Report for ICP-ANACOM

Update of the mobile LRIC model: change report PUBLIC VERSION

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Contents

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1 Introduction

ICP-ANACOM has commissioned Analysys Mason Limited (Analysys Mason) to update the bottom-up long-run incremental cost (BU-LRIC) model ("new model") for the purpose of understanding the cost of mobile voice termination in Portugal that Analysys Mason itself developed between 2010 and 2012 ("old model"). This wholesale service falls under the designation of Market 2[1] (previously Market 7, according to the 2009 European Commission Recommendation on relevant markets).

This report, which has been prepared for exclusive use of ICP-ANACOM, should be read in conjunction with the model documentation and the concept paper. Its objective is to provide an overview of the changes made to the model.

The remaining sections of this document are structured as follows:

- Section 2 describes all the model updates that were needed due to the evolution of market demand, 2G and 3G technology developments (based on data provided by the operators)
- Section 3 describes the model updates that were required to include the 4G network.

Note: confidential inputs were removed and replaced by the mark [✂].

[1] Commission of The European Communities, *COMMISSION RECOMMENDATION of 9.10.2014 on relevant product and service markets within the electronic communications sector susceptible to* ex ante *regulation*, 9 October 2014.

2 Model update – Demand and 2G/3G network parameters

This section describes all the changes that we have made to the old model to reflect the evolution of the Portuguese market (e.g. macroeconomic changes and demand for mobile services) and updates to the characteristics of networks already present in the old model (e.g. loading and capacity upgrades of the 2G and 3G network). The arrangement of subsections follows the order and logical flow of the Excel model.

2.1 Macroeconomics

In the "Operator_Demand" worksheet we have updated the following macroeconomic indicators to reflect the latest data available (see Figure 2.1 and Figure 2.2):

- **National population**, on the basis of updated projections from third-party sources like the EIU, Euromonitor, ITU and Analysys Mason Research; like the old model, the new one uses an average of the forecasts from the various third-party analysts.
- **Inflation**, on the basis of third-party sources like the EIU and Euromonitor. Consistently with the old model, we have used the Euromonitor's data for the forecast and assumed constant 2% inflation after 2025.

It should be noted that the data between 2011 and 2013 in the old model were assumptions or forecasts and might have been revised in the meantime by the sources we are using. Hence, we decided to use in the new model the updates figures. Similarly, we have updated the figures from before 2011 if they have been revised in order to make sure that the model is run with the most reliable source of information on the Portuguese market that are available today.

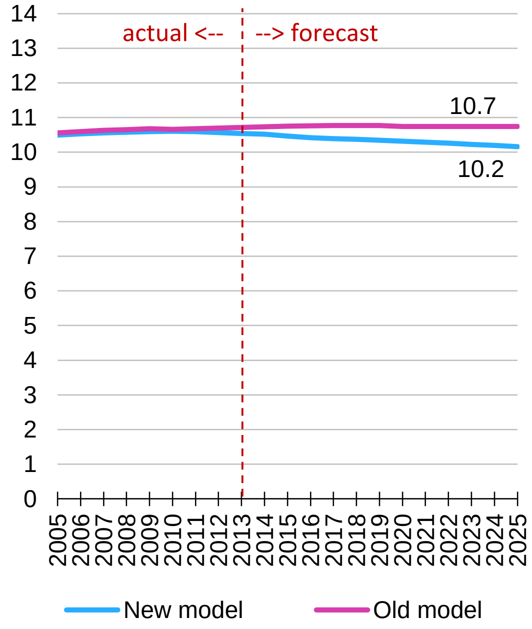


Figure 2.1: Comparison of national population forecast (million inhabitants) [Source: Analysys Mason based on EIU, Euromonitor, ITU and Analysys Mason Research, 2015]

