComReg as part of future price control period reviews.

The three inputs are used in the service demand calculation summarised in equation (4):

$$\begin{aligned} service\ demand_t &= (number\ of\ subscribers)_t \times (demand\ per\ service\ per\ subscriber)_t \\ &\times (split\ by\ geo\text{-}type)_t \times (breakdown\ by\ technology)_t \end{aligned} \tag{4}$$

Each service demand is thus computed in the original units (minutes for voice, messages for SMS and MMS, and MB for data) on an annual basis. What remains is to profile the demand by the busy hour (discussed in section 4.3.1), convert the traffic into common units, i.e. into Erlangs and MB/s (discussed in section 4.3.2), and calculate the route factored volumes (discussed in section 4.3.3).

4.3 Conversion of service demand to traffic load

4.3.1 Busy hour traffic

The hypothetical efficient existing operator is modelled to design a network capable of servicing peaks in its annual traffic. Typically bottom-up cost modelling analysis considers this peak-capacity dimensioning in the form of a busy hour load; where the network load used to dimension required network elements is based on traffic levels at the busiest times. Were average annual traffic to be used, this would imply uniform traffic distribution over time and therefore would not adequately account for the additional capacity that a network needs to be able to serve. This is taken into account by considering the level of traffic observed in an operator's busy hour. The operator data request specified traffic profile data on the basis of technology, service group and geo-type, potentially allowing operators to provide up to 21 separate busy hour profiles to apply to subsets of services. For example, the 24 hour traffic profile for 3G data usage in urban areas. Data returns by operators are then applied to each service in line with its categorisation, as discussed below.

Service demand, as discussed previously in this section, is calculated on an annual traffic basis. To determine busy hour traffic load by service, a proportion of this traffic is attributed to the busy hour, based on traffic load statistics provided by operators. To obtain the representative busy hour, the annual traffic is divided by the number of "busy days" (see equation (5)).

$$\begin{aligned} (BH\ service\ demand)_t &= \frac{(service\ demand)_t \times (\%\ of\ traffic\ in\ BH)}{(number\ of\ busy\ days)} \\ &\times (\%\ of\ annual\ traffic\ in\ busy\ days) \end{aligned} \tag{5}$$

The busy hour occurs in a different part of the day for each service. The use of data peaks later in the day than the use of voice, for instance (see Table 8). The network is dimensioned on the basis of all busy hours in order to account for the random occurrence in traffic peaks and therefore to protect against the model under-dimensioning the network when considering busy hour traffic loads. As a consequence, the model calculates the ceiling value for traffic load as implied by operator data returns; with network traffic peaks implicitly assumed to be coincident, to ensure that the calculated load in the model does not underestimate the potential load that an operator may dimension the network for.

244 busy days are assumed in a year, based on 253 weekdays less nine public holidays in 2013. The share of total voice traffic that occurs in the 244 busy days is calculated from operators' data response weekly traffic profiles, adjusted for the nine public holidays. To obtain an estimate closer to the national average, the calculation takes into account the weekly profile of traffic weighted by geo-type and technology-specific traffic volumes provided by the operators. Based on this calculation, 77.6% of voice traffic occurs in the busy days, while the overall traffic proportion in the busy days is 72.9% due to a smoother weekly data traffic profile provided in operator data returns. The proportion of voice traffic in busy days varies from approximately 73% to 80% across the operators.

The busy hour profile is assumed to be constant over the time horizon of the model. This is based on the weighted average of the four operators' data request responses. The data is presented in Table 8.

Table 8: Share of daily traffic in the busy hour uplifted range

Service name	Geo-type flag	Proportion of daily traffic in the busy hour
2G Mobile minutes	Urban	8.3%
2G Mobile minutes	Suburban	8.1%
2G Mobile minutes	Rural	7.9%
3G Mobile minutes	Urban	8.7%
3G Mobile minutes	Suburban	8.3%
3G Mobile minutes	Rural	8.3%
2G Data traffic	Urban	6.8%
2G Data traffic	Suburban	6.4%
2G Data traffic	Rural	6.8%
3G Data traffic	Urban	7.6%
3G Data traffic	Suburban	7.4%
3G Data traffic	Rural	8.3%
LTE Data traffic	Urban	7.6%
LTE Data traffic	Suburban	7.4%
LTE Data traffic	Rural	8.3%
2G SMS or MMS	Urban	7.9%
2G SMS or MMS	Suburban	7.9%
2G SMS or MMS	Rural	7.9%
3G SMS or MMS	Urban	7.9%
3G SMS or MMS	Suburban	7.9%
3G SMS or MMS	Rural	7.9%

Service name	Geo-type flag	Proportion of daily traffic in the busy hour
3G SMS or MMS	Urban	7.9%
3G SMS or MMS	Suburban	7.9%
3G SMS or MMS	Rural	7.9%

Source: *Operators' data request response, weighted average.*

The peak in traffic is modelled by the average busy hour uplifted by a factor of 10%. This uplift is included to capture variance across daily busy hours and to account for fluctuations in network load. This assumption implies that the network is able to deliver services with a 10% higher busy hour than on average. Prior to consultation operators were provided with an annotated extract of the calculations to show how their input data has been applied to generate the busy hour estimates. In addition to this uplift, a cell-specific load factor is applied for RAN dimensioning, to account for traffic peaks occurring at specific cells and peak-to-mean factors are also applied to recognise that peaks in traffic are also likely to occur within the busy hour itself.

4.3.2 Traffic conversion

As the large majority of 2G network traffic is voice load, busy hour loading calculations and network dimensioning for 2G elements is undertaken in Erlangs. In contrast, data traffic comprises the large majority of 3G traffic load and consequently MB/s traffic load is used for 3G elements. Voice bit rates of 12.2 kbit/s and 9.6 kbit/s are assumed at 2G and 3G respectively, and these values are used to convert data to equivalent voice Erlangs for the 2G calculations and to convert voice to equivalent data Mbit/s for the 3G calculations. The GSM voice bitrate is based on the Adaptive Multi-Rate codec as defined by ETSI's Technical Specification.[32] There is no overhead in the voice bit rate encoding standard, it is added afterwards to account for redundancy and signalling.

The traffic in MB/s and Erlangs are obtained from equations (6) and (7). The former is on a per second throughput basis and the latter on an annual traffic basis. The MB/s measures a throughput of one second of traffic in a busy hour.

$$\begin{aligned}(BH\ service\ demandin\ erlangs)_t \\ &= (service\ demand)_t \times (conversion\ factor\ into\ erlangs) \\ &\times (3G\ and\ LTE\ normalisation\ factor\ ) \times (\%\ of\ traffic\ in\ BH)\end{aligned} \tag{6}$$

$$\begin{aligned}&(BH\ service\ demandin\ MB/s)_t \\ &= \frac{(service\ demand)_t \times (conversion\ factor\ into\ MB) \times (\%\ of\ traffic\ in\ uplifted\ BH)}{(244\ of\ busy\ days) \times (3600\ seconds\ per\ hour) \times (\%\ of\ traffic\ in\ business\ days)}\end{aligned} \tag{7}$$

Table 9 shows the assumptions made in converting the units into MB and Erlangs. A 2G minute is assumed to be 1/60 of an Erlang. The remaining conversion factors are proportional to the values in the table. As part of the pre-consultation process, one operator noted that as voice and data are

---

[32] ETSI, ETSI TS 126 090 v12.0.0, http://www.etsi.org/deliver/etsi_ts/126000_126099/126090/12.00.00_60/ts_126090v120000p.pdf

considered together as part of the network dimensioning process, it is important to recognise that data service can be operated on a best effort basis and as a consequence, may imply a lower network load for a given unit of traffic, as compared to voice. This is accepted and accounted for in the differential load factors and payload factors for voice and data that are applied in the network dimensioning algorithms.

Table 9: Conversion factors assumptions

Assumptions	
2G - speech minute in Erlangs	1/60
2G data: Equivalent minutes bit rate (bit/s)	12,200
3G - speech rate (bit/s)	9,600
LTE - speech rate (bit/s)	9,600
Average characters per SMS	80
Bits per character in SMS	7
Normalisation factor based on 2G data equivalent minute bit rate	12,200
Bits in a byte	8
Bytes in a kB	1,024
kB in a MB	1,024

The model includes a 2G voice bit rate assumption called “2G data: Equivalent minutes bit rate”. Within the model, the 2G calculations use busy hour Erlangs as the measurement unit and therefore this bit rate assumption is used as one parameter in the conversion of the 2G data load (measured in Mbit/s) into equivalent busy hour Erlangs for subsequent analysis within the model. Thus changing this bit rate assumption does not affect the 2G voice Erlang load calculated by the model, but will change the Erlang equivalent 2G data load.

The revised final model includes a 3G and LTE normalisation factor. It is based on the 2G data equivalent minute bit rate and is implemented to ensure that the 3G and LTE voice Erlang conversion factors are not affected if the “2G data: Equivalent minutes bit rate (bit/s)” is modified by the model user from the existing input of 12.2 kbit/s. This parameter is equal to $\frac{\alpha}{12{,}200}$, where α represents the input for “2G data: Equivalent minutes bit rate” in bit/s, and 12,200 is the input for “Normalisation factor based on 2G data equivalent minute bit rate”, as shown in Table 9. Equation (6) shows how this factor is implemented in the calculation. It is equal to 1 when “2G data: Equivalent minutes bit rate (bit/s)” is set to 12,200.

4.3.2.1 Other parameters

Other parameters include factors such as payload overhead, load factor and the busy-hour peak to mean ratio. These parameters are, inter alia, used to convert the annual traffic data into network demand volumes in order to size, and ultimately cost, the various network components. Nevertheless, none of these definitions are exact, since the parameters themselves are only modelling assumptions, not technically quantifiable elements.

Payload overhead factor represents the overhead that occurs when packetizing different payloads. Effectively it is the difference between the basic payload bit-rate and the number of bits that are carried on the network. Thus, it includes headers and synchronising bits within the bit stream, framing information, packet overhead bits (headers, trailers, addresses etc.), check bits, packet stuffing and other redundancy, user metadata, signalling information and network management information, among other components.

The **load factor** represents the proportion of payload traffic carried to the theoretical network peak traffic capacity. Thus the resulting capacity represents the load carrying capability of a practical network under normal traffic conditions. This is the nearest equivalent to translating voice traffic into an Erlang carrying capacity. The load factor also allows for periodic peak to mean traffic variations across the year, i.e. seasonal, monthly, weekly, daily variations, unforeseen traffic peaks, among others.

The **busy-hour peak to mean ratio** represents the ratio of the peak bit rate that is carried in the busy hour to the mean bit rate that is carried in the busy hour, and allows for the handling of instantaneous peaks within the busy hour. Thus voice, which has a low latency tolerance, is assigned a higher peak to mean ratio (so it carries a higher instantaneous peak bit rate) than data, which with a higher latency tolerance, can be buffered for longer to effectively smooth out more of the peaks.

The overhead described above is added per aggregate bit steam, not per carrier (3G radio). This approach is adopted in order to avoid a circular reference in the computation flow; in order to calculate the bandwidth per cell (and therefore the number of carriers per cell), one needs to calculate how many cells there are. Moreover, the number of cells depends on the total traffic demand (including the overhead). Thus, adding the overhead after knowing how many carriers per cell exist would lead to a circular reference (which cannot be readily solved in excel by e.g. a recursive process that guarantees conversion). Therefore, the overhead is added to the individual bit streams before the number of carriers is computed. The overhead is thus applied directly to the aggregate network voice busy hour volumes per geo-type.

Nevertheless, if the overhead parameter is set correctly, and since the overhead is only a fraction of the aggregate payload, then the effect on the model accuracy is small. Furthermore, due to working with “average” cells, the effect tends to cancel out since for individual cells it tends to underestimate the demand for lightly loaded cells and overestimate the demand (i.e. add more redundancy than is strictly necessary) for heavily loaded cells. i.e. for “average” cells these effects are always balancing each other out to a certain extent.

Finally, the results were tested so that, for a given total load, the number of sites, cells, and number of carriers calculated by the model was calibrated against the operators’ reported data.

4.3.3 Route factored volumes

The route factor table, contained in Appendix A and on sheet d5 of the model determines how intensively a network element is used by a service.

A factor of 2 is used when an element is used twice for a given service; for instance, a site is used twice in an on-net call as it includes two subscribers connecting through two sites (or the same site twice).

A factor of 1 indicates that an element is used once in a service; for instance a terminating off-net call uses 1 site only, since the origination of the call is carried over a site from another operator.

A factor of 1.5 is used for the MSC-S. This is due to an assumption that there are 3 MSC-S deployed and that a mobile call is twice as likely to call another mobile on the same MSC-S (implied by a community interest factor). Since one MSC-S is used when the call is made on the same MSC-C and two if the call is made on different MSC-S, this yields a route factor of 1.5.

Route factored volumes indicate the traffic load per element in the network per each volume of traffic and are therefore used to apportion the cost of network elements to services, on the basis of the relative intensity with which a service uses the element. Route factors are used to calculate the traffic load on each of the elements in the network as well as to attribute the cost of elements to services in the cost module. They are calculated by matrix multiplication of route factors and demand volumes as shown in equation (8). The demand volumes are in the formats presented in equations (4) in section 4.2, (6) in section 4.3.2, and (7) also in section 4.3.2.

$$\underset{E \times T}{(route\text{-}factored\ volumes)} = \underset{E \times S}{(route\ factors)} \cdot \underset{S \times T}{(service\ demand)} \tag{8}$$

where *E, S,* and *T* denote the element, service, and time dimension respectively and the operator · indicates matrix multiplication. The service demand can take the format of annual traffic in original units (equation (4)) busy hour MB/s or Erlangs (equations (5) and (7)).

4.4 Load module output

The load module calculates demand on the basis of annual traffic and busy hour as well as in original units, MB/s throughput and for Erlangs. These formats are described by equations (1) through (7). Three output sheets are used in the remaining two modules:

- Service volumes (used in the network and cost modules);
- Route factored volumes (used in the network module); and
- Route factors table (used in the cost module).

The number of calls in a busy hour is calculated by dividing the busy hour minutes by the average duration of a call (in minutes), by service. The calculation of busy hour minutes is presented in section 4.3.1 and call durations are defined based on inputs from operators. This calculation also incorporates an assumed additional average ring time per call of ten seconds (assumed by Deloitte). When considering the number of busy hour call attempts in network element dimensioning, a further uplift factor is applied to this value to reflect unsuccessful calls.

These outputs are presented on sheets b1 and b2 and d5 of the model respectively.

5 Network Module

5.1 Network parameters

The network module calculates the number of elements required based on network design parameters and the network demand, as specified in the load module.

The numbers of required elements are then passed through a normalisation algorithm; which detects and corrects for any temporary dips in the number of elements required, due to variations in annual traffic load.

The normalised number of required elements per year is then passed through an element purchasing algorithm; to determine the quantity of elements that are required to be purchased each year to satisfy network load. The algorithm determines the purchase profile on the basis of major investment cycles as well as in-fill element purchases, to cope with intermediate increases in network load. The number of elements required and the annual purchasing profile of these elements is defined for the traffic scenario as defined in the final model.[33]

The outputs of the network module are as follows:

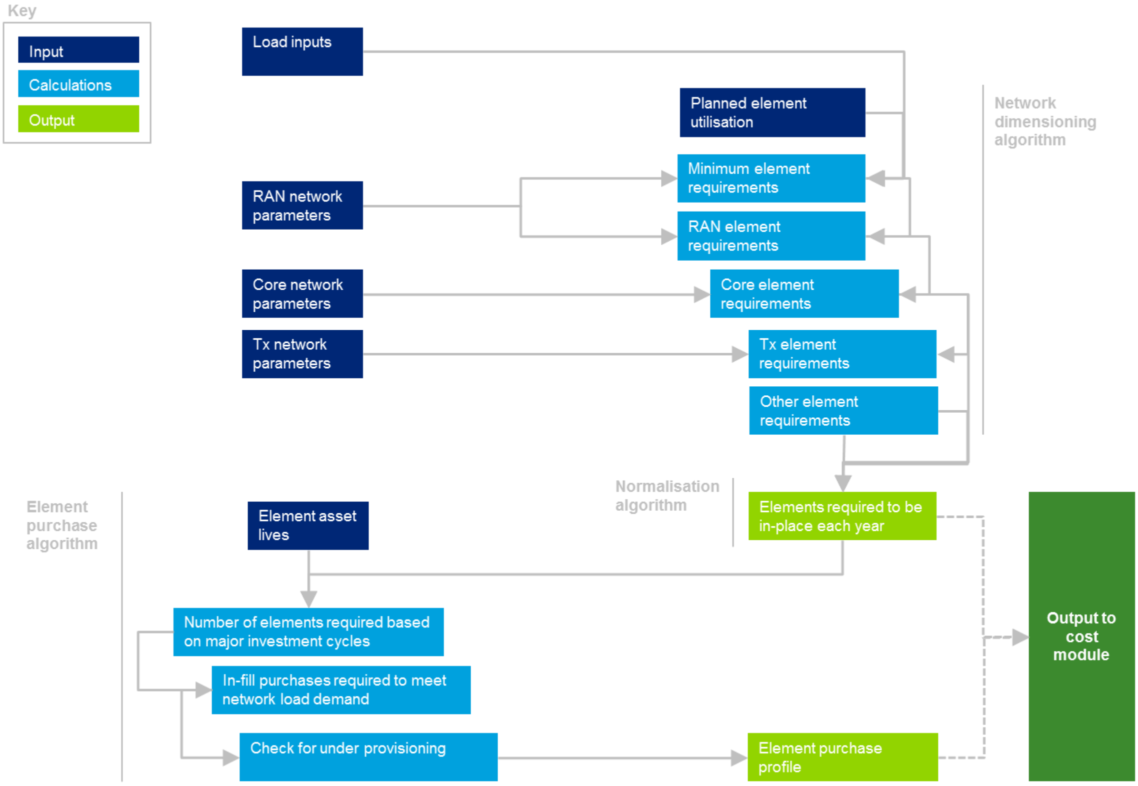
- the required number of elements each year due to the traffic load scenario; and
- the purchasing profile of the required elements due to the traffic load scenario.

The logical flow of the module is represented in the diagram below.

---

[33] The scenario defined in the model is dependent on the VBA macro. For example, this may present total traffic, or total traffic less the termination increment.

Figure 13: Network module logical flow



Source: *Deloitte analysis.*

The sections that follow summarise the range of network design parameters used in the final model and the network dimensioning algorithm rules, after which the normalisation and purchasing algorithms are discussed.

5.1.1 RAN parameters

RAN parameters define the network required for dimensioning network elements in the RAN, for 2G and 3G network loads. The calculations that use these inputs to define the number of elements required are presented in section 5.3.1.

5.1.1.1 Land area

The land area of Ireland is defined as 69,797km^2, as reported by Eurostat.[34]

5.1.1.2 Land area breakdown

The land area of Ireland is classified into urban, suburban and rural. The breakdown of land area into these geo-types was informed by operator data. The resulting implied land area breakdown by geo-type is as presented below and is generated based on total land area in Ireland and

---

[34] Eurostat, Area – NUTS 3 Regions, series: ‘demo_r_d3area’.

geographic network coverage. Geo-type disaggregation allows the model to consider traffic load and network dimensioning parameters that vary because of factors that include traffic profiles, network design, and topological / civil planning variation. To the extent that operator inputs are disaggregated across geo-types and demonstrate a differential network design, traffic load or cost, these are reflected in the inputs, calculations and outputs of the model.

Table 10: Land area by geo-type

Geo-type	Area (km^2)	Area (%)
Urban	1,142	1.6%
Suburban	5,691	8.2%
Rural	62,964	90.2%
Total	**69,797**	**100%**

Source: *Operator data as a response to September 2013 Section 13(D) request.*

5.1.1.3 Network coverage area

Network coverage area is defined for 2G and 3G separately, by geo-type. The coverage area of 2G and 3G RAN are defined in terms of geographic coverage. Assumed coverage areas are based on operator-reported coverage areas and are presented below. The distinction between indoor and outdoor coverage is not explicitly modelled as part of the RAN dimensioning. Operator data returns on the number of sites, cell radii and the configuration of sites were provided on an average basis across their networks, disaggregated by geo-type, and as such the use of these parameters incorporate implicitly any supporting equipment and nodes that are required to provide adequate indoor coverage. The tables below present the steady state level of geographic coverage that the hypothetical existing operator deploys.

Table 11: 2G coverage area

Geo-type	Area (km^2)	Area (%)
Urban	1,089	98%
Suburban	5,087	90%
Rural	52,948	84%
Total	**59,124**	**84%**

Table 12: 3G 2100MHz coverage area

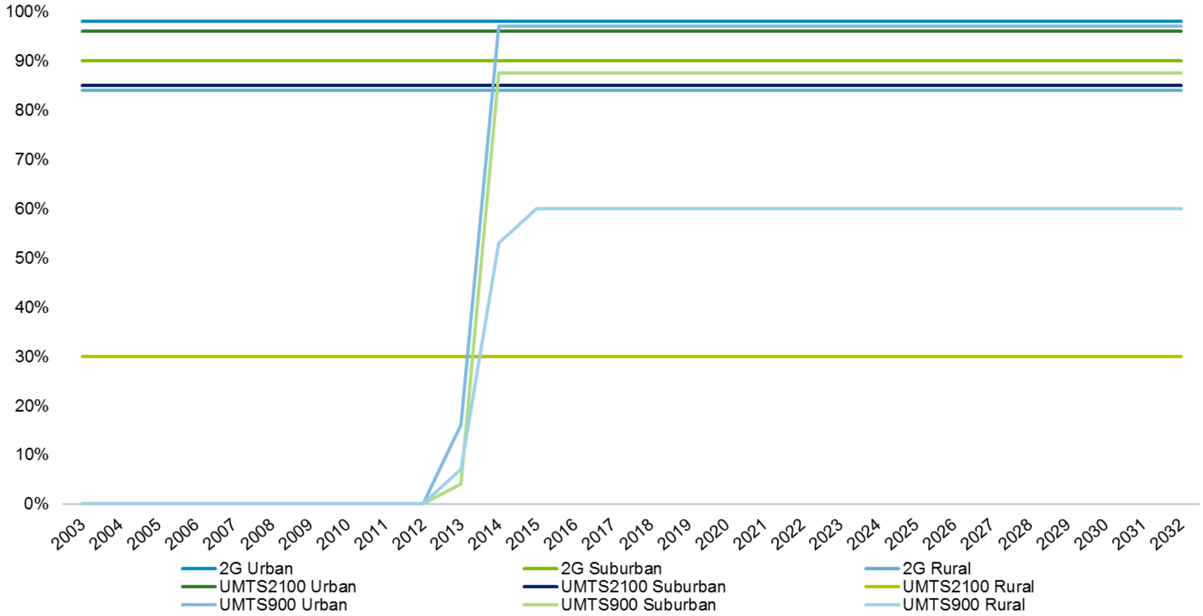
Geo-type	Area (km^2)	Area (%)
Urban	1,067	96%
Suburban	4,805	85%
Rural	18,910	30%
Total	**24,781**	**31%**

Table 13: 3G 900MHz coverage area from 2015*

Geo-type	Area (km^2)	Area (%)
Urban	1,078	97%
Suburban	4,946	88%
Rural	37,820	60%
Total	**43,844**	**60%**

***900MHz coverage area is 0% in 2012, increasing through 2013 and 2014 to the amount reported in 2015.**

Figure 14: Geographic network coverage profile



Source: *Deloitte analysis.*

5.1.1.4 Sectorisation and sectorisation factor

Cell sectorisation is the process of increasing the number of antenna at a RAN node. Each sector acts as an additional cell with its own set of frequency channels. As a consequence, a higher degree of sectorisation allows the network design algorithm to scale the RAN for higher traffic load through more intensive use of existing cells; rather than solely through deploying additional omni-sector sites for capacity.

In the final model, the extent of sectorisation is defined separately for the 2G and 3G network. The degree of sectorisation is also separately specified by geo-type. The extent of sectorisation is expressed as a proportion of sites that are sectorised and presented below.

Table 14: Proportion of omni-sectorisation 2G RAN

Geo-type	% omni-sectorisation
Urban	0%
Suburban	10%
Rural	20%

Table 15: Proportion of omni-sectorisation 3G RAN

Geo-type	% omni-sectorisation
Urban	0%
Suburban	0%
Rural	0%

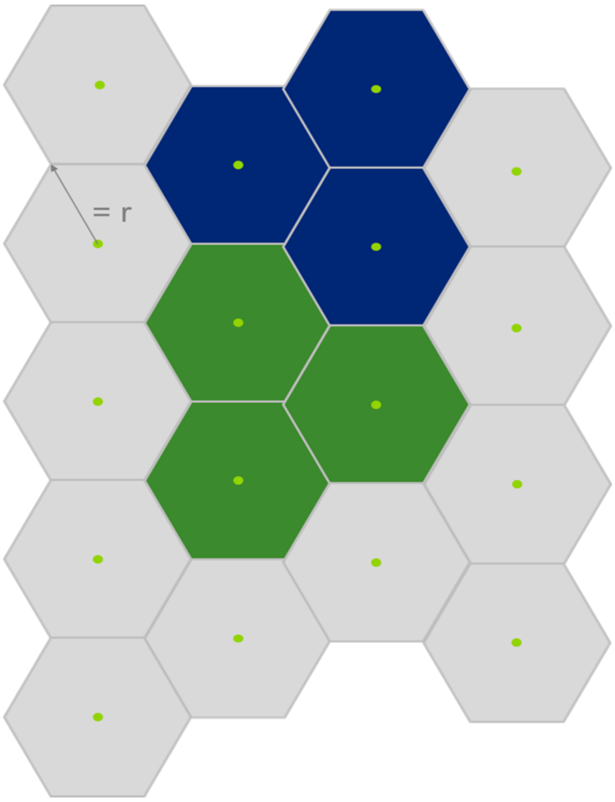
There was a degree of variation across operator data returns on the extent of sectorisation across geo-types for 2G. While some operators provided returns indicating almost full tri-sectorisation, others provided returns indicating a material degree of omni- or bi-sectorisation. As a consequence, the assumed profile falls between these values for 2G: urban areas are assumed to be fully tri-sectored, whilst 10% omni-sectorisation in assumed in suburban areas and 20% in rural areas. Operator returns on 3G sectorisation were more consistent across return and were close to or equal to 100% across geo-types. Consequently 100% tri-sectorisation is used in the final model for 3G.

The sectorisation factor specifies the degree of sectorisation. The sectorisation factor takes a value of three for tri-sectorised nodes and a value of one for omni-sectorised nodes.

5.1.1.5 Tessellation and spectral reuse factor

The final model calculates the coverage area of the cells. The radio network consists of a number of cell sites. Within the final model, cells are assumed to be hexagonally shaped, and are located so as to provide tessellating coverage as shown in the diagram below.

Figure 15: Illustration of cell area, tessellation and cell clusters



Source: *Deloitte analysis.*

Each site is assumed to provide either omni directional coverage (i.e. 360° coverage around the cell centre) or sectorised coverage (i.e. 3 x 120° arcs of coverage around the cell centre).

The quantity of the equipment at each site depends on the coverage area of the cell and the required level of traffic within the cell.

The coverage area is assumed to be the sum of the areas covered by each cell, adjusted by the tessellation factor. The factor represents the amount that cells overlap with each other due to the vagaries of radio propagation over an imperfectly flat terrain and the need to provide overlap between cells for hand-over and cell breathing in 3G systems. In both cases, the final model contains a cell tessellation factor of 33% i.e. due to the range of factors explained above, the cell is assumed to effectively cover two thirds of the implied hexagonal cell area.

For 2G systems with tessellating cells, the spectral re-use factor is used to determine the available spectrum at each cell. Consequently, dividing the total available spectrum by the re-use factor gives the spectrum available for each individual cell. For 3G it is assumed that the spectrum can be fully re-used across all cells and this is confirmed by the data returns provided by an operator.

Operators reported a wide range of spectral reuse factors, including 1*1 synthesised frequency hopping and cell cluster sizes ranging from 4 to 16. A midpoint factor of 1/10 is used in the final model.

5.1.1.6 Site collocation

Multiple network nodes are typically collocated at the same physical site, to simplify network management, reduce costs and use optimal site locations to their best advantage.

The extent of collocation of 1800MHz, 900MHz UMTS and 2100MHz cells at 900MHz GSM sites may vary due to a variety of factors including the cell radii and network design strategy of the operator. The final model uses operator-reported collocation statistics, details of which can be found in section 5.3.1.1. These values have been revised upon a receipt of further operator-reported collocation statistics as part of UMTS900 dimensioning.

5.1.1.7 Spectrum holding

As discussed in section 2.3.2 the hypothetical existing operator is assumed to hold 900MHz, 1800MHz and 2100MHz spectrum bands to operator 2G and 3G networks.

In line with actual holdings by network operators and the spectrum available in the Irish market, the hypothetical existing operator’s assumed spectrum holding is presented below. This holding is based on an average of operator holdings and aligns with the assumed market share of the hypothetical existing operator.

Table 16: Hypothetical existing operator spectrum holdings

Frequency bands	2013 values
900MHz	
900MHz 2G (GSM)	2 x 3.6MHz
900MHz 3G (UMTS)	2 x 5MHz

Frequency bands	2013 values
1800MHz	2 x 14.8MHz
2100MHz	2 x 15MHz

As discussed further in section 5.3.4.1, the spectrum holding of the operator is not varied between the full traffic scenario and the traffic scenario without mobile termination. The quantity of spectrum held by the hypothetical operator is specified in line with the “1/N” approach, as used for determining the efficient existing operator’s market share. While it is recognised that this holding may not align with the block sizes available in the most recent spectrum auctions, it is aligned with calculating the cost of providing mobile services for “1/N” of the Irish market.

Moreover, it is assumed that UMTS technology uses 5MHz increments of spectrum, compared to 0.2MHz increments for GSM technology. Therefore an operator with 5MHz of UMTS spectrum has one UMTS channel available with the next possible spectrum increment of 10MHz for two channels. The spectrum holdings are rounded accordingly to avoid implying the hypothetical operator would acquire a quantity of spectrum that it is not able to efficiently employ, for example 5.3MHz of spectrum for UMTS.

5.1.1.8 Cell radii

The effective average cell radii used in the network dimensioning algorithm is a calculated value, based on traffic load, the available spectrum, the reuse factor, the cell traffic capacity and the grade of service. The calculated cell radii are constrained by a minimum and maximum radii range. Operators provided data on the maximum feasible and average cell radii. Technically feasible minimum radii are applied for the lower bound.

Under the full traffic scenario and the traffic scenario without voice termination, the maximum 2G cell radii values are based on a weighted average of operator data returns on 900MHz and 1800MHz cells.[35] The tables below contain the parameters used in the final model.

Table 17: 2G minimum and maximum cell radii

Geo-type	Minimum (km)	Maximum (km)
Urban	0.1	1.3
Suburban	0.2	4.2
Rural	0.3	33.0

Table 18 shows the minimum and maximum cell radii for 3G technology. The minimum cell radii are interference, not propagation limited and are thus the same for UMTS2100 and UMTS900, specific to each geo-type. UMTS2100 maximum cell radii are based on the data from the operators. The UMTS900 values are based on the Okumura-Hata model for propagation and the

---

[35] As discussed in Appendix D, the 2G maximum cell radii used in the coverage scenario is defined only on the basis of 900MHz cell radii maximums, as 1800MHz is not considered for the coverage scenario.

values used for 2100MHz.[36] The Okumura-Hata model computes that the path loss at 900MHz is 9.79dB less than the equivalent path loss at 2100MHz. Based on this calculation, and the operator provided radii used for 2100MHz, we have assumed that the maximum cell radii are1.8 times larger for 900MHz, which is reflected in the input values.

Table 18: 3G by UMTS2100 and UMTS900 minimum and maximum cell radii

Geo-type	Minimum (km)	Maximum for UMTS2100 (km)	Maximum for UMTS900
Urban	0.05	0.47	0.85
Suburban	0.10	3.77	6.79
Rural	0.20	9.57	17.16

5.1.1.9 Grade of service

For the 2G network, the capacity of each BTS is calculated on the basis of an Erlang B calculation for the number of available time slots at a given busy hour grade of service. The model allows the grade of service to be adjusted in discrete levels from 0.5% to 5%, based on look up values in a table of Erlang values.

Operator data returns provided grade of service inputs of either 1% or 2%, with the majority reporting the latter. Typically BU-LRIC models produced by other European NRAs also contain a value of 1% or 2%.[37] As a consequence, the base case grade of service assumption is 2% throughout the time horizon of the model.

5.1.1.10 2G cell-specific loading

The model calculates the average busy hour load per unit for each geo-type, based on the served area and the split of total traffic per geo-type. This is then adjusted by a cell specific loading factor to allow for the impact of highly localised traffic demand that may lead to peaks on a cell-by-cell basis.

2G busy hour Erlang traffic load is uplifted by a cell-specific load factor of 10%. This factor accounts for additional, cell-specific, load beyond that accounted for by considering traffic in the busy hour and the traffic uplift factor applied in the load module.

5.1.1.11 3G cell-specific loading

3G busy hour traffic load is also uplifted for cell-specific load and this factor is also anticipated to be 10%, over and above that dimensioned from the load module.

---

[36] For further details on the Okumura-Hata model, see for instance Seybold, John S. (2005). *Introduction to RF Propagation*. New Jersey: Wiley-Interscience, pages 151-153.

[37] For example ANACOM (Portugal) applies a 1% grade of service factor and Ofcom (UK) uses 2%.

5.1.2 Minimum element requirements

A minimum quantity of elements is specified in the model. This defines the quantity of elements needed for a one-call coverage network (discussed below), or in the event that dimensioned load is insufficient to require an adequate quantity of elements that a mobile operator would reasonably be expected to deploy. This accounts for network dimensioning rules that in practice may be driven by factors other than traffic/subscriber-based metrics. Minimum 3G equipment quantities have been included as part of the minimum equipment requirement to be consistent with the assumption that 2G and 3G technologies incur costs from 2003, i.e. from the first year being modelled and throughout the time horizon. If an element is assigned a minimum requirement above one, this is typically driven by considerations such as diversity, redundancy and resilience. Values used are implied by the underlying network design, the characteristics of the Irish market and data returns from operators on the minimum number of elements.

With the exception of 2G RAN elements (discussed above), the quantity of minimum elements is defined statically as the minimum number required for a mobile network in Ireland across all years. The minimum elements defined to be required in 2013 are defined in the table below.

Table 19: Minimum element requirements

Element name	2013 minimum element requirement in final model
Site	111
BTS	111
TRX	111
BSC	3
Node B	1
3G radio	1
RNC	2
MSC-S	2
GMSC	2
MGW	6
HLR	2
EIR	1
AuC	1
SMSC	1
MMSC	1
IN	1
NMC	1
Signalling platform	2
Number portability platform	1
Abis (BTS_BSC)	111
IuCS (RNC_MGW)	1
IuCS (RNC_MSC/VLR)	1
Iur (RNC_RNC)	1
Iub (NB_RNC)	1
Nb (MGW_MGW)	1
E (MSC/VLR_GMSC)	1
A (BSC_MGW)	1

Element name	2013 minimum element requirement in final model
Mc (MSS/VLR_MGW)	1
900MHz 2G spectrum fees	3.6
1800MHz spectrum fees	14.8
900MHz 3G spectrum fees	5
2100MHz spectrum fees	15
Wholesale billing platform	1
VMS	2

Spectrum fee quantities are defined in terms of 2x1MHz blocks and therefore an element quantity of 15 corresponds to 2x15MHz in the model.

5.1.3 Planned element utilisation

An allowance is made against each of the specified technical capacities of each element, to take account of the maximum loading factors that apply for each network component relative to the theoretical design capacity of the element. This adjustment also takes account of the fact that network capacity upgrades have to occur in advance of the network reaching capacity limits.

Planned element utilisation figures are broadly consistent with the data returns provided by operators. Operator submissions on planned utilisation by element varied across elements. Variation may be due to differences in network operational planning procedures undertaken by each operator, with TRX and BTS typically rated at higher utilisation levels as compared to other elements. Larger variances in data request returns were observed where operators provided either actual current utilisation values, or results of stress testing analysis conducted by vendors. Utilisation values are held constant over time, with the exception of BTS, TRX, and BSC.[38]

The utilisation values used in the model are presented below (and these are located in d.6.1 of the model). Utilisation by element is assumed to be constant over the time horizon of the model, except for 2013 and 2014 when the utilisation of BTS, TRX, and BSC is assumed to be at 90%. Due to the temporary decrease in the hypothetical efficient operator’s holdings of the GSM900 spectrum in 2013 and 2014, the 2G RAN network is assumed to be utilised more heavily in these two years.

Table 20: List of assumed planning utilisation values

Element code	Element name	Planning utilisation value in final model
E01_001	Site	70%
E01_002	BTS*	75%
E01_003	TRX*	85%
E01_004	BSC*	70%
E01_005	Node B	70%
E01_006	3G radio	70%

---

[38] See Appendix F for discussion on utilisation values amendment of BTS, TRX, and BSC.

Element code	Element name	Planning utilisation value in final model
E01_007	RNC	70%
E02_001	MSC-S	70%
E02_002	GMSC	70%
E02_003	MGW	70%
E02_004	HLR	70%
E02_005	EIR	70%
E02_006	AuC	70%
E02_007	SMSC	70%
E02_008	MMSC	70%
E02_009	IN	70%
E02_010	NMC	70%
E02_011	Signalling platform	70%
E02_012	Number portability platform	70%
E03_001	Abis (BTS_BSC)	70%
E03_002	IuCS (RNC_MGW)	70%
E03_003	IuCS (RNC_MSC/VLR)	70%
E03_004	Iur (RNC_RNC)	70%
E03_005	Iub (NB_RNC)	70%
E03_006	Nb (MGW_MGW)	70%
E03_007	E (MSC/VLR_GMSC)	70%
E03_008	A (BSC_MGW)	70%
E03_009	Mc (MSS/VLR_MGW)	70%
E04_002	900MHz 2G spectrum fees	100%
E04_003	1800MHz spectrum fees	100%
E04_004	900MHz 3G spectrum fees	100%
E04_005	2100MHz spectrum fees	100%
E04_006	Wholesale billing platform	70%
E04_007	VMS	70%

**planned utilisation value is 90% in 2013 and 2014.*

Elements that do not represent logical groups of network equipment, such as spectrum fees, are included in the utilisation table and attributed a utilisation value of 100%, to allow a consistent calculation methodology across elements.