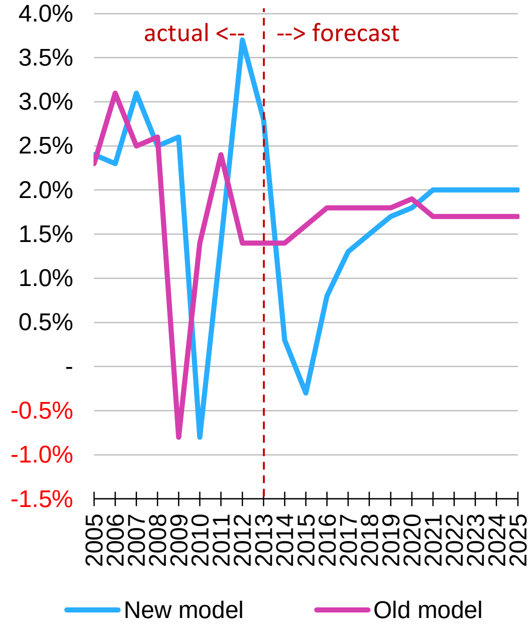


Figure 2.2: Comparison of inflation forecast [Source: Analysys Mason based on Euromonitor, 2015]

We also updated data on population by *freguesia* in the "Geotypes" worksheet with the latest census[2] figures from 2011, including a slight methodology change: indeed, the new model uses the number of individuals present in each *freguesia* instead of the resident population as the new population metric, since this better reflects the number of users generating traffic in a given area.

2.2 Connections and traffic

2.2.1 Connections

We have updated and upgraded the mechanics (as further explained later in this section) of the market module in the "Operator_Demand" worksheet. Whenever possible, we have continued to use the same sources we used for the old model, that is:

- ICP-ANACOM for actual data[3]
- third-party analyst forecasts (e.g. GSMA Intelligence, ITU and Analysys Mason Research) to inform our projections.

A broader set of data and information on the Portuguese market is now available, compared to when we developed the old model. Hence, we decided to upgrade the mechanics of the market module in order to take account of the new data and produce a better informed forecast.

2 Instituto nacional de Estatistica, Censos 2011, available at http://mapas.ine.pt/download/index2011.phtml.

3 ICP-ANACOM, Estatisticas, available at http://www.anacom.pt/render.jsp?categoryId=520&tab=379826.

Among other items, the model now includes the following market data:

- traffic from mobile networks to non-geographic numbers
- the number of datacards/dongles present in the market
- mobile data traffic in megabytes (including details of datacard traffic)
- SMS traffic split by destination.

The latest available data indicates that mobile penetration is expected to be lower than was forecast in 2011 (see Figure 2.3), due to both the economic turmoil and a reduction in the number of secondary and tertiary SIMs. The lower penetration, along with a trend of declining population, results in a lower forecast for total mobile subscribers compared to the old model (see Figure 2.4).

Figure 2.3: Comparison of mobile penetration forecasts [Source: Analysys Mason, 2015]

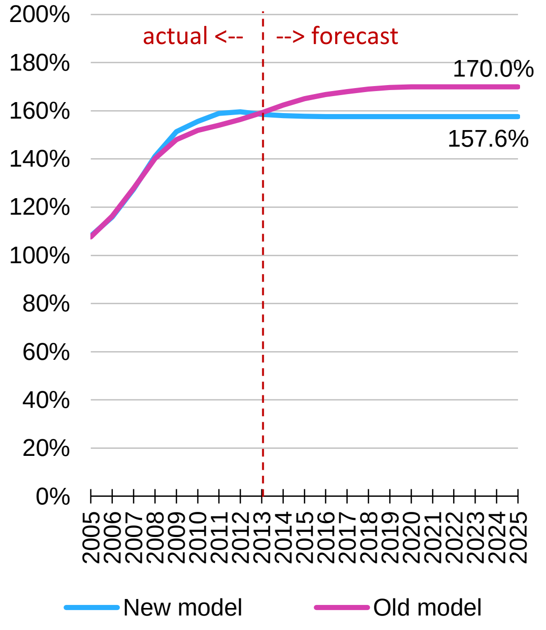
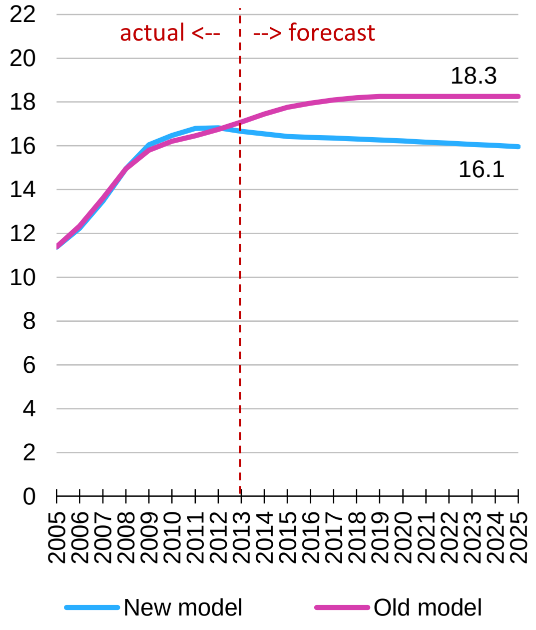