5.1.4 Asset lives

The asset life defines the useful economic life over which the asset is expected to be used. It serves as an input to the network purchasing algorithm in the network module. Assets are purchased to service traffic load and over time are removed in line with their asset lives and subsequently replaced with new elements in the appropriate quantity, given the traffic load of the network.

The table below presents the high and low of asset lives provided by operators, a sample of asset lives used in models developed by other European NRAs and the value used in the final model. It should be noted that network element lists are not consistent across NRA models and therefore the closest comparator has been included where more than one is available for the purposes of populating the table below. The asset lives in the final model are selected from operator data returns where a complete view of cost, utilisation and element dimensioning parameters are available and are cross-referenced against asset lives used by other European NRAs.

Spectrum fee costs are calculated on an annuity basis and therefore an asset life of one is used so that the annualised payment is applied each year.

The asset life of NMC has been revised down to 10 from 15 years. In addition, its unit capex and opex have been proportionately decreased, so as to maintain the same unit cost per year of asset life, in line with data returns provided by operators.

Table 21: List of minimum and maximum asset lives

Element name	Asset life in final model	Lowest life provided by operators	Highest life provided by operators	Portugal NRA	Romania NRA	Sweden NRA	UK NRA
Site	8	5	40	15	10	25	18
BTS	8	5	8	10	8	10	10
TRX	8	5	8	10	8	10	8
BSC	8	4	8	7	8	8	9
Node B	8	5	20	10	8	10	8
3G radio	8	5	20	10	8	10	8
RNC	8	3	8	7	8	8	8
MSC-S	8	N/A	N/A	8	8	8	10
GMSC	8	3	8	8	8	8	10
MGW	8	3	8	7	8	8	N/A
HLR	8	3	8	8	8	8	10
EIR	8	N/A	N/A	6	N/A	8	N/A
AuC	8	N/A	N/A	6	N/A	8	N/A
SMSC	8	N/A	N/A	5	8	6	10
MMSC	8	N/A	N/A	5	8	6	10
IN	3	3	3	5	7	6	N/A
NMC	10	N/A	N/A	6	7	10	6
Signalling platform	8	N/A	N/A	N/A	7	N/A	N/A
Number portability platform	8	N/A	N/A	N/A	7	N/A	N/A
Abis (BTS_BSC)	8	5	40	10	7	5	10
IuCS (RNC_MGW)	8	5	20	10	15	5	10
IuCS (RNC_MSC/VLR)	8	5	20	10	15	5	10
Iur (RNC_RNC)	8	5	20	10	15	5	10
Iub (NB_RNC)	8	5	40	10	7	5	10
Nb (MGW_MGW)	8	5	20	10	15	5	10
E (MSC/VLR_GMSC)	8	5	20	10	15	5	10
A (BSC_MGW)	8	5	20	10	15	5	10

Element name	Asset life in final model	Lowest life provided by operators	Highest life provided by operators	Portugal NRA	Romania NRA	Sweden NRA	UK NRA
Mc (MSS/VLR_MGW)	8	5	20	10	15	5	10
900MHz 2G spectrum fees	1	N/A	N/A	100	N/A	20	50
1800MHz spectrum fees	1	N/A	N/A	100	N/A	20	50
900MHz 3G spectrum fees	1	N/A	N/A	100	N/A	20	50
2100MHz spectrum fees	1	N/A	N/A	100	N/A	20	50
Wholesale billing platform	8	N/A	N/A	3	7	N/A	N/A
VMS	8	N/A	N/A	6	7	N/A	N/A

Source: *Operator data and Deloitte analysis*

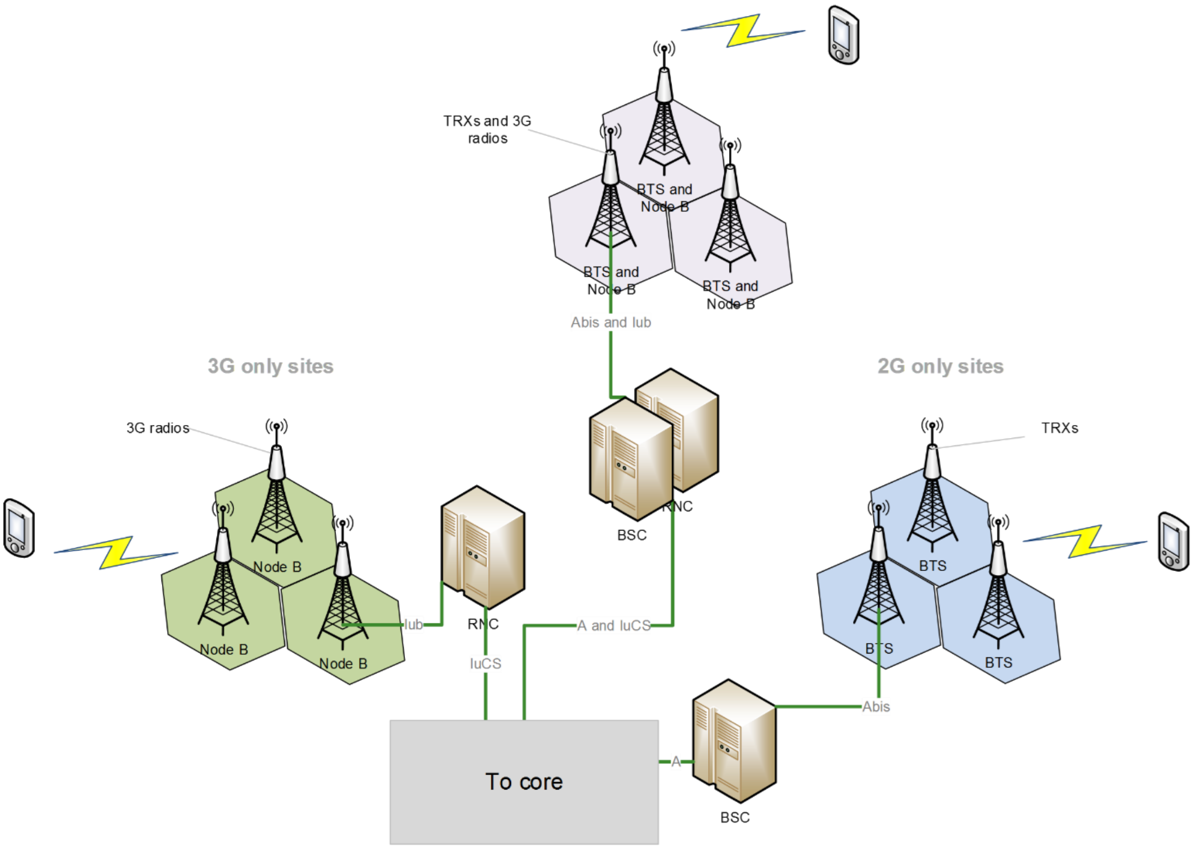
The majority of operators reported relatively consistent asset life profiles for active network equipment in both the access and core, typically in the range of five to eight years, though in some cases this was as low as three. As a consequence, the majority of operators provide data that is broadly aligned to values used in models developed by other NRAs, a sample of which is presented in the table above.

This range of asset lives (five to eight) has also been provided by most operators for transmission and site equipment, with the exception of one operator that provided values of 20 to 40 years. This operator also provided a 20 year life for active 3G RAN network equipment. Cost data provided by this operator however did not relate to the unit cost of elements, but instead corresponded to network upgrade costs throughout the year and as a consequence these values are not applied for the asset lives or cost values. This range of asset lives provided by operators is lower than that seen in other models. The upper bound figure provided by operators is taken for these elements in the final model.

5.2 Network diagrams

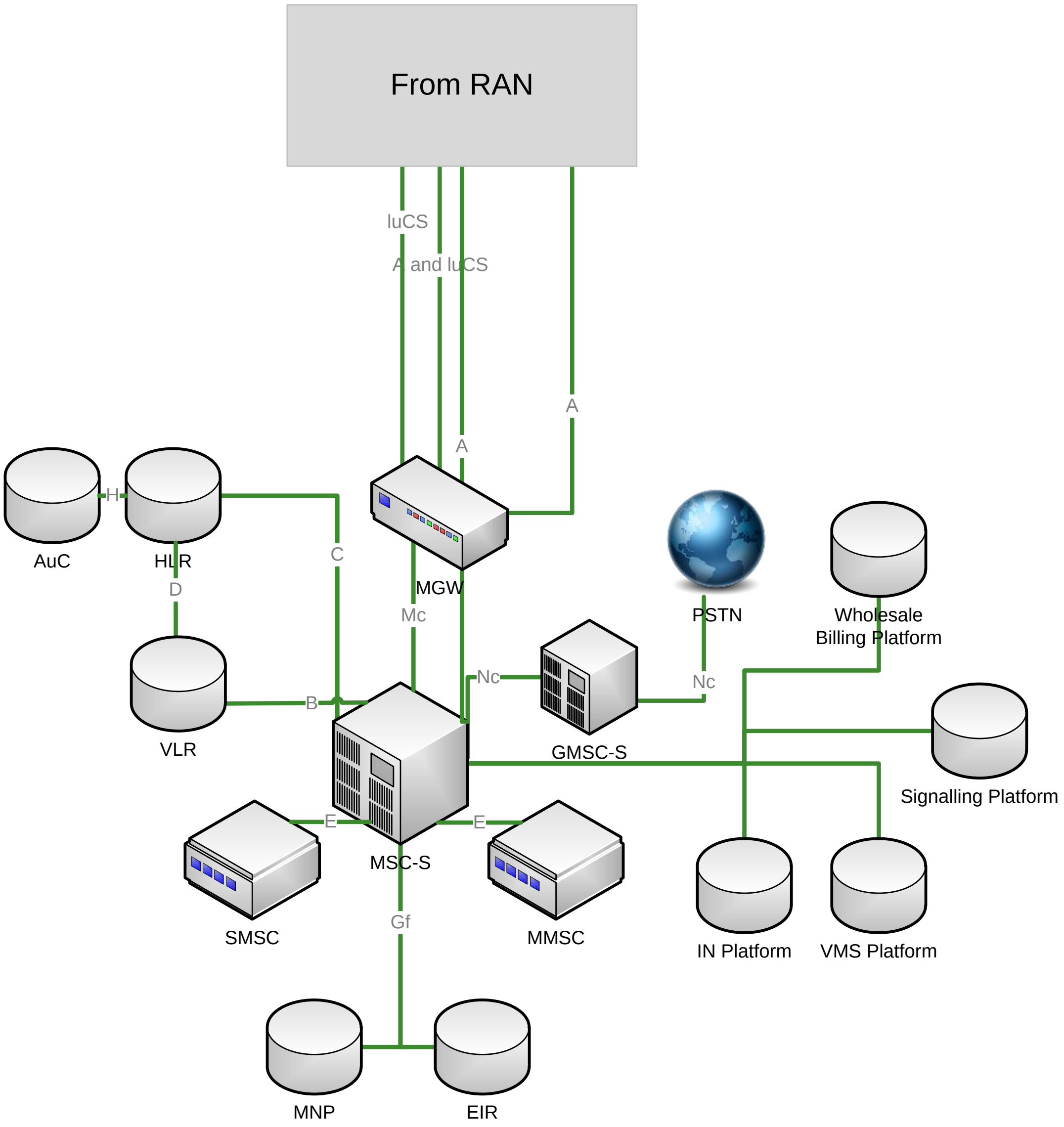
The RAN and core network diagrams are presented below.

Figure 16: Logical RAN elements of the hypothetical existing operator



Source: *Deloitte analysis.*

Figure 17: Logical core elements of the hypothetical existing operator



Source: *Deloitte analysis.*

5.3 Element dimensioning

Each element defined in the model is dimensioned subject to a specific dimensioning rule, or defined by the minimum assumed quantity required.

In the sections that follow, the rules used to dimension elements are defined. In each case, planned element utilisation values, discussed in section 5.1.2, are applied. To avoid duplication and repetition, this step is not documented for each element, but can be seen and reviewed in the corresponding sections of the worksheets that contain dimensioning rules.

The final model considers the pure LRIC of mobile termination. The model therefore includes the relevant elements that are used by voice services. Any elements dedicated, for example, to data services are not included as they are not relevant to voice services. This avoids introducing unnecessary calculations in the dimensioning, purchasing profile and cost attribution, for elements which are not related to voice termination and which thus cannot be considered as a contributor to the pure LRIC of this service.

5.3.1 Radio Access Network (RAN)

This section defines the network elements contained in this element group and the dimensioning rules used in the model to determine the quantities required each year.

5.3.1.1 Sites

Sites are the physical premises and ancillary equipment at which a RAN node is located. The site may take a variety of forms including a rooftop location, or a plot of land. The site costs include towers and antennas, equipment shelters, power provision, security fencing etc.

Dimensioning rule

The annual number of required sites is calculated from the outputs of 2G and 3G cell dimensioning. It is assumed that 900MHz and 1800MHz 2G cells as well as 2G and 3G cells are collocated to the extent this is feasible.

The degree of collocation varies materially across data returns. This variation might be driven in part by the geo-classification used by each operator, as well as the design of each network and the timing of deployment of different network technologies. Collocation values used in the model align with the geo-classification of traffic and other network parameters and are static across the time horizon of the model. As the radii of 900MHz and 1800MHz cells may differ, it is not assumed that all 1800MHz sites will be collocated at 900MHz sites. However, factors such as cost savings and service quality benefits from using optimal sites are expected to lead to some collocation. The values used in the final model are presented in Table 22 below. These values have been updated in the revised final model, reflecting updated data responses from the operators.

The calculation of the proportion of 2G 1800MHz cell collocation with 900MHz cells is presented below. This is defined separately for each geo-type.

$$\%\ 2G\ 1800MHz\ collocation = \frac{\%\ combined\ 900MHz\ \&\ 1800MHz\ sites}{1 - \%\ 3G\ only\ sites} \qquad (9)$$

Table 22: Proportion of 2G 1800MHz cells collocated with 2G 900MHz cells

Geo-type	2003-2013	2014-2032
Urban	76%	84%
Suburban	98%	98%
Rural	100%	100%

3G sites are also assumed to be collocated at existing 2G sites, to the extent that this is feasible. The calculation of the degree of 3G collocation is presented below. This is defined separately for each geo-type.

$$\%\ 3G\ 2100MHz\ collocation = \frac{\%\ combined\ 2G\ \&\ 3G\ sites}{\%\ combined\ 2G\ \&\ 3G\ sites + \%\ 3G\ only\ sites} \tag{10}$$

The degree of 3G collocation at 2G sites as used in the final model are presented in the table below.

Table 23: Proportion of 3G sites collocated at 2G sites

Geo-type	2003-2013	2014-2032
Urban	96%	95%
Suburban	94%	91%
Rural	95%	89%

Calculation of sites, based on number of cells

The number of sites required for 2G 900MHz, 2G 1800MHz, 3G 2100MHz and 3G 900MHz cell locations are calculated based on the number of required cells and the degree of sectorisation of these cells. These values differ from the actual number of physical sites; as various sites may be collocated at the same location.

Calculation of actual physical sites, given collocation

The calculation of the number of sites is presented below.

$$2G\ \&\ 3G\ sites_t = 3G\ sites_t - 3G\ only\ sites_t \tag{11}$$

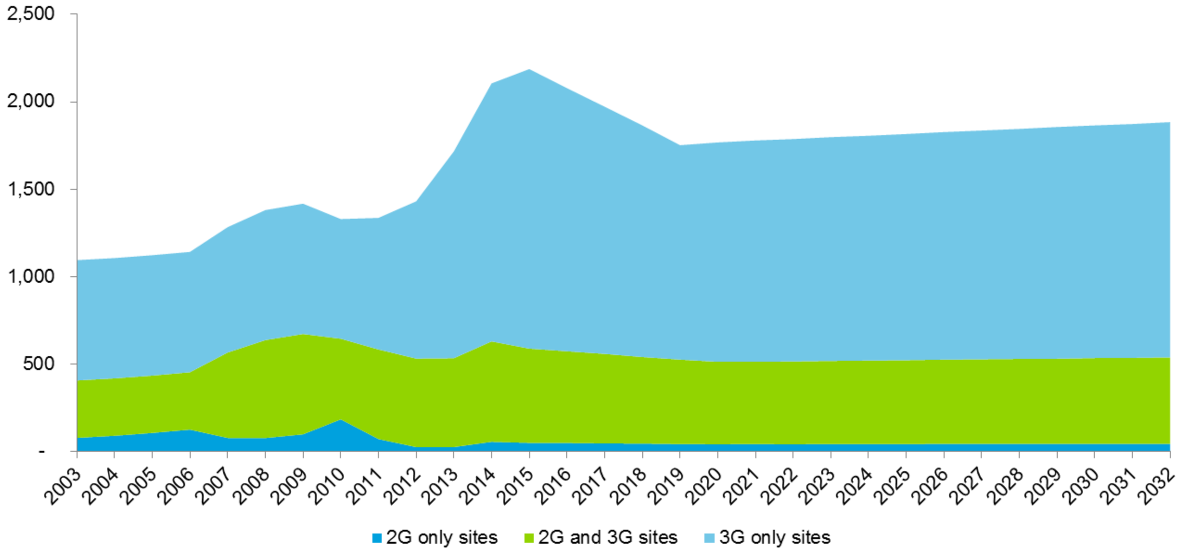
$$2G\ only\ sites_t = 2G\ sites_t - Combined\ 2G\ \&\ 3G\ sites_t \tag{12}$$

$$3G\ only\ sites_t = 3G\ sites_t - (Combined\ 2G\ \&\ 3G\ sites_t \cdot \%\ 2G\ \&\ 3G\ collocation_t) \tag{13}$$

Dimensioning calculation steps used to generate the required number of cells can be found in BTS/TRX and NodeB/3G radio sections (sections 5.3.1.2 and 5.3.1.4 respectively). The profiles of sites dimensioned in the network for the full traffic scenario are presented in the figure below. As can be seen, the broad trend over the period of interest of the model is one of a decrease in standalone 2G sites, which are converted to 2G and 3G sites, followed by a modest drop in combined sites, as LTE rollout occurs. After this point, combined 2G and 3G site quantities increase slightly, as overall data usage and population growth leads to a sustained growth in overall traffic.

The increase in the number of sites in 2013 and 2014 is due to the increase in 2G sites. This is a consequence of the low amount of GSM900 spectrum held by the hypothetical operator. i.e., 3.6MHz in the two years as a result of the assumption that UMTS900 is launched in 2013, with 2x5MHz of 900MHz refarmed from GSM to UMTS, and the fact that the "1/N" methodology yields 8.6MHz of 900MHz spectrum in 2013-14. This increase is subdued by the normalisation algorithm that is subsequently applied to element quantities.

Figure 18: Profile of site types in final model



Source: *Deloitte analysis.*

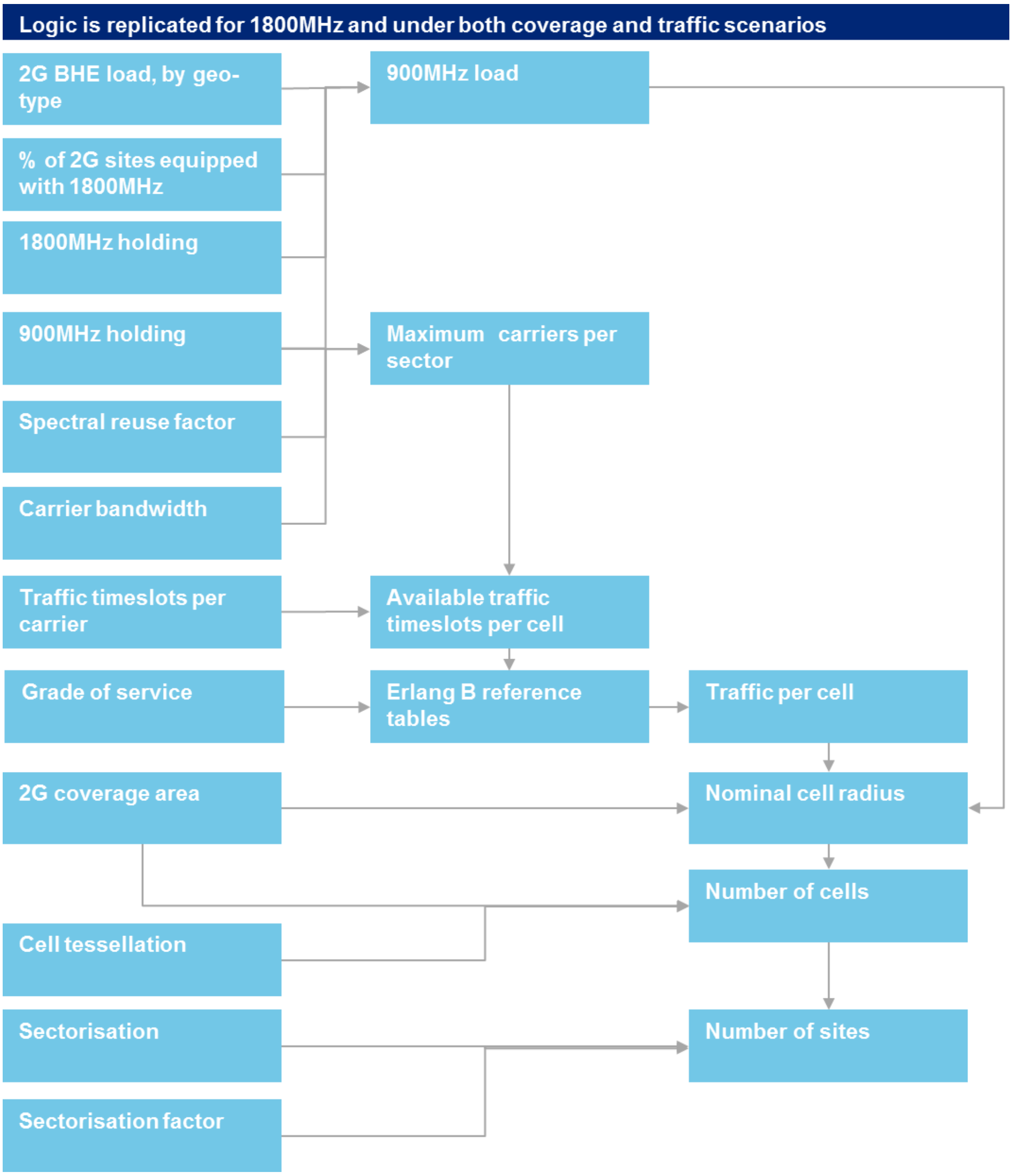
5.3.1.2 BTS and TRX

The BTS is made up of electronics equipment and antennae that together comprise a 2G access site. The TRX is active network equipment that transmits and receives communication signals between user equipment and the mobile network. TRXs are part of the BTS, but as the number of TRX required can vary independently of the number of BTS, they are considered separately for this analysis.

Dimensioning rule

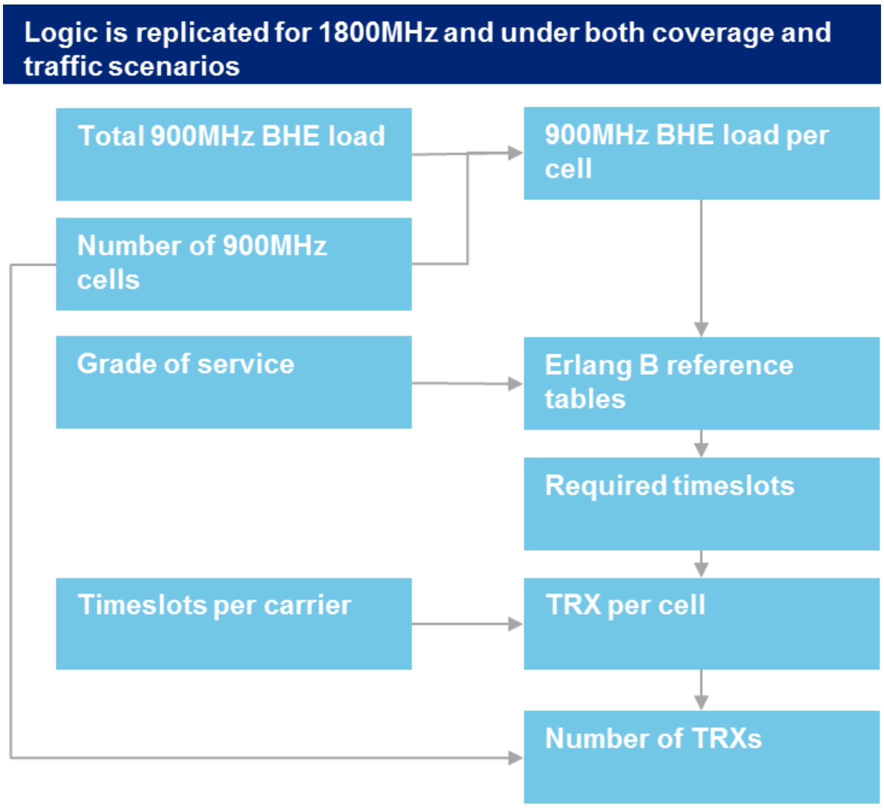
The dimensioning rule for BTS and TRX is a multistage process. The diagram below shows a simplified step-by-step calculation flow for BTS and TRX, which are then explained in more detail below.

Figure 19: High-level logical flow of BTS calculations (presented for 900MHz)



Source: *Deloitte analysis.*

Figure 20: High-level logical flow of TRX calculations (presented for 900MHz)



Source: *Deloitte analysis.*

The steps below summarise the methodology and calculation flow for element dimensioning. The calculations presented below relate to 900MHz elements. A similar process is undertaken for 1800MHz, but for the avoidance of duplication, the steps are not repeated in this document.

BTS – 2G cells

Route factored 2G busy hour voice and data load is determined, by geo-type, in busy hour Erlang. 2G busy hour traffic load is apportioned to 900MHz (or 1800MHz) spectrum on the basis of spectrum holding and the proportion of sites equipped with 1800MHz as shown below:

$$900MHz\ load_{t,g} = \frac{2G\ load_{t,g}}{\left(1 + \left(\%\ sites\ equipped\ with\ 1800MHz \times \frac{1800MHz\ holding}{900MHz\ holding}\right)\right)} \qquad (14)$$

where *t* denotes the year of service and *g* denotes the geo-type.

- The maximum carriers per sector are calculated as follows:

$$Maximum\ carriers\ per\ sector = \frac{900MHz\ holding}{Carrier\ bandwidth} \times Spectral\ reuse\ factor \qquad (15)$$

- Available timeslots per cell are determined from the number of traffic timeslots per carrier[39] and the maximum carriers per sector, as per equation (15).

- The calculated traffic per cell is calculated, based on a call against the Erlang B table, using the number of available traffic timeslots per cell and the radio path grade of service. It should be noted that the Erlang B table provides linear approximation.

- The nominal radius, per geo-type, is calculated as follows:

$$Nominal\ radius_{t,g} = \left(\frac{Traffic\ per\ cell_{t,g}}{Hexagonal\ area\ parameter \times \frac{900MHz\ load_{t,g}}{2G\ area\ covered_{t,g}}} \right)^{\frac{1}{2}} \tag{16}$$

where *t* denotes the year of service and g denotes the geo-type.

- The computed nominal cell radii are compared against defined maximum and minimums, to check if the result is outside the specified propagation range.

- The number of cells is derived from the nominal radii, coverage area and cell tessellation factor, as follows:

$$Number\ of\ 900MHz\ cells_{t,g} = \frac{Geo\text{-}type\ area \times 2G\ coverage_{t,g}}{Hexagonal\ area\ parameter \times Nominal\ radius_{t,g}^{2} \times (1 - tesselation\ factor)} \tag{17}$$

where *t* denotes the year of service and g denotes the geo-type.

- The number of sites is derived from the number of cells, the degree of sectorisation and the sectorisation factor. This output, along with the counterpart for 1800MHz cells and 3G cells, serve as an input to the site calculations presented in section 5.3.1.1. The calculation in the final model is as follows:

$$Number\ of\ 900MHz\ sites_{t,g} = \frac{Number\ of\ 900MHz\ cells_{t,g}}{\%\ omnisector\ sites_{t,g} + (Sectorisation\ factor \times \%\ trisector\ sites)} \tag{18}$$

where *t* denotes the year of service and g denotes the geo-type.

TRX

- The effective busy hour Erlang load per cell, by geo-type, is then calculated, based on the total 900MHz busy hour Erlang load and the total number of 900MHz cells.

---

[39] Eight timeslots are available per carrier, with (on average) 0.5 timeslots reserved for signalling.

- The implied number of required timeslots associated with this load is determined, by calling against the Erlang B table, using load per cell and the radio path grade of service.
- The required number of TRX per cell is calculated by dividing the required number of timeslots by the number of traffic timeslots per carrier. The revised final model incorporates the utilisation factor of the TRX in this calculation. The calculation of the number of TRX per cell required is set to 1 when the calculation results in a value strictly between 0 and 1. This ensures that an average cell does not deploy less than 1 TRX.
- The number of TRX required is determined by multiplying the number of TRX per cell, calculated in the previous step, by the number of cells.

5.3.1.3 BSC

The BSC is equipment that manages the BTS, assigning and controlling radio resources. The BSC also acts as a concentrator/switch between BTS and MSC. BSCs may be collocated with the MSC, or remote.

Dimensioning rule

Element quantities are calculated based on the number of BTS a BSC is capable of managing. The minimum is defined based on the coverage scenario as discussed in section 5.1.2 and Appendix D.

5.3.1.4 Node B and 3G radio[40]

The access node of the 3G network transmits and receives communication signals from user equipment and the rest of the mobile network. The 3G radio, the carrier card, serves the same purpose in the 3G network as the 2G TRX.

Dimensioning rule

The dimensioning rule for Node B and 3G radios is a multistage process. As with 2G, the model calculates the cell radii based on capacity available for a given bit rate, separately for UMTS2100 and UMTS900, the available spectrum and the calculated demand per square km.

The dimensioning rule has been revised to directly reference the 3G busy hour voice traffic in units of MB as opposed to first referencing the Erlang value and then converting it into MB. This does not impact the overall traffic load, but simplifies the calculation process by avoiding an additional step in conversion. This calculation is consistent with the assumption that 3G elements dimensioning is on the basis of traffic in Mbit/s units.[41]

The throughput is calculated according to the following formula:

---

[40] See sections 4.3.2 and 4.3.2.1 for further detail on specific factors that account for additional load headroom in 3G radio dimensioning.

[41] As discussed in section 4.3.2.

$$Throughput(kbit/s) = \left(\frac{W \times LF}{Eb/No \times V \times \left((1-a)+i\right).}\right) \tag{19}$$

where:

W = bit rate

LF = Load Factor

Eb/No = required Energy per bit over noise

V = channel activity factor

a = orthogonality factor

i = other to own cell interference

This throughput is calculated for a range of HSPA Air Interface (AI) bit rates from 1,800 bit/s to 21,100 bits/s. The model allows each bit rate to be selected or de-selected.

The model then determines the actual cell radii for each geo-type from the calculated throughput, the amount of available spectrum and the traffic per unit area according to the following process:

- For each HSPA bit rate
    - The lower of (the maximum cell radius and the calculated cell radius)
    - The higher of (the minimum cell radius and the calculated cell radius)

  where the calculated cell radius is the square root of the traffic per cell divided by 2.6 x the total traffic.

The 3G busy hour traffic load is apportioned to 2100MHz and 900MHz spectrum band respectively by a formula similar to that used for the 2G spectrum split.

$$2100MHz\ load_{t,g,v} = \frac{3G\ load_{t,g,v}}{\left(1 + \left(\%\ area\ illuminated\ with\ UMTS900 \times \frac{900MHz\ holding}{2100MHz\ holding}\right)\right)} \tag{20}$$

where *t* denotes the year of service, *g* denotes the geo-type, and v denotes voice or data traffic.

Based on this, the model calculates the number of cells for each geo-type, each spectrum band, and each AI bandwidth, taking into account the total served area and the cell tessellation factor.

$$Number\ of\ 2100MHz\ cells_{t,g} = \frac{Geo\text{-}type\ area \times 3G\ coverage_{t,g}}{Hexagonal\ area\ parameter \times Nominal\ radius_{t,g}^{2} \times (1 - tesselation\ factor)} \tag{21}$$

where t denotes the year of service and g denotes the geo-type.

Taking the maximum active AI bandwidth gives the nominal cell radius per geo-type, from which the model is able to calculate the number of sites and required number of radios per cell.[42] The number of 3G sites required is derived from the number of cells, the degree of sectorisation and the sectorisation factor. This output, along with the equivalent calculation for 1800MHz cells and 3G cells, serve as an input to the site calculations presented in section 5.3.1.1. The calculation in the final model is as follows:

$$Number\ of\ 2100MHz\ sites_{t,g} = \frac{Number\ of\ 2100MHz\ cells_{t,g}}{\%\ omnisector\ sites_{t,g} + (Sectorisation\ factor \times \%\ trisector\ sites)} \quad (22)$$

where t denotes the year of service and g denotes the geo-type. The same calculation follows for 900MHz 3G sites.

The number of 3G radios is determined by the product of the number of cells and the number of radios per cell that are required. In the revised final model, the number of radios per cell also incorporates the utilisation factor for 3G radios and a floor at 1 is introduced, so that the number of 3G radios per an average cell is at least 1. This ensures that the number of radios does not fall below 1 per cell, which would imply that some cells deploy 0 physical number of radios.

The total number of 3G sites is given by the sum of UMTS900 and UMTS2100 sites, adjusted for the degree of their collocation.

Sectorisation and collocation factors are incorporated within the calculation as described in the 2G description above.

Checks are made in the model to determine whether the radio parameters are propagation limited, (i.e. the maximum cell radius is reached), or interference limited (i.e. the minimum cell radius is reached) and to ensure that the required number of radios per cell does not exceed the capacity of the available spectrum.

5.3.1.5 RNC

The RNC is the 3G counterpart to the BSC equipment; managing Node Bs and assigning and controlling radio resources.

Dimensioning rule

Element quantities are calculated based on the number of 3G cells a RNC is capable of managing.

---

[42] The model calculates the maximum AI bandwidths under full traffic scenario (TS_0) and uses these bandwidths for the remaining traffic scenarios, the scenario excluding voice termination (TS_1). This calculation in the updated model is further discussed in Appendix F.

5.3.2 Core

This section defines the network elements contained in this element group and the dimensioning rules used in the model to determine the quantities required each year.

5.3.2.1 MSC-S

Equipment that co-ordinates traffic and routing across both 2G and 3G network (assuming the core network is all IP).

Dimensioning rule

The minimum number of MSC-S assumed in the network is set to four. Element quantities are dimensioned dynamically on the basis of busy hour call attempts and corresponding capacity, if quantities exceed the minimum required. Busy hour call attempts are included from inputs from the load module. Call attempts are modified by the addition of an uplift factor of 30% for unsuccessful calls to capture attempts that are either called subscriber busy or are unanswered. Subscriber capacity, per MSC-S is included as a further potential dimensioning constraint. The maximum of the two resulting required elements is taken as the number of elements required in a given year.

5.3.2.2 GMSC

The GMSC provides switching functionality for traffic onto or off the network, to other mobile networks or to fixed networks. During the pre-consultation process operators offered to review whether or not input data was available on the cost, dimensioning, utilisation and asset life estimate costs of the GMSC port. The comments by the operators during the consultation processes have been taken into account. Following these comments, the assumption on GMSC incrementality has been amended so that the cost of PoI-facing ports is considered incremental to mobile termination services. For the purposes of calculating MTR a cost estimate of the PoI-facing port has been assigned to GMSC.

Dimensioning rule

It is assumed that the number of GMSC required is determined by the capacity of a 2Mbit/s PoI facing port. The element cost has been assigned to reflect the cost of interconnection ports.

5.3.2.3 MGW

The media gateway includes the functionality to act as a bridge between 2G and 3G networks; transcoding both media and signalling. The element also provides call control and signalling functionality as determined by the controlling MSC-S.

Dimensioning rule

Element quantities are dimensioned on the basis of busy hour call attempts and corresponding element capacity. Busy hour call attempts are included from inputs from the load module. Call attempts are modified by the addition of an uplift factor of 30%, for unsuccessful calls; to capture attempts that are either called subscriber busy or are unanswered.

5.3.2.4 AuC

The authentication centre confirms the identity of SIM cards attempting to attach to the network.

Dimensioning rule

Element quantities are based on subscriber capacity and a minimum of one AuC is assumed across the model time horizon.

5.3.2.5 NMC

The NMC includes network management/operational systems as well as core testing and monitoring equipment.

Dimensioning rule

It is assumed that one NMC is required throughout the model time horizon.

5.3.2.6 HLR

HLR contains both hardware and software that maintains the database of registered subscribers.

Dimensioning rule

Element quantities are based on the subscriber database capacity. For resilience a minimum of two elements are assumed to be required.

5.3.2.7 EIR

The equipment identity register provides IMEI verification services.

Dimensioning rule

Element quantities are based on the subscriber database capacity. One EIR is assumed through the model time horizon.

5.3.2.8 SMSC

The SMSC element receives, stores and retrieves short messages sent to subscribers on the network.

Dimensioning rule

Element quantities are based on the SMS throughput capacity per second, compared to the dimensioned busy hour traffic for SMS, per second.

5.3.2.9 MMSC

The MMSC element receives stores and retrieves multimedia messages sent to subscribers on the network.

Dimensioning rule

Element quantities are based on the MMS throughput capacity per second, compared to the dimensioned busy hour traffic for MMS, per second.

5.3.2.10 IN

The Intelligent Network platform provides value-added traffic services, primarily related to voice calls. It works alongside the signalling platform and delivers services such as call screening, reverse charges and premium rate number provision.

Dimensioning rule

One element is assumed to be required over the time horizon of the model.

5.3.2.11 Signalling platform

The signalling platform element includes equipment required to maintain the signalling network layer; providing network service functions such as routing, call set up/teardown and transmitting call-related information.

Dimensioning rule

One element is assumed to be required over the time horizon of the model.

5.3.2.12 Number portability platform

The number portability platform element includes the equipment and systems required to facilitate porting.

Dimensioning rule

One element is assumed to be required over the time horizon of the model.

5.3.3 Transmission (Tx)

This section defines the network elements contained in this element group and the dimensioning rules used in the model to determine the quantities required each year.