Figure 2.4: Comparison of mobile subscribers forecast [Source: Analysys Mason, 2015]



2.2.2 Traffic

Voice and data usage

The reduced number of subscribers is partially offset by a higher forecast for minutes of usage (MoU) (see Figure 2.5), which could also be due to a reduction in multi-SIM usage. We now expect SMS usage to fall significantly over the forecast period (see Figure 2.6). The negative yearly growth rate used in the new model is informed by the negative usage trend reported in the first three quarters of 2014 in ICP-ANACOM's reports. The root cause of this reduction in SMS usage lies in the rapid adoption of instant messaging services from over-the-top (OTT) players (e.g. WhatsApp, iMessage) among Portuguese subscribers.

Figure 2.5: Comparison of forecasts for minutes of usage [Source: Analysys Mason, 2015]

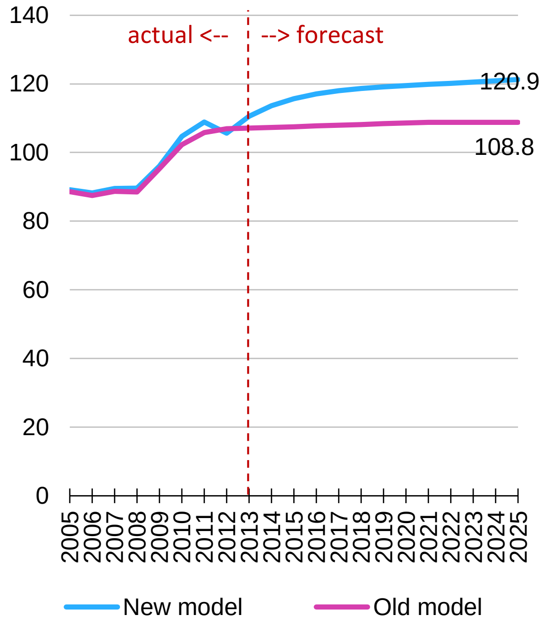
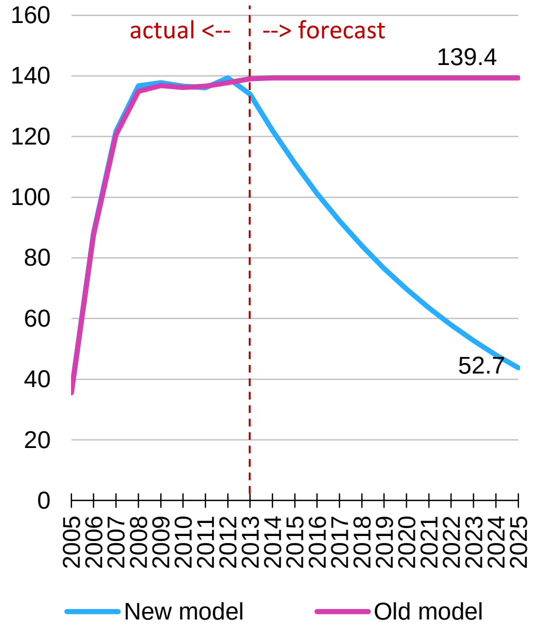


Figure 2.6: Comparison of forecasts for SMS consumption per user [Source: Analysys Mason, 2015]



Given the growing importance of data traffic in the Portuguese mobile market, we have upgraded the mechanism used to forecast total megabytes of traffic generated by data users. This has involved performing the following tasks:

- defining a migration of subscribers from 2G to 3G and 4G[4] (see Figure 2.7)
- segmenting the market by mobile device type (i.e. handsets, datacards/dongles) (see Figure 2.8)
- forecasting the rate of adoption of data services by device type and technology
- assuming a profile of data consumption of data users by device type and technology, and forecasting its evolution according to European benchmarks.