Dimensioning rule

Backhaul links (Abis and Iub) are assumed to share the same common medium when RAN nodes are collocated.

Operator data returns provided data on the proportion of sites backhauled using various transmission media. Microwave links and fibre links were predominately observed.

The number of microwave and fibre backhaul links is determined based on the quantity of sites, and the proportion of these sites that are linked by microwave or fibre, in line with operator submissions.

The relative aggregate mix of microwave and fibre backhaul use is applied in the cost module to define the average cost of backhaul.

As sites may be dedicated to one technology or to both 2G and 3G, the backhaul of shared sites is equally distributed between Abis and Iub elements.

Core links are assumed to be operated on a national ring and to be entirely fibre-based. In the final model, seven nodes are assumed to be on the fibre ring, distributed across major Irish cities. The calculation assumes that all core elements are collocated at these seven sites to the extent it is possible. This ring is also assumed to be partially meshed.

Additional sites are considered, dependent on the number of elements dimensioned for each logical link. Costs of the ring are apportioned to each element, based on the number of links required for each interface. Any additional links required for a specific element are directly attributed to that element.

Consequently both backhaul and core links present in the final model represent physical links. Collocated 2G and 3G RAN sites will share a single physical backhaul link, the cost of which is apportioned between 2G or 3G backhaul elements. Similarly the physical core links are apportioned between logical core transmission links using the same methodology.

5.3.4 Other

This section defines the network elements contained in this element group and the dimensioning rules used in the model to determine the quantities required each year.

5.3.4.1 Spectrum licence fees

Spectrum licence fees represent the annual cost of a 2x1MHz block of spectrum, in the corresponding frequency.

Dimensioning rule

Quantities are defined, in line with those presented in section 5.1.1.7, and are assumed to be static across the time horizon of the model, except for a reduction of 2x5MHz in available 2G spectrum in the 1800MHz band, in 2014, which is assumed to be cleared for LTE.

The 2009 EC Recommendation indicates that only spectrum considered incremental to the provision of the increment of interest should be considered in the calculation of pure LRIC.[43] As a consequence, it would be necessary to consider that an operator would have purchased less spectrum without the provision of mobile termination traffic.

The dimensioning outputs of the RAN elements discussed throughout section 5.3 are dependent, either directly or through the dimensioning of other elements, on the quantity of spectrum held by the hypothetical existing operator. A reduction in the quantity of spectrum held by the hypothetical existing operator would, all else equal, lead to a countervailing dampening in the reduced quantity of active network elements required.

5.3.4.2 Wholesale billing platform

This element includes costs associated with running billing systems associated with wholesale transactions.

Dimensioning rule

One billing platform is assumed to be in place throughout the time horizon of the model.

5.3.4.3 VMS

This element includes costs associated with maintaining the voicemail system.

Dimensioning rule

This element is dimensioned on the basis of subscriber capacity and the minimum elements required.

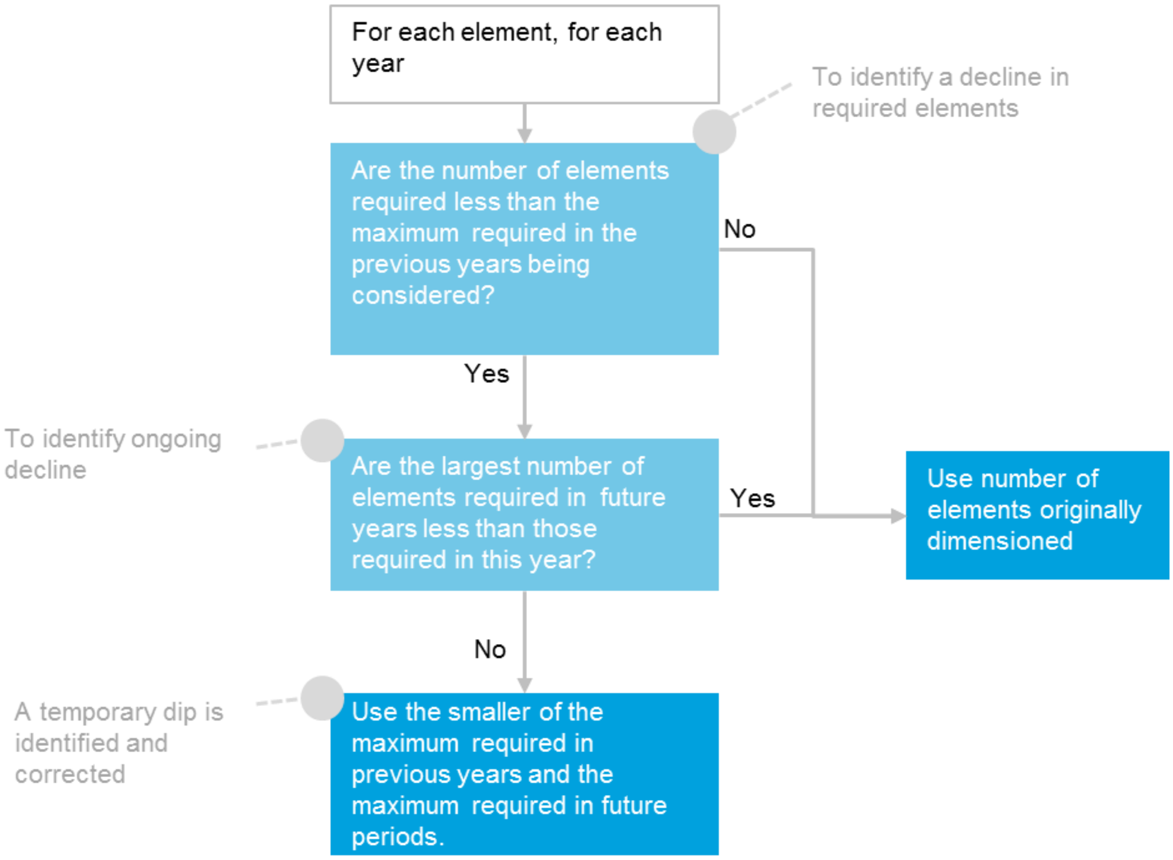
5.4 Normalisation algorithm

The number of elements required to be in service each year is passed through a normalisation algorithm. The algorithm identifies and corrects for any temporary dips in network load in a given year, due to factors such as population profiles, or macroeconomic conditions. Were a temporary decline in the required elements to coincide with a major reinvestment cycle, the outputs of the model would imply that an operator restricts its capital reinvestment, only to be required to reinvest in further incremental purchases in future years. Instead, the purchasing profile is smoothed to account for temporary dips in annual network load by implying the operator does not respond to temporary dips in load by reconfiguring or reducing its network capability. The logical flow of the algorithm is presented below.

---

[43] 2009 EC Recommendation, page 8.

Figure 21: Logical flow of the normalisation algorithm



***Source:** Deloitte analysis.*

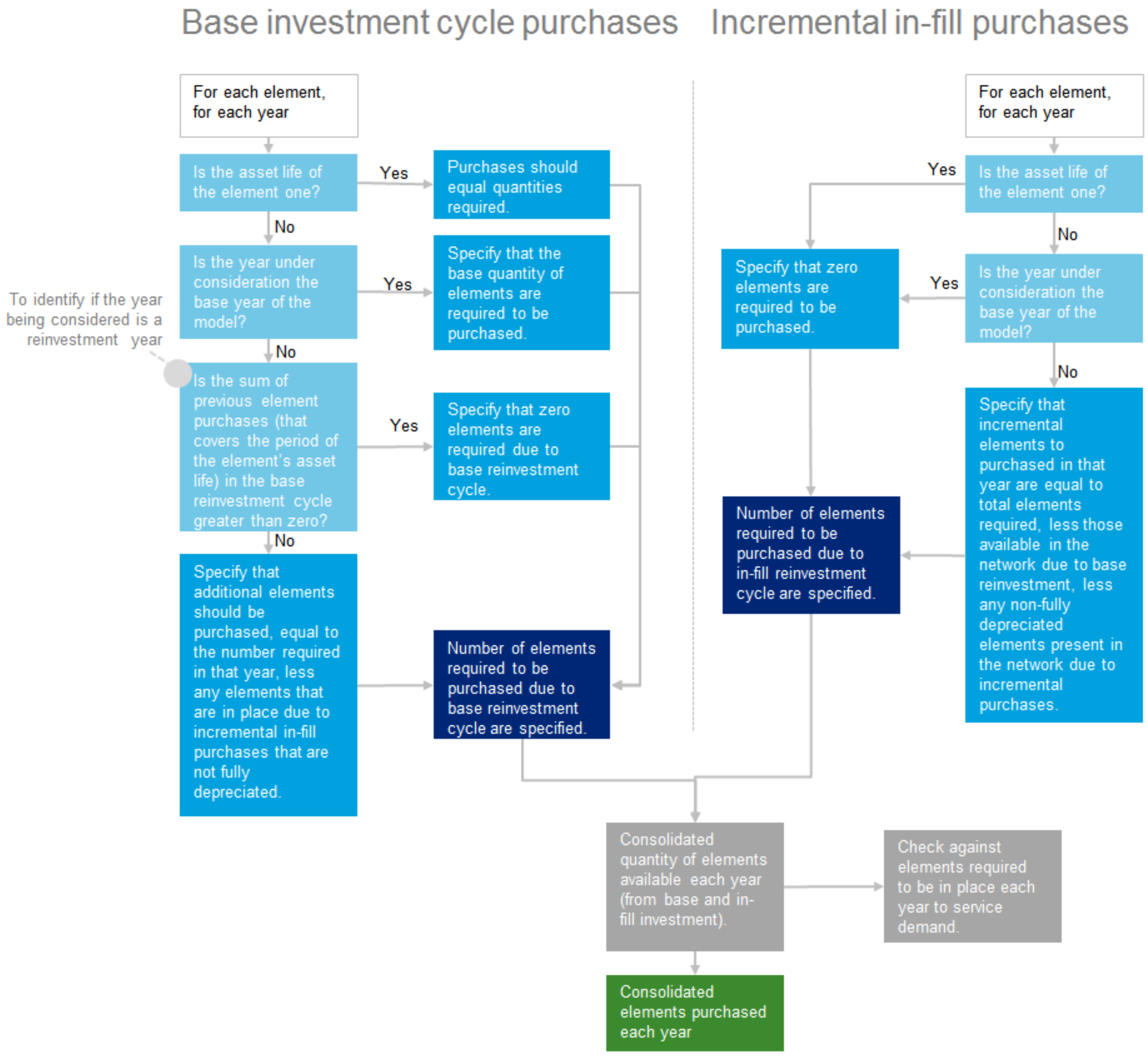
5.5 Purchasing algorithm

The purchase profile algorithm determines the number of elements to be purchased each year to satisfy service load each year. The algorithm considers purchases in two stages:

- major re-investment cycles, determined by the asset life of the element; and
- in-fill investment in years between major investment cycles, to add further elements to the network if required.

If the number of elements required falls, between investment cycles, then a new, lower, number of elements are repurchased at a lower level in the next cycle. A check is in place to ensure that elements available each year are adequate to satisfy demand. It is possible that the number of elements available exceed those required between investment cycles, if network load falls after elements have been purchased.

Figure 22: Logic of purchase algorithm



Source: *Deloitte analysis.*

5.6 Network module outputs

The outputs of the network module are as follows:

- the required number of elements each year due to the traffic load scenario;
- the required number of elements in the coverage-only scenario;
- the purchasing profile of the required elements for both traffic load and coverage-only scenarios; and
- backhaul transmission mix.

5.7 Network module results

The table below presents the quantity of elements dimensioned in the full traffic scenario in the final model for the period 2013-15.

Table 24: Quantity of network elements 2013-15[44]

Element	2013	2014	2015	2013 minimum reported by operators	2013 maximum reported by operators
Site	1,708	2,105	2,188	1,229	2,200
BTS	2,334	2,375	2,091	1,614	2,230
TRX	3,733	3,733	3,733		
BSC	12	12	12	1	25
Node B	1,680	2,045	2,138	1,367	1,754
3G radio	10,975	17,059	18,656	7,035	8,646
RNC	4	6	6	1	10
MSC-S	3	3	3	2	4
GMSC	1,012	1,054	1,096	2	4
MGW	6	6	6	2	5
HLR	2	2	2	1	2
EIR	1	1	1	2	4
AuC	1	1	1	2	4
SMSC	1	1	1	1	4
MMSC	1	1	1	1	4
IN	1	1	1	1	3
NMC	1	1	1	1	1
Signalling platform	2	2	2		
Number portability platform	1	1	1		
Abis (BTS_BSC)	360	360	318	1,129	2,128
IuCS (RNC_MGW)	3	2	3	8	20
IuCS (RNC_MSC/VLR)	2	2	2		
Iur (RNC_RNC)	2	2	2		
Iub (NB_RNC)	1,404	1,745	1,870	1,229	1,482
Nb (MGW_MGW)	3	2	3	20	20

---

[44] Note: care should be taken in interpreting the element quantities in the model and reported by operators for backhaul links (Abis and Iub) and more broadly on transmission links. Values reported in the table of values provided by operators correspond to the number of logical elements. In contrast, the number of links reported in the model represents the quantity of physical links attributable to each network technology and so do not duplicate any logical links that are physically collocated on the same transmission medium.

Element	2013	2014	2015	2013 minimum reported by operators	2013 maximum reported by operators
E (MSC/VLR_GMSC)	-	-	-		
A (BSC_MGW)	5	4	4	50	50
Mc (MSS/VLR_MGW)	3	2	3		
900MHz 2G spectrum fees	4	4	4		
1800MHz spectrum fees	15	10	19		
900MHz 3G spectrum fees	5	5	5		
2100MHz spectrum fees	15	15	15		
Wholesale billing platform	1	1	1		
VMS	2	2	2	1	6

The number of elements in the model falls broadly within the ranges of elements provided by the operators. Element quantities typically vary by the operator’s network load and market share. However the core elements and the associated transmission links are usually defined by the overall network topology and therefore may be less sensitive to the market share.

The number of sites and Node Bs lie in the range of values provided by operators in 2013. The number of sites, which is one of the material contributors to the network cost, falls within the middle of the interval provided by the operators and responds appropriately to the assumed market share (and therefore spectrum holdings) and network coverage.

The number of TRXs deployed on the network was not provided by the operators. Nevertheless, the implied quantity of TRXs can be calculated from the reported number of BTSs and the number of TRXs per sector. The implied numbers yield a range of TRXs deployed per operator that contains the dimensioned number of TRXs deployed by the hypothetical existing operator. Moreover, it is consistent for all scenarios when scenario analysis on market share is undertaken.

There is a decrease in the amount of GSM900 spectrum held by the hypothetical operator, i.e. 3.6MHz in the two years (2013 and 2014) as a result of the assumption that UMTS900 is launched in 2013, with 2x5MHz of 900MHz refarmed from GSM to UMTS, and the fact that the “1/N” methodology yields 8.6MHz of 900MHz spectrum in 2013-14 (a total of 30MHz paired spectrum was available in the two years). As a result, a faster migration of traffic from 2G to 3G is assumed in 2013 and 2014 than was reported by the operators. For this reason, the 3G network carries a higher share of overall traffic than that reported by the operators as part of the Section 13(D) data request in September 2013. The number of 3G radios increases from 9,968 in 2012 to 10,975 in 2013. The number of Node Bs in the model is in the range reported by the operators, which considering the higher number of 3G radios, is expected to be due to the assumption of no bi-sectorisation. With lower average sectorisation, determined by the sectorisation factor of UMTS2100 and UMTS900 (which lies between 1 and 3), the number of Node Bs would increase. The number of Node Bs is further determined by the number of 3G cells and busy hour traffic. The results in the table above assume a sectorisation factor of 3 for UMTS2100 and UMTS900. Operators report that cells are tri-sectorised in more than 90% of cases.

As in the previous version of the model, the core element quantities are also broadly consistent with operator submissions which also exhibited less variation between submissions.

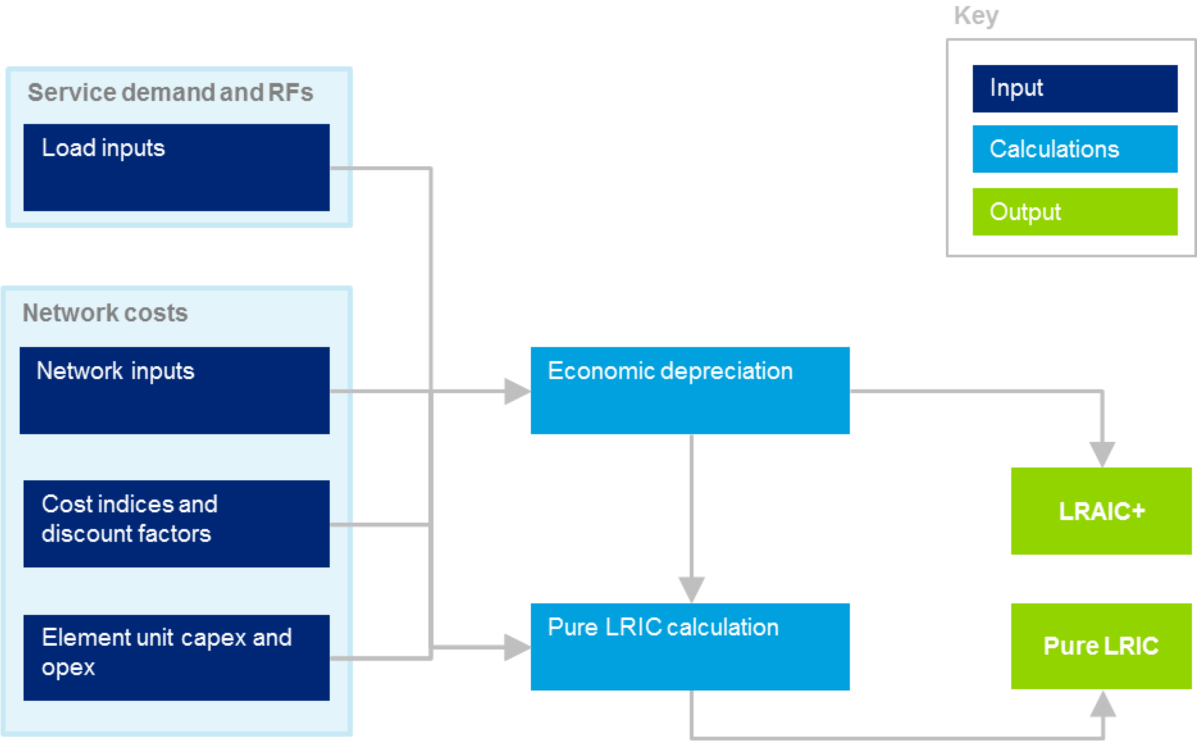
6 Cost Module

The cost module takes the load outputs of service volumes and route factors as well as the network element purchasing profile from the network module to calculate the long-run costs of relevant increments.

Outputs from the load and network modules are combined with unit capex and opex prices, indirect mark-ups and price indices to determine the annual expenditure associated with installing, maintaining and operating the network dimensioned to support the specified network load.

This annual expenditure is then attributed to each year of the model and across the set of services, in line with the economic depreciation algorithm. This calculation is run under the full traffic scenario and without mobile voice termination, to generate the outputs of the final model.

Figure 23: Cost module logical flow



Source: *Deloitte analysis.*

6.1 Network costs

6.1.1 Element costs and indirect mark-ups

Element unit capex values are based on the operators' data responses, and comparison with international precedent. The ranges of potential input values are presented in the tables below. The following table present the unit capex values currently used in the model.

The unit capex of NMC has been revised to account for the revision of its asset life from 15 to 10 years. This is reflected in the tables below, both for capex and opex. Moreover, the GMSC unit cost has been set to the value listed below. The figure is based on the cost of a PoI facing port. These amendments have no impact on the pure LRIC as neither of these network elements is modelled to be incremental to termination traffic. In the case of NMC, the overall cost attributed to termination traffic remains unchanged. As for the GMSC, it is assumed that the boundary of the mobile termination call services is defined at, but not including, the GMSC port. Backhaul links, Abis and Iub capex and opex are calculated from the weighted cost based on geo-type relevant traffic.

Table 25: Element unit capex cost comparison in 2013 EUR

Element name	Capex in the model	Lowest capex provided by operators	Highest capex provided by operators	Portugal NRA	Romania NRA	Sweden NRA	UK NRA
Site	88,392	75,000	127,500	154,919	59,238	97,948	58,135
BTS	34,839	7,596	34,839	46,028	19,123	18,126	
TRX	3,030	2,500	3,030	1,967	705	1,864	1,745
BSC	861,703	400,000	2,134,790	553,880	552,545	949,450	250,777
Node B	33,713	10,932	33,713	46,028	17,801	9,322	25,461
3G radio	20,197	5,000	20,197	9,834	1,939	9,322	1,590
RNC	1,317,259	380,000	1,692,307	791,257	521,172	690,509	426,018
MSC-S	2,274,289	2,274,289	7,770,242	1,092,599	998,017	863,136	2,447,296
GMSC	1,200			Due to wide range in specification of elements and definition of network, NRA mappings have not been undertaken.			
MGW	925,000	925,000	1,940,037				
HLR	750,000	347,121	2,011,489				
EIR	1,750,000						
AuC	750,000						
SMSC	400,000						
MMSC	400,000						
IN	324,219	324,219	324,219				
NMC	31,975,376	47,963,064	47,963,064				
Signalling platform	10,000,000						
Number portability platform	1,000,000						
Abis (BTS_BSC)	41,748	8,000	94,304				
IuCS (RNC_MGW)	94,304	8,000	94,304				
IuCS (RNC_MSC/VLR)	94,304	8,000	94,304				
Iur (RNC_RNC)	94,304	8,000	150,000				
Iub (NB_RNC)	41,748	8,000	94,304				
Nb (MGW_MGW)	94,304	8,000	150,000				
E (MSC/VLR_GMSC)	94,304	8,000	150,000				
A (BSC_MGW)	94,304	8,000	94,304				
Mc (MSS/VLR_MGW)	94,304	8,000	150,000				

Element name	Capex in the model	Lowest capex provided by operators	Highest capex provided by operators	Portugal NRA	Romania NRA	Sweden NRA	UK NRA
900MHz 2G spectrum fees	-	N/A	N/A				
1800MHz spectrum fees	-	N/A	N/A				
900MHz 3G spectrum fees	-	N/A	N/A				
2100MHz spectrum fees	-	N/A	N/A				
Wholesale billing platform	1,000,000	N/A	N/A				
VMS	4,000,000						

Table 26: Element unit opex cost comparison in 2013 EUR

Element name	Opex in the model	Lowest opex provided by operators	Highest opex provided by operators	Portugal NRA	Romania NRA	Sweden NRA	UK NRA
Site	17,678	16,000	21,000	7,910	3,598	7,104	7,610
BTS	6,968			1,789	956	1,812	
TRX	606			87	35	186	632
BSC	172,341			2,002	27,627	390,720	25,078
Node B	6,743	1,416	16,000	4,520	890	1,279	4,079
3G radio	4,039			1,130	97	1,279	159
RNC	263,452			339,000	26,059	284,160	188,228
MSC-S	454,858			565,000	49,901	473,600	322,088
GMSC	240			Due to wide range in specification of elements and definition of network, it is difficult to compare between models.			
MGW	185,000						
HLR	150,000	167,000	307,200				
EIR	350,000	17,000	17,000				
AuC	150,000						
SMSC	80,000						
MMSC	80,000						
IN	64,844						
NMC	6,395,075						
Signalling platform	2,000,000						
Number portability platform	200,000						
Abis (BTS_BSC)	8,350	0	8,000				
IuCS (RNC_MGW)	18,861	14,000	75,000				
IuCS (RNC_MSC/VLR)	18,861	14,000	75,000				
Iur (RNC_RNC)	18,861	14,000	75,000				
Iub (NB_RNC)	8,350	0	8,000				
Nb (MGW_MGW)	18,861	14,000	75,000				
E (MSC/VLR_GMSC)	18,861	14,000	75,000				

Element name	Opex in the model	Lowest opex provided by operators	Highest opex provided by operators	Portugal NRA	Romania NRA	Sweden NRA	UK NRA
A (BSC_MGW)	18,861	14,000	75,000				
Mc (MSS/VLR_MGW)	18,861	14,000	75,000				
900MHz 2G spectrum fees	771,982						
1800MHz spectrum fees	480,982						
900MHz 3G spectrum fees	771,982						
2100MHz spectrum fees	714,888						
Wholesale billing platform	-						
VMS	200,000						

Operators provided fewer data points for direct unit opex associated with each network element in comparison to unit capex. As a consequence, a ratio has been specified for unit opex as a proportion of capex, which has been set at 20%.This methodology has some limitations, namely that while unit capex cost may be a reasonable indicator of required opex in some cases,[45] this is not necessarily always the case. The approach of applying a ratio against capex for opex values was considered to be most appropriate given data inputs and is more conducive to top-down reconciliation with inputs data provided by operators. This approach is deployed by ANCOM, where the value is set at 5%. A comparison of the simple average implied ratio of opex to capex in Portugal, Sweden and UK presented in Table 25 and Table 26 generate results of 16%, 23% and 20% respectively.

Indirect capital and opex mark-ups are applied to create a fully-loaded cost per element. As bottom-up models are developed to dimension the required network elements needed to service a specified level of traffic load, additional network support functions that an operator needs to invest in, or incur ongoing costs for, are added onto the cost of network equipment.

The indirect mark-ups represent costs such as power consumption, device cooling and maintenance tools; costs incurred in provisioning the network elements modelled and supporting the network. Operators provided limited information on mark-ups and therefore an aggregate mark-up has been applied instead.

BU-LRIC models developed by other European NRAs typically include an aggregate mark-up value across elements. Where element-specific mark-ups have not been provided, an aggregate mark-up value has been applied, partly guided by reconciliation discussed below. For capex, this value is set at 40% and for opex the value is set at 20%. In comparison, the ANACOM model uses 34% and 13% for indirect capex and opex mark-up, respectively. The table below provides the indirect capex and opex mark-ups applied to each element.

---

[45] More expensive network equipment may require more cooling, may have higher power draw and may require a greater attribution of network operations man power to maintain.

Table 27: Indirect cost mark-ups

Element name	Indirect capex mark-up	Indirect opex mark-up
Site	40%	20%
BTS	40%	20%
TRX	65%	20%
BSC	40%	20%
Node B	40%	20%
3G radio	40%	20%
RNC	40%	20%
MSC-S	40%	20%
GMSC	40%	20%
MGW	40%	20%
HLR	40%	20%
EIR	40%	20%
AuC	40%	20%
SMSC	40%	20%
MMSC	40%	20%
IN	40%	20%
NMC	40%	20%
Signalling platform	40%	20%
Number portability platform	40%	20%
Abis (BTS_BSC)	40%	20%
IuCS (RNC_MGW)	40%	20%
IuCS (RNC_MSC/VLR)	40%	20%
Iur (RNC_RNC)	40%	20%
Iub (NB_RNC)	40%	20%
Nb (MGW_MGW)	40%	20%
E (MSC/VLR_GMSC)	40%	20%
A (BSC_MGW)	40%	20%
Mc (MSS/VLR_MGW)	40%	20%
900MHz 2G spectrum fees	N/A	0%
1800MHz spectrum fees	N/A	0%
900MHz 2G spectrum fees	N/A	0%
2100MHz spectrum fees	N/A	0%
Wholesale billing platform	40%	20%
VMS	40%	20%

The resulting aggregate outputs have been compared to aggregate operator financial data to assess if the resulting cost values approximate those experienced by Irish operators. One operator provided a monthly income statement compiled for March 2013. Depreciation and amortisation for the one month period implied an annualised value of approximately €154m. This is broadly in line with the average depreciation profile produced for the hypothetical existing operator of €152m per year for the five-year period 2009-2013.[46] Segmented financial statements of Eircom for 2012 and 2013 report a total capital expenditure of €177m and €51m respectively for its mobile operator (Meteor).[47] The annual capex calculated in the model is broadly in a similar range. In the one month management account statements provided by another operator, opex, excluding commercial and support function, summed to €9.8m for the relevant month, implying an estimated annual opex, excluding these categories, of €116m. In 2013, the model generates a network opex value of €162m, up from £106m in 2012.[48] The model is considered to provide a reasonable representation of the cost profile of an Irish operator.

6.1.2 Site costs

Site costs are a mixture of macro and micro sites. The unit capex and opex values used in the model are a weighted combination of costs of each of these site types as provided by an operator.

Operators may share site space with other mobile network operators or other communication providers. Sharing sites may result in a reduced effective unit cost for an operator. This may be through a variety of mechanisms including the following examples:

- if the network operator owns the site, the operator may receive a revenue stream from other communications providers which effectively reduces the net cost of ownership of the site;
- if the network operator leases space on another network operator’s site, or a third party site, this may be at a cost that is lower than self-provision; or
- alternatively an operator may have a cooperative agreement with another operator whereby access to sites is shared with reciprocity.

As part of data requests returns, operators provided information on the proportion of their sites which is shared with an effective cost saving (i.e. for the purposes of the modelling exercise, sites that are shared but do not result in an effective cost saving are not distinguished from standalone sites). Operators also submitted their estimates of the effective opex and capex cost saving by site,

---

[46] The profile of capex in the model is not smooth and results in substantial changes from year to year as a result of the investment profile based on elements’ asset lives, which is the reason for averaging capex over the five-year period. Capex values after economic depreciation is less appropriate, as the value depends on the relative amount of HEO’s traffic volume in 2013. The economic depreciation smooths the capex profile in line with HEO’s annual traffic volumes. For instance, a relatively high amount of traffic in 2013 would result in a relatively high amount of capex depreciation in 2013 (including the expected future capex). The opposite is true if the 2013 traffic volume in the model was relatively low.

[47] Eircom, Annual Report for Bondholders years end June 30 2013, http://siteassets.eircom.net/assets/static/pdf/IR/EHIL_Annual_Report_for_Bondholders_years_end_June_30_2013.pdf, p156, Retrieved 2014.

[48] This value excludes opex associated with the annuity value of spectrum licences, in line with management account data provided by the operators.

for these sites. Estimates submitted by operators were broadly aligned with approximately 50% site savings for capex costs and 33% savings for opex, for each site that is shared, with a resulting cost saving. The proportion of sites shared (which induce an effective cost saving) and the extent of that cost saving are applied to the total unit opex and unit capex of site costs. As part of the pre-consultation process, operators were provided with the calculations used to define this adjustment.

6.1.3 Spectrum fees

Spectrum fees are obtained from ComReg's 2012 Multi-Band Spectrum Auction[49] with the assumption that "Final Upfront Fees" and "Total Spectrum Usage Fees" of ComReg Document Number 12/123 are in present value terms. Moreover, Ofcom[50] provides the price ratios of 800, 900 and 1800MHz bands resulting from the Irish auction, as part of a review of spectrum auction prices. Combining the two sources of information, the present value of paired 1MHz blocks per year for each band is calculated. The value for 2100MHz band comes from a DotEcon report commissioned by ComReg.[51] The report details an auction-band average value of €29.4m for a 15-year licence. The WACC for the hypothetical existing operator is applied as the discount factor and the resulting annuity values for the 15-year licence periods are obtained. The implied price and annuity values of paired 5MHz blocks are presented in the following table. The annuity is higher than the implied price due to the cost of capital that is used to finance spectrum fees. The cost of capital used 8.63%, as in the rest of the model and as per ComReg Decision 15/14 (Cost of Capital),[52] The operator uses 900MHz for both 2G and 3G technologies, due to refarming of paired 5MHz blocks of 900MHz spectrum in 2013. As a result, the same price for 2G and 3G 900MHz spectrum is used, based on the value below.

Table 28: Spectrum fees

Band	2013 implied price for 5MHz of paired spectrum (EUR)	Annuity of 5MHz of paired spectrum (EUR)
900MHz	1,982,977	3,852,380
1800MHz	1,267,805	2,400,369
2100MHz	1,960,000	3,568,041

***Source:** ComReg, Ofcom, and Deloitte internal calculation.*

6.1.4 Indices

Network operators provided unit capex and unit opex cost values, by network element for their most recent period of financial statements (typically 2012/13) and an estimate for 2014. Based on this input data, the calculations within the model determine the network element requirements and consequent equipment purchasing profiles over a 30-year period. Therefore, it is necessary to

---

[49] ComReg Document Number 12/123.

[50] Ofcom (10 October 2013) "Annual licence fees for 900MHz and 1800MHz spectrum: Consultation", Figure 4.2.

[51] ComReg Document Number 12/23.

[52] http://www.comreg.ie/_fileupload/publications/ComReg14136.pdf

identify an appropriate unit cost to apply in each year of the model, for any elements purchased in that year.

Capex and opex are entered in the model in terms of their 2013 values. In order to obtain nominal capex and opex values by element, per year, capex and opex nominal price indices are applied. These indices reflect the implied price index for the modern equivalent asset (MEA) of each element. For each element, the annual MEA price change is taken as constant over the time horizon of the model, thus resulting in compound growth or a decrease in nominal prices. These price trends, presented in Table 29 and Table 30, display the annual percentage changes applied to each categorised group of elements and are based on indices observed in BU LRIC models developed by other European NRAs.

The annual change in MEA prices is assumed to be small but positive for sites, which are subject to property prices. The remaining elements fall in categories with either constant or decreasing price trends. The annual change in elements' capital and operating costs is consistent with NRA precedent, taking into account that the model uses a nominal price change and so includes both real MEA price change and inflation effects. For instance, ANACOM's[53] model (Portugal) uses real indices. Its capex real annual price change is assumed to be 1% for sites and between 0% and -6% for most other elements. This is broadly comparable to the indices used in the current model, assuming average inflation of 1.75% in Ireland. ANACOM also assumes a constant real price in opex for sites and most transmission, 5% appreciation in TRX and IN and decreasing opex prices for other equipment. Moreover, ANCOM's model (Romania), which uses nominal price indices, assumes higher appreciation in site capex (8%) which may be driven by Romanian property prices and higher average inflation in the late 2000s, and a reduction of 5% per annum for other element capex. Its opex is assumed to be 6% for sites and transmission, and 5% for other equipment.

Table 31 shows the index codes assigned to each element.

Table 29: Capex nominal price indices

Index code	Element index category	Annual change
CI_001	Data servers	-4%
CI_002	Tx and switches	-3%
CI_003	Core	-1%
CI_004	Constant	0%
CI_005	Sites	2%

Table 30: Opex nominal price indices

Index code	Element index category	Annual change
OI_001	Data servers	-4%
OI_002	Tx and switches	-2%
OI_003	Core	-1%
OI_004	Constant	0%
OI_005	Sites	2%

---

[53] http://www.anacom.pt/text/render.jsp?contentId=1125693&showMetadata=0&contentStatistics=0&showTags=1&channel=graphic, Retrieved 2013

Table 31: Price index to element mapping

Element name	Capex price index	Opex price index
Site	CI_005	OI_005
BTS	CI_001	OI_001
TRX	CI_001	OI_001
BSC	CI_001	OI_001
Node B	CI_002	OI_002
3G radio	CI_001	OI_001
RNC	CI_002	OI_002
MSC-S	CI_002	OI_002
GMSC	CI_002	OI_002
MGW	CI_002	OI_002
HLR	CI_002	OI_002
EIR	CI_002	OI_002
AuC	CI_002	OI_002
SMSC	CI_002	OI_002
MMSC	CI_002	OI_002
IN	CI_002	OI_002
NMC	CI_002	OI_002
Signalling platform	CI_002	OI_002
Number portability platform	CI_002	OI_002
Abis (BTS_BSC)	CI_003	OI_003
IuCS (RNC_MGW)	CI_003	OI_003
IuCS (RNC_MSC/VLR)	CI_003	OI_003
Iur (RNC_RNC)	CI_003	OI_003
Iub (NB_RNC)	CI_003	OI_003
Nb (MGW_MGW)	CI_003	OI_003
E (MSC/VLR_GMSC)	CI_003	OI_003
A (BSC_MGW)	CI_003	OI_003
Mc (MSS/VLR_MGW)	CI_003	OI_003
900MHz 2G spectrum fees	CI_004	OI_004
1800MHz spectrum fees	CI_004	OI_004
900MHz 3G spectrum fees	CI_004	OI_004
2100MHz spectrum fees	CI_004	OI_004
Wholesale billing platform	CI_002	OI_002
VMS	CI_002	OI_002

The WACC and inflation used in the final model is as displayed in Table 32. For more details on WACC, see section 2.6. In the updated model, the WACC has been revised to the value given below. The GDP deflator is taken as the measure of inflation as more specific deflators are unavailable for this period. This is considered to be more appropriate than the consumer price index (CPI), since the network equipment is not well reflected in the CPI.

Table 32: Discount factors and the values of the selected years

Series	Source	Type of a series	2013	2014	2015
Nominal pre-tax WACC	ComReg	Constant	8.63%	8.63%	8.63%
GDP Deflator (2013=100%)	World Bank Database (NY.GDP.DEFL.ZS), extracted Nov. 2013.	Variable until 2013.	100.00		
Inflation	Calculation based on the GDP deflator historical values and ComReg suggested forecast.	Based on the GDP deflator until 2013. Assumed forecast of 1.75% p.a. (2014-2032)	1.61%	1.75%	1.75%
Nominal discount factor (2013 = 100)	Calculation	Variable series; WACC adjusted for inflation.	100%	92%	85%

6.1.5 Capex and opex calculation

The element purchasing profiles and element requirements determine the number of elements needed for the network to provide the services demanded by the subscribers. These are calculated in section 5.

Capital expenditures per element are calculated by taking the number of elements purchased in a given year and multiplying it by that year's price. The price is obtained from the 2013 value indexed against the respective category, as discussed in 6.1.4. This is displayed in equation below,

$$\begin{aligned}(capital\ expenditure)_{e,t} &= (element\ purchases)_{e,t} \times (unit\ capex)_{e,2013} \\ &\times (capex\ index\ by\ category)_{e,t}\end{aligned} \tag{23}$$

where the subscript *e* denotes the element in the list (for the full list see Table 4) and *t* denotes the year (2003-2032).

Operating expenditures are calculated in a similar manner. The value is obtained by multiplying the number of elements in operation by the opex nominal price:

$$\begin{aligned}(operating\ expenditure)_{e,t} &= (network\ element\ requrements)_{e,t} \times (unit\ opex)_{e,2013} \\ &\times (opex\ index\ by\ category)_{e,t}\end{aligned} \tag{24}$$

Where, again, *e* denotes the element in the list (for the full list see Table 4) and *t* the year of calculation (2003-2032).

Capex and opex add up to the total nominal costs incurred by the network in a given year. Along with the service volumes these are primary inputs to the economic depreciation.

6.1.6 Business overhead mark-up

The costs described above relate to the direct and indirect cost of network operations and do not account for costs associated with the administrative and other associated overhead costs incurred as part of maintaining the hypothetical operator's business. To account for business overheads, the full network costs are marked-up by 12%.The business overhead mark-up was determined on the basis of Irish operator information. This result is also in-line with parameters used in other BU-LRAIC+ models.[54]

6.2 Economic depreciation

In line with the 2009 EC Recommendation, as described in section 2.5, the model uses economic depreciation in the calculation of current costs.

The model uses 2013 costs of capex and opex and nominal price indices to profile the nominal costs of the network elements across the time horizon of the model. The 2013 prices are based on values submitted by the Irish operators. Moreover, a nominal pre-tax WACC is used for discounting in the model. A nominal pre-tax WACC is used to discount the inflation and pre-tax cash flows of the mobile operator. Consequently, the outputs are expressed in nominal terms, meaning that the calculated termination rate and economic costs are expressed in nominal amounts.

Capex and opex are depreciated separately by the same algorithm in order to profile the total costs with the service demand volumes.

The intuition behind the algorithm is the following.

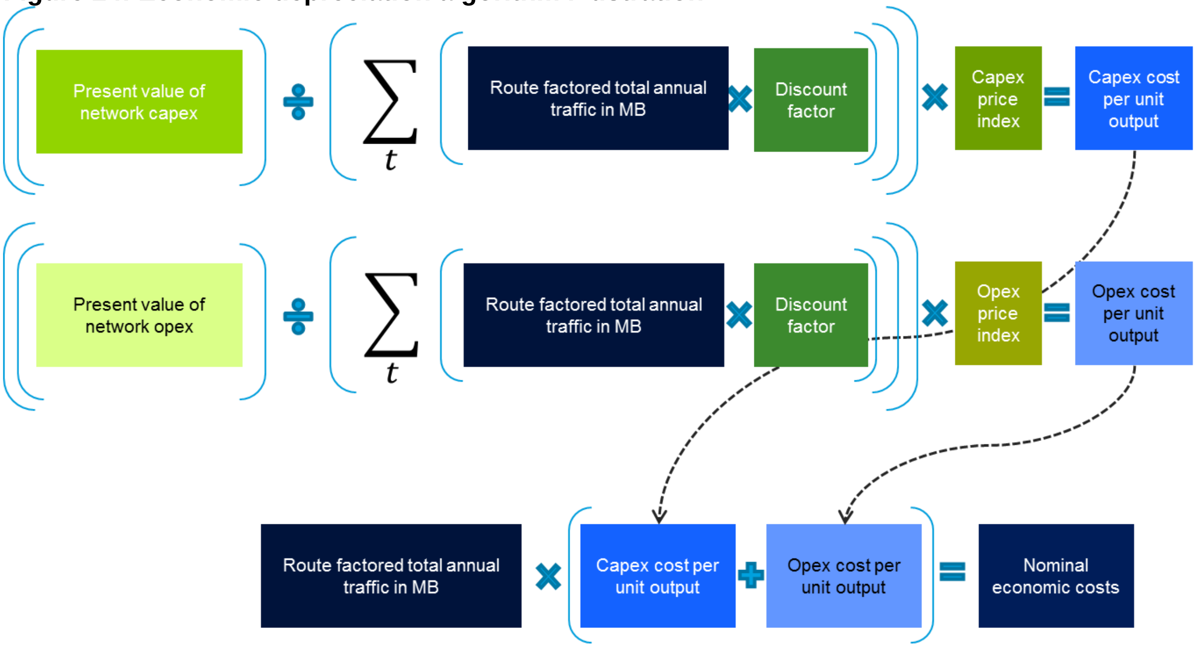
- Firstly, the capex and opex costs are discounted to the 2013 present value and divided by the discounted volumes (using the same discount factor based on nominal pre-tax WACC). This yields the present value of costs per unit of traffic at the network launch;
- Secondly, the present 2013 costs per unit of traffic are profiled with the capex and opex indices to yield nominal costs per unit of traffic for each year of modelled time horizon; and
- Finally, multiplying these costs by total volumes yields the total costs per year and the full recovery of the present value costs.

Economic depreciation is used in the model in the calculation of total economic costs as well as the incremental costs that are the basis for the pure LRIC.

---

[54] For example, the Swedish regulator (PTS) used a business overheads mark-up of 6%, the Portuguese regulator (ANACOM) applied a mark-up of 4.5% on average over the timespan of the model and in the UK Ofcom applied a value of 11%. It should be noted that the business overheads are not necessarily defined in the same way across different jurisdictions, so the international figures may not be directly comparable.

Figure 24: Economic depreciation algorithm illustration



Source: *Deloitte analysis.*

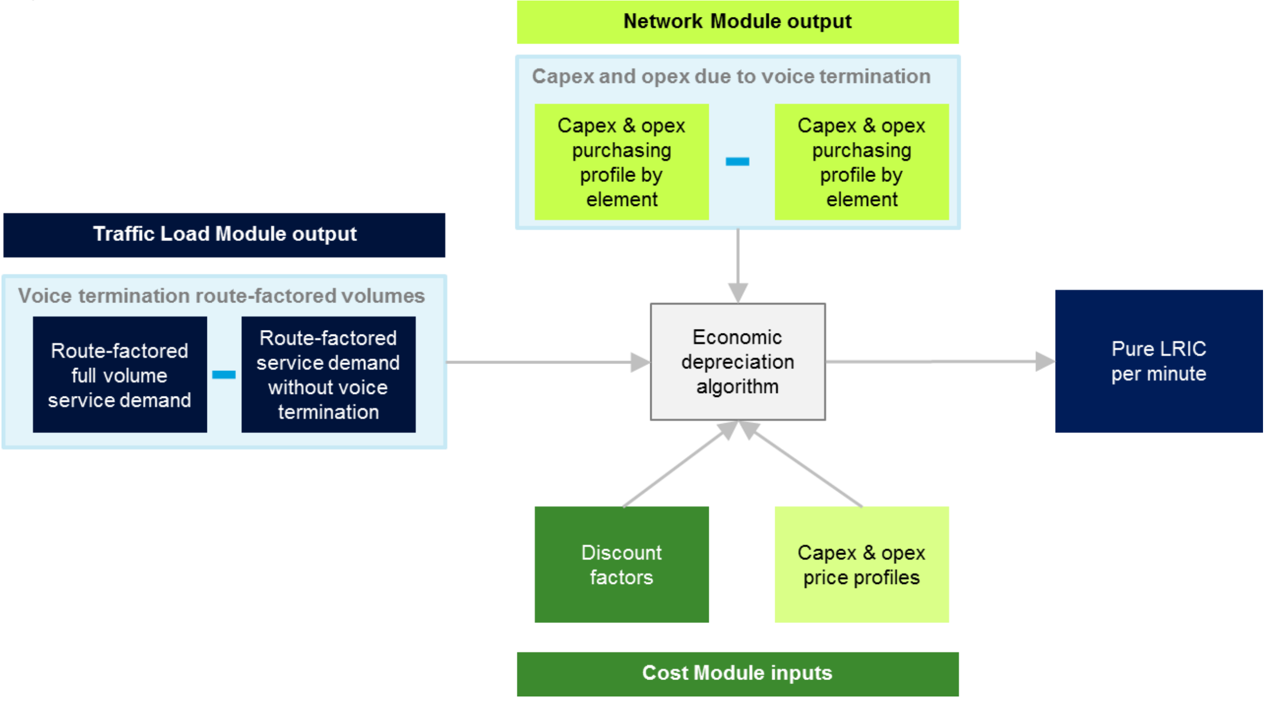
The figure above demonstrates the calculation flow of economic depreciation algorithm. Upper case sigmas represent summation over the time horizon of the model.

A worked example and formal mathematical explanation of the calculation are provided in Appendix C.

6.3 Pure LRIC

The increment considered for mobile termination is calculated via economic depreciation of termination volumes and avoidable costs due to depreciation. The calculation algorithm is displayed in Figure 25.

Figure 25: Pure LRIC of voice termination



Source: *Deloitte analysis.*

6.3.1 Avoidable vs. common and joint costs

In the long-run setting of pure LRIC, all costs are considered to be variable, as the operator is not constrained by short-term restraints, such as contracts. According to the 2009 EC Recommendation explanatory note[55] "*a pure LRIC approach implies the exclusion of costs which would not be avoidable if the wholesale termination service were discontinued,*" i.e. joint and common costs. These are explained in the following paragraphs.

Avoidable costs are defined as only those costs that would not be incurred if that service in question (i.e. wholesale call termination) were no longer produced.[56] According to the 2009 EC Recommendation it is justified to apply a pure LRIC approach for the recovery of the avoidable costs.

---

[55] European Commission document C(2009) 3359 final. Commission staff working document accompanying the Commission Recommendation on the Regulatory Treatment of Fixed and Mobile Termination Rates in the EU, page 17.

[56] Ibid.

Common costs are defined as costs which are not directly attributable to specific services (increments), for example the coverage network.[57] Costs that arise from more than one increment are either common or joint.

The model assumes that the costs arising from the following network elements are common with respect to the relevant increment:

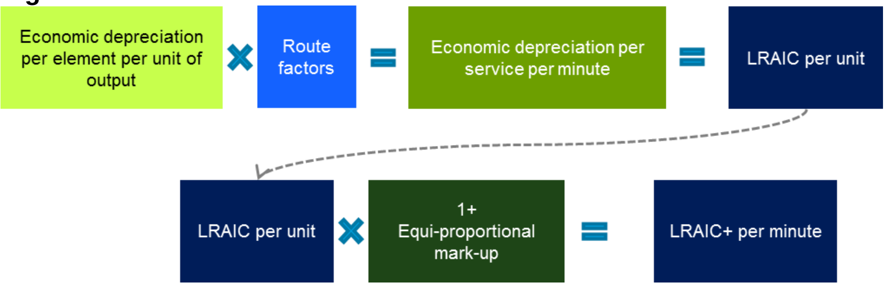
- coverage network;
- signalling platform;
- number portability platform;
- 900MHz spectrum fees;
- 1800MHz spectrum fees;
- 2100MHz spectrum fees;
- wholesale billing platform; and
- VMS.

Costs arising from all other elements are avoidable in the case of the wholesale call termination increment. For further discussion on the non-incrementality of spectrum, see section 5.3.4.1.

6.4 LRAIC+

LRAIC+ allows for the recovery of the common costs as defined above. Service-specific equi-proportional mark-ups are used to apportion the amount of common costs attributable to the relevant service. Moreover, the derivation of cost per unit of service differs from pure LRIC in that it considers average cost per unit of traffic instead of the marginal cost of an additional unit of traffic. The figure below illustrates the broad steps in the calculation of LRAIC+ for voice termination.

Figure 26: Illustration of calculation of LRAIC+ for voice termination



Source: *Deloitte analysis.*

---

[57] Ibid. p. 14

The five equations below set out the calculation of LRAIC+ in more detail.

Equi-proportional mark-ups are specific to 2G, 3G, and shared network equipment.

$$(equi - proportional\ mark - up)_{j,t} = \eta_{j,t} = \frac{(common\ economic\ costs)_{j,t}}{(incremental\ economic\ costs)_{j,t}} \tag{25}$$

where j denotes equipment technology use category: 2G, 3G, or shared. Common and incremental costs are obtained from

$$(common\ economic\ costs)_{j,t} = \sum_{e} 1_{j_e \in J} \times (economic\ cost)_{e,t} \times \rho_e \tag{26}$$

and

$$(incremental\ economic\ costs)_{j,t} = \sum_{e} 1_{j_e \in J} \times (economic\ cost)_{e,t} \times (1 - \rho_e) \tag{27}$$

where $1_{j_e \in J}$ is the indicator variable denoting the technology category of element e. $(economic\ cost)_{e,t}$ represents the cost of the network element in year t after economic depreciation. Finally, ρ_e represents the share of the cost of element e that is common.

The calculation of LRAIC+ per service is as follows,

$$LRAIC_{s,t} = \sum_{e} \left(\frac{(economic\ cost)_{e,t}}{RFV_{e,t}} \times RF_{s,e} \right) \tag{28}$$

$RFV_{e,t}$ represents the route factored volume carried over element e in relevant units (minutes, SMS, Erlang, etc.) and $RF_{s,e}$ is the route factor of service s and across all elements. The final step is to incorporate the equi-proportional mark-up in order to account for the common costs,

$$LRAIC +_{s,t} = LRAIC_{s,t} \times \left(1 + \eta_{j_s,t}\right) \times (1 + \xi_t) \tag{29}$$

$\eta_{j_s,t}$ is service s and year t specific equi-proportional mark-up calculated in equation (25) and ξ_t represents the business overhead mark-up parameter.

When a given increment includes several services, traffic-weighted average determines the cost of the increment LRAIC+.

Appendix A Route Factor Matrix

	E01_001	E01_002	E01_003	E01_004	E01_005	E01_006	E01_007	E02_001	E02_002	E02_003	E02_004	E02_005	E02_006	E02_007	E02_008	E02_009	E02_010	E02_011	E02_012	E03_001	E03_002	E03_003	E03_004	E03_005	E03_006	E03_007	E03_008	E03_009	E04_002	E04_003	E04_004	E04_005	E04_006	E04_007
S02_001	2.0	2.0	2.0	2.0	-	-	-	1.5	-	-	2.0	2.0	2.0	-	-	1.0	2.0	2.0	2.0	2.0	-	-	-	-	2.0	2.0	2.0	2.0	2.0	2.0	-	-	-	1.0
S02_002	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5	-	-	2.0	2.0	2.0	-	-	1.0	2.0	2.0	2.0	1.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0	1.0	1.0	1.0	-	1.0
S02_003	1.0	1.0	1.0	1.0	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	1.0	1.0	1.0	1.0	-	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	-
S02_004	1.0	1.0	1.0	1.0	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	1.0	1.0	1.0	1.0	-	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	-
S02_005	1.0	1.0	1.0	1.0	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	1.0	1.0	1.0	1.0	-	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	-
S02_006	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0	-
S02_007	1.0	1.0	1.0	1.0	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	1.0	1.0	1.0	1.0	-	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	1.0
S02_008	1.0	1.0	1.0	1.0	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	1.0	1.0	1.0	1.0	-	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	1.0
S02_009	1.0	1.0	1.0	1.0	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	1.0	1.0	1.0	1.0	-	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	1.0
S02_010	1.0	1.0	1.0	1.0	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	1.0	1.0	1.0	1.0	-	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	-
S02_011	2.0	2.0	2.0	2.0	-	-	-	1.5	-	-	2.0	2.0	2.0	2.0	-	1.0	2.0	2.0	2.0	2.0	-	-	-	-	2.0	2.0	2.0	2.0	2.0	2.0	-	-	-	-
S02_012	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5	-	-	2.0	2.0	2.0	2.0	-	1.0	2.0	2.0	2.0	1.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0	1.0	1.0	1.0	-	-
S02_013	1.0	1.0	1.0	1.0	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0	1.0	-	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	-
S02_014	1.0	1.0	1.0	1.0	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0	1.0	-	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	-
S02_018	1.0	1.0	1.0	1.0	-	-	-	1.0	-	1.0	1.0	1.0	1.0	-	-	-	1.0	1.0	-	1.0	-	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	-	-	-	-
S03_001	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5	-	-	2.0	2.0	2.0	-	-	1.0	2.0	2.0	2.0	1.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0	1.0	1.0	1.0	-	1.0
S03_002	2.0	-	-	-	2.0	2.0	2.0	1.5	-	-	2.0	2.0	2.0	-	-	1.0	2.0	2.0	2.0	-	2.0	2.0	2.0	2.0	2.0	2.0	-	2.0	-	-	2.0	2.0	-	1.0
S03_003	1.0	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	-	-	1.0	1.0	1.0	-
S03_004	1.0	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	-	-	1.0	1.0	1.0	-
S03_005	1.0	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	-	-	1.0	1.0	1.0	-
S03_006	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0	-
S03_007	1.0	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	-	-	1.0	1.0	1.0	1.0
S03_008	1.0	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	-	-	1.0	1.0	1.0	1.0
S03_009	1.0	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	-	-	1.0	1.0	1.0	1.0
S03_010	1.0	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	-	1.0	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	-	-	1.0	1.0	1.0	-
S03_011	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5	-	-	2.0	2.0	2.0	2.0	-	1.0	2.0	2.0	2.0	1.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	-	-	1.0	1.0	-	-
S03_012	2.0	-	-	-	2.0	2.0	2.0	1.5	-	-	2.0	2.0	2.0	2.0	-	1.0	2.0	2.0	2.0	-	2.0	2.0	2.0	2.0	2.0	2.0	-	1.0	-	-	2.0	2.0	-	-
S03_013	1.0	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	-	-	1.0	1.0	1.0	-
S03_014	1.0	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	-	-	1.0	1.0	1.0	-
S03_015	2.0	-	-	-	2.0	2.0	2.0	1.5	-	-	2.0	2.0	2.0	-	2.0	1.0	2.0	2.0	2.0	-	2.0	2.0	2.0	2.0	2.0	2.0	-	2.0	-	-	2.0	2.0	-	-
S03_016	1.0	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	-	-	1.0	1.0	1.0	-
S03_017	1.0	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	-	-	1.0	1.0	1.0	-
S03_019	1.0	-	-	-	1.0	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0	-	-	-	1.0	1.0	-	-	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	-	-	1.0	1.0	-	-
S04_020	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0	-	-	-	-	-	-

Appendix B VBA Macro Code

The following code is used by the macro. The lines of code beginning with an apostrophe (‘) describe the calculation sections.

The macro runs the model under two scenarios:

1. Full traffic scenario (TS_0)

2. Without voice termination (TS_1)

Under each of the scenarios the macro copies and pastes (i) the element purchasing profiles, (ii) network element requirements from the network module output and (iii) route factored volumes from the load module output. These three tables are used in the calculation of the pure LRIC.

Note: the macro needs to be run after any changes to inputs in order to obtain the relevant pure LRIC values.

```
Sub run_pure_LRIC()

' ************************************
' **                               **
' **   Pure LRIC and LRAIC+ macro   **
' **                               **
' ************************************

Application.Calculation = xlcalculatemanual
Application.ScreenUpdating = False

'0. PRELIMINARY

    Sheets("c2.Pure LRIC").Select
    Range("c2.Traffic.Switch").Select
    ActiveCell.FormulaR1C1 = "TS_0"
    Calculate

    Cost = ThisWorkbook.Name
    Sheets("d3.Network inputs").Select
    FormulaText = Range("F12").Formula
    StartPoz = InStr(FormulaText, "[")
    EndPoz = InStr(FormulaText, "]")
    Network = Mid(FormulaText, StartPoz + 1, EndPoz - StartPoz - 1)

    Windows(Network).Activate
    Sheets("c1.RAN").Activate
    Range("RAN.3.2.1").Select
    Selection.Copy
    Range("RAN.3.2.2").Select
```

```
    Selection.PasteSpecial Paste:=xlPasteValues
    Range("RAN.3.3.1").Select
    Selection.Copy
    Range("RAN.3.3.2").Select
    Selection.PasteSpecial Paste:=xlPasteValues


'I. TRAFFIC SCENARIO 1: WITHOUT VOICE TERMINATION

    'Run TS_1
    Windows(Cost).Activate
    Sheets("a0.Control").Select
    Application.ScreenUpdating = True
    Application.ScreenUpdating = False

    Sheets("c2.Pure LRIC").Select
    Range("c2.Traffic.Switch").Select
    ActiveCell.FormulaR1C1 = "TS_1"
    Calculate
    Application.ScreenUpdating = False

    'Copy aggregate voice minutes without voice termination
    Sheets("d1.Load inputs").Select
    Range("J523:AM525").Select
    Selection.Copy
    Sheets("b3.No voice termination (TS_1)").Select
    Range("G10").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone,
SkipBlanks _
        :=False, Transpose:=False
    Application.CutCopyMode = False

    'Copy element investment without voice termination
    Sheets("d3.Network inputs").Select
    Range("d3.2.1").Select
    Selection.Copy
    Sheets("c2.Pure LRIC").Select
    Range("c2.2.2").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone,
SkipBlanks _
        :=False, Transpose:=False

    'Copy element requirement without voice termination
    Sheets("d3.Network inputs").Select
    Range("d3.1.1").Select
    Selection.Copy
    Sheets("c2.Pure LRIC").Select
    Range("c2.3.2").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone,
SkipBlanks _
        :=False, Transpose:=False

    'Copy RF volumes without voice termination
    Sheets("c2.Pure LRIC").Select
    Range("c2.4.1").Select
    Selection.Copy
    Sheets("c2.Pure LRIC").Select
```

```
    Range("c2.4.3").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone,
SkipBlanks _
        :=False, Transpose:=False


'II. TRAFFIC SCENARIO 0: ALL VOLUMES (with voice termination)

    'Run TS_0
    Sheets("c2.Pure LRIC").Select
    Range("c2.Traffic.Switch").Select
    ActiveCell.FormulaR1C1 = "TS_0"
    Calculate

    'Copy aggregate voice minutes with termination
    Sheets("d1.Load inputs").Select
    Range("J523:AM525").Select
    Selection.Copy
    Sheets("b2.Full traffic scenario (TS_0)").Select
    Range("G10").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone,
SkipBlanks _
        :=False, Transpose:=False

    'Copy element investment with termination
    Sheets("d3.Network inputs").Select
    Range("d3.2.1").Select
    Selection.Copy
    Sheets("c2.Pure LRIC").Select
    Range("c2.2.1").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone,
SkipBlanks _
        :=False, Transpose:=False

    'Copy element requirement with termination
    Sheets("d3.Network inputs").Select
    Range("d3.1.1").Select
    Selection.Copy
    Sheets("c2.Pure LRIC").Select
    Range("c2.3.1").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone,
SkipBlanks _
        :=False, Transpose:=False

    'Copy RF volumes with termination
    Sheets("c2.Pure LRIC").Select
    Range("c2.4.1").Select
    Selection.Copy
    Sheets("c2.Pure LRIC").Select
    Range("c2.4.2").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone,
SkipBlanks _
        :=False, Transpose:=False


'III. DISPLAY RESULTS
```

```
    Calculate
    Sheets("a0.Control").Activate


Application.Calculation = xlcalculateautomatic

End Sub
```

Appendix C Economic Depreciation Derivation and Worked Example

In contrast to common accounting depreciation methodologies such as straight-line, or declining balance, economic depreciation may be considered conceptually more complex. The calculation is also comparatively more complex. Alongside the discussions provided in section 2.5 and section 6.2, a simplified worked example is provided below to illustrate the calculation methodology included in the model. Following this worked example, a technical presentation of the calculations is presented.

Consider the following set of inputs to the economic depreciation algorithm:

- A single network element which is used by a single service, with a route factor of one.
- The element is purchased for €1,000 in 2013 and operates over its lifetime of five years, after which it is removed.
- The operator incurs operating expenses of €100 in 2013, €110 in 2014, and so on as shown in the table below, which corresponds to the usage of that network element. The rising nominal cost each year reflects an increase in the underlying input cost (e.g. labour expenses).
- The operator's pre-tax nominal WACC is 10%, which is applied as a discount factor each year.
- The network element produces an output of 100,000 minutes in its first year which grows over time as shown in the table below. Economic depreciation assumes that the present value of the revenue stream from the service equate to the present value of expenses incurred by the operator.

Table 33: Example economic depreciation

	2013	2014	2015	2016	2017
Element capex (€)	1,000	0	0	0	0
Element opex (€)	100	110	120	130	140
Element investment	1	0	0	0	0
Discount factor	1	$\left({}^{1}/_{1.1}\right)^{1}$	$\left({}^{1}/_{1.1}\right)^{2}$	$\left({}^{1}/_{1.1}\right)^{3}$	$\left({}^{1}/_{1.1}\right)^{4}$
Service volume (min)	100,000	120,000	140,000	135,000	145,000

The example incorporates the capex and opex price indices in the capex and opex series for clarity. Applying equation (30) to these inputs produces the following capital and operational costs per unit of output:

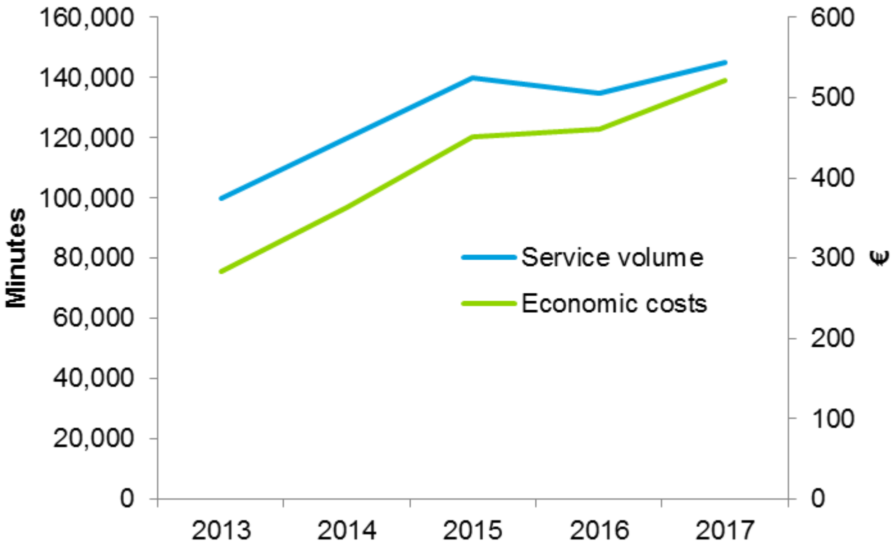
Capital cost per unit of output (€):	0.00190	0.00200	0.00209	0.00219	0.00228
Operating cost per unit of output (€):	0.00094	0.00103	0.00113	0.00122	0.00131

The table above yields the cost per unit of service after economic depreciation. Profiling against the service volume as in equation (31), yields the following economic depreciation profile:

Economic costs (€):	284.14	363.64	450.70	460.11	521.59

The economic costs profiled against traffic profiles are shown below. Although most of the costs are incurred in the first year (2013), economic depreciation recovers costs in later years when utilisation is higher.

Figure 27: Economic depreciation example



Source: *Deloitte analysis.*

C.1 Formal presentation of the economic depreciation algorithm

The section that follows formally presents the calculation methodology of the economic depreciation algorithm. For further information, a conceptual introduction to the method is provided in section 2.5 and a simplified numerical example is provided in Appendix C.

Let *E* and *S* denote the number of network elements and services respectively and *T* the number of years covered by the time horizon in the model.[58] Moreover, define the list of matrices and vectors for capex costs as following:

Capital cost per unit output (EUR):	C $E \times T$
Operating cost per unit output (EUR):	O $E \times T$
Capex incremental investment by element by year (units):	$CIncrement$ $E \times T$
Capex element price (2013 EUR):	$CPrice$ $E \times T$
Capex nominal price index:	$CIndex$ $1 \times T$

---

[58] The capex nominal price index varies by element in the model, however it is defined as a vector here for simplification.

Nominal discount factor (2013 = 100 as the base year): $\underset{T \times 1}{d}$

Route factors matrix:[59] $\underset{E \times S}{RF}$

Service traffic volumes (MB equivalent): $\underset{E \times S}{SVolume}$

Next, define the operator ⊖ as pointwise division,

$$\begin{pmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & & \vdots \\ \vdots & & \ddots & \vdots \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{pmatrix} \ominus \begin{pmatrix} b_{11} & b_{12} & \dots & b_{1n} \\ b_{21} & b_{22} & & \vdots \\ \vdots & & \ddots & \vdots \\ b_{m1} & b_{m2} & \dots & b_{mn} \end{pmatrix} = \begin{pmatrix} \frac{a_{11}}{b_{11}} & \frac{a_{12}}{b_{12}} & \dots & \frac{a_{1n}}{b_{1n}} \\ \frac{a_{21}}{b_{21}} & \ddots & & \vdots \\ \vdots & & & \\ \frac{a_{m1}}{b_{m1}} & \dots & & \frac{a_{mn}}{b_{mn}} \end{pmatrix}$$

when $b_{ij} \neq 0$ and setting $\frac{a_{ij}}{b_{ij}} = 0$ otherwise. Moreover, let ⊙ denote the pointwise multiplication (Hadamard product) and · the matrix multiplication. The capital cost per unit of output is then,

$$\underset{E\times T}{C} = \left(\left(\underbrace{ \left(\underbrace{\underset{E\times T}{CIncrement}}_{\text{purchasing profile}} \odot \underbrace{\left(\underset{E\times 1}{CPrice} \cdot \underset{1\times T}{CIndex} \right)}_{\text{nominal price profile}} \right) \cdot \underset{T\times 1}{d} }_{\text{"PV of capex costs"}} \right) \ominus \left(\underbrace{ \underbrace{\left(\left(\underset{E\times S}{RF} \cdot \underset{S\times T}{SVolume} \right) \odot \left(\underset{E\times 1}{1} \cdot \underset{1\times T}{CIndex} \right) \right)}_{\text{indexed output per element}} \cdot \underset{T\times 1}{d} }_{\text{"PV of total output"}} \right) \right) \cdot \underset{1\times T}{CIndex} \qquad (30)$$

Similarly, the opex cost per unit output is calculated in this fashion with the respective increments, prices, and the index replaced for opex. The total cost per unit output is *C* + *O*. The economic cost by element and by year are obtained as follows:

$$\underset{E\times T}{Economic\,costs} = \left(\underset{E\times S}{RF} \cdot \underset{S\times T}{SVolume} \right) \odot \left(\underset{E\times T}{C} + \underset{E\times T}{O} \right) \qquad (31)$$

This yields the nominal economic cost per element per year.

---

[59] Note that the route factor matrix is transposed in the model.

Appendix D Coverage Scenario Definition

As noted in section 5.1.2, for 2G RAN elements, the minimum number of elements required are defined under the scenario of a notional one-call network, in line with 2009 EC Recommendation that “*coverage can be best described as the capability or option to make a single call from any point in the network at a point in time.*”[60]

The hypothetical existing operator is assumed to carry a notional volume of traffic of 1 Erlang in each geo-type, in the busy hour, across the 2G coverage area as specified in section 5.1.1.3.

Due to the low traffic volume, the hypothetical existing operator is assumed to use only 900MHz frequency and to use omni-sectorisation across all sites.

The level of traffic under this scenario leads the RAN dimensioning algorithm to select the maximum defined cell radii for each geo-type. As opposed to 2G cell radii values presented in section 5.1.1.8, in the coverage scenario, the maximum call radii are based on 900MHz values alone, and do not include 1800MHz radii ranges.

---

[60] European Commission document 2009/396/EC Commission Recommendation, p. 7

Appendix E Glossary

Short text	Full text
2G, 3G and 4G	2nd, 3rd and 4th generation networks
A	Interface between BSCs and MGWs
Abis	Interface between BTS and BSC
AuC	Authentication Centre
BH	Busy Hour
BSC	Base Station Controller
BTS	Base Transceiver Station
BU	Bottom up
CPI	Consumer Price Index
CSFB	Circuit Switched FallBack
CSO	Irish Central Statistics Office
E	Interface between two MSCs
EC	European Commission
EIR	Equipment Identification Register
GDP	Gross Domestic Product
GMSC	Gateway Mobile Switching Centre
GSM	Global System for Mobile Communications
HLR	Home Location Register
HSPA	High Speed Packet Access
IMEI	International Mobile Equipment Identity
IN	Intelligent Network
IP	Internet Protocol
IuCS	Interface between the Circuit Switched Core Network and RNCs
Iur	Interface between RNCs and RNCs
Iub	Interface between Node Bs and RNCs
kB	Kilobyte
km	Kilometre
LRIC	Long Run Incremental Cost
LTE	Long-term Evolution
M2M	Machine-to-machine communications
MB	Megabyte
Mc	Interface between MSCs and MGWs
MEA	Modern equivalent asset
MGW	Media Gateway

Short text	Full text
MHz	Megahertz
MMS	Multimedia Message Service
MMSC	Multimedia Messaging Service Centre
MSC-S	Mobile Switching Centre Server
MTR	Mobile Termination Rate
Nb	Interface between two MGWs
NGN	Next Generation Network
NMC	Network Management Centre
NRA	National Regulatory Authority
PoI	Point of Interconnect
RAN	Radio Access Network
RNC	Radio Network Controller
SMS	Short Message Service
SMSC	Short Messaging Service Centre
TRX	Transceiver
Tx	Transmission
UMTS	Universal Mobile Telecommunications System
VBA	Visual Basic for Applications
VMS	Voicemail System
WACC	Weighted Average Cost of Capital

Short text	Full text
2G, 3G and 4G	2nd, 3rd and 4th generation networks
A	Interface between BSCs and MGWs
Abis	Interface between BTS and BSC
AuC	Authentication Centre
BH	Busy Hour
BSC	Base Station Controller
BTS	Base Transceiver Station
BU	Bottom up
CPI	Consumer Price Index
CSFB	Circuit Switched FallBack
CSO	Irish Central Statistics Office
E	Interface between two MSCs
EC	European Commission
EIR	Equipment Identification Register
GDP	Gross Domestic Product
GMSC	Gateway Mobile Switching Centre

Short text	Full text
GSM	Global System for Mobile Communications
HLR	Home Location Register
HSPA	High Speed Packet Access
IMEI	International Mobile Equipment Identity
IN	Intelligent Network
IP	Internet Protocol
IuCS	Interface between the Circuit Switched Core Network and RNCs
Iur	Interface between RNCs and RNCs
Iub	Interface between Node Bs and RNCs
kB	Kilobyte
km	Kilometre
LRIC	Long Run Incremental Cost
LTE	Long-term Evolution
M2M	Machine-to-machine communications
MB	Megabyte
Mc	Interface between MSCs and MGWs
MEA	Modern equivalent asset
MGW	Media Gateway
MHz	Megahertz
MMS	Multimedia Message Service
MMSC	Multimedia Messaging Service Centre
MSC-S	Mobile Switching Centre Server
MTR	Mobile Termination Rate
Nb	Interface between two MGWs
NGN	Next Generation Network
NMC	Network Management Centre
NRA	National Regulatory Authority
PoI	Point of Interconnect
RAN	Radio Access Network
RNC	Radio Network Controller
SMS	Short Message Service
SMSC	Short Messaging Service Centre
TRX	Transceiver
Tx	Transmission
UMTS	Universal Mobile Telecommunications System
VBA	Visual Basic for Applications
VMS	Voicemail System
WACC	Weighted Average Cost of Capital

Appendix F Drivers of the increase in Pure LRIC since ComReg Supplementary Consultation 15/19

In the process of updating the model since the version presented as part of ComReg Supplementary Consultation 15/19, the value of pure LRIC MTR has been affected by several drivers.[61] These are described below. Nevertheless, it should be noted that these drivers are interrelated and so adjusting one of them may affect others. These drivers also may have offsetting effects on the value of pure LRIC. Attributing the exact changes to pure LRIC to each of the drivers (each associated with the respective model modification) is not possible to document due to the interdependence of the drivers. Moreover, their impact on pure LRIC depends on the sequence of the execution of the respective modifications that have been performed since the version of the model presented as part of ComReg Supplementary Consultation 15/19. Therefore it is not possible to attribute one specific value of impact on pure LRIC from each of the modifications undertaken.

The pure LRIC calculated in the draft model published in ComReg Document 15/19 was 0.71 euro cent per minute for 2015. The modifications to the model resulted in an increase in pure LRIC to 0.87 in 2015 due to the changes listed below. The impacts relate to the year 2015 unless specified otherwise. Pure LRIC relates to the costs of voice termination.

- **Decrease in 900MHz spectrum holdings**: the spectrum holding of the hypothetical existing operator has been revised from 8.6MHz to 7.2MHz during 2003-2012. This has an upward impact on pure LRIC.

- **Constant market share**: the market share of the modelled operator is assumed to remain constant during the modelled time period from 2003 through 2032. A market share of 25% has been set. The associated on-net and off-net per subscriber traffic and spectrum assignments have been adjusted in relation to this market share.

- **GMSC incrementality**: the GMSC incrementality assumption has been revised. Its PoI-facing ports are assumed to contribute to pure LRIC. This amendment has a minor upward impact on pure LRIC.

- **Reversion of geotype breakdown as per Eurostat and operator data:** The breakdown of land-area by geo-type has been reverted to the value inputs presented during the Original Consultation process detailed in ComReg Document 14/29. This input reflects Ireland's land area, including inland water as per Eurostat. The geotype classification of urban, sub-urban, and rural areas is based on operator data. This classification relates to a more recent Irish demographic distribution than that reported by the CSO. This has a minor

---

[61] For the increase in pure LRIC MTR between ComReg Document 14/29 and 15/19, see Draft Specification Document accompanying Draft for Consultation Model v2.01. https://www.comreg.ie/_fileupload/publications/ComReg1519a.pdf

impact on calculation of weighted cost of site backhaul, thereby changing unit capex and unit opex of 2G links (Abis) and 3G links (lub).[62]

- **Penetration rate**: The penetration rate for 2014 has been revised to 125.3%, reflecting the information from ComReg's Q4 2014 QKD. The subsequent penetration rate figures from 2015-2032 have been revised in light of this information also. This change does not have a material impact on the pure LRIC based MTR.

- **Revision of on-net to off-net mobile traffic ratio**: this ratio is informed by the relationship observed in ComReg's QKD data on operator market shares and the proportion of their mobile minutes that are on-net. The ratio has been revised to be informed by a larger QKD dataset, covering Q2 2012 through Q3 2014. This amendment has a minor downward impact on pure LRIC.

- **Minor revision of voice and SMS traffic migration to 3G in rural areas**: the profile of voice and SMS traffic migration from 2G to 3G network has been slightly revised between 2012 and 2015 in rural areas. The profile has been amended to assume a smoother migration in those years in order to be consistent with the smooth profiles assumed for urban and suburban areas. This has a very minor impact on pure LRIC.

The sequence of the amendments may affect the size and the direction of the impact on pure LRIC. The reason is that the changes are interrelated. However, the end result is always the same after all the modifications are implemented.

---

[62] See Table 25 and Table 26 for capex and opex respectively.