► *Stakeholder comments*

For what concerns data traffic, one party **[NOS]** deems that the overall data traffic is underestimated due to two major factors:

- Data card traffic – Missing inclusion of machine-to-machine (M2M) and Internet of Things (IoT) data cards, which, even if generating low amounts of unit traffic, are forecast to experience a significant take-up in the next years, then generating a non-negligible amount of traffic in the medium term

- Unit and overall traffic forecast – The party thinks that the overall forecast data traffic volume is underestimated in light of the data currently available; **[BC]** [✂] **[EC]**. This is further

[4] A user is defined as a 4G subscriber if he/she owns a 4G-capable device and SIM and subscribes to 4G services.

demonstrated by the data published by ICP-ANACOM about 4Q 2014, which report an average data traffic consumption for mobile broadband users of 1.14 GB/month and 6 GB/month for data card users, which is significantly higher than the 4.1 GB/month assumed by the model.

According to this party, the underestimation of the data traffic volume leads to a parallel overestimation of the mobile termination cost.

Conversely, another party **[MEO]** deems the data traffic volume projections to be overestimated in light of two main factors:

- Overestimation of the 4G take-up, in light of the actual data already available:
  - 5% of the customer base having a 4G-capable device as of the end of 2014 (which does not necessarily mean having a 4G subscription), against a forecast 11%
  - Missing consideration of the substitution market, for which also in the short term a share of the 4G-capable devices sold represent the substitution market for other 4G devices
- Missing inclusion of the Wi-Fi off-loading effect:
  - **[BC]** [✂] **[EC]**
  - The availability of widespread Wi-Fi networks on which off-loading the traffic is one of the purchase decision drivers on the retail market
  - Wi-Fi networks are expected to be further widely adopted, increasingly off-loading the mobile networks.

Also another party **[DECO]** claims for more conservative assumptions on the data traffic growth.

Regarding voice traffic, one party **[NOS]** does not agree with the voice traffic flatting foreseen from 2017 onwards, adducing three main reasons, the first two of which apply also to SMS:

- The increasing take-up of all-net and fixed price voice bundles, which zero the incremental price for one additional minute of voice traffic
- The not complete substitutability between OTT services and the legacy mobile voice services (e.g. in terms of quality of service and of service availability)
- The actual data reported by ICP-ANACOM, which, with the exception of 2012, has shown a 20% increase between 2010 and 2014, with a 10% increase just between 2013 and 2014.

A second party **[DECO]** believes that a further increase of voice traffic should be assumed in light of the existence of large voice bundles in the market.

A third party **[MEO]** conversely argued about the total voice traffic being overestimated over time due to the not appropriate consideration of the impact of OTT services (in this case VoIP, with explicit reference to the recently launched WhatsApp call service) on the voice traffic projections, which, according to this party, appear too aggressive in light of the likely significant take-up of these services.

Another party **[Vodafone]** argued about inconsistencies in the impact that the evolution of voice traffic has on the mobile termination pure LRIC, presenting a couple of examples. Amongst them, the respondent argues that the mobile termination cost is not impacted by a change of voice traffic as it was expecting and as it is highlighted by an article published by Analysys Mason in 2010.

Finally, one party **[DECO]** thinks that the fall in the SMS traffic has been over estimated. The cannibalisation of the SMS by alternative services usually happens when messages are not included in the bundles. Most common bundles continue including SMS today and the average user will continue sending SMS through mobile.

► *Analysys Mason response*

The responses received are somehow in contradiction among them, some of which claiming for too aggressive and other ones for too conservative projections, sometimes with opposite arguments (e.g. the one about the effective degree of substitutability between traditional voice and OTT VoIP services).

Inputs about the traffic forecast were requested as part of the data request process (namely from Q9 to Q14).

With respect to the party **[NOS]** that claims total data traffic to be underestimated, it is worth of being remarked the following:

- Data card traffic – We do not deem the missing inclusion of M2M/IoT to significantly deviate the model results in light of the foreseen negligible amount of traffic generated
- Unit and overall traffic forecast – Data traffic volume projections have been based on and informed by three main sources, namely the actual data made available by ICP-ANACOM, the data provided by the respondents to the data request and international benchmarks. More in detail, the projections have been made following the model’s annual structure, which is consistent with the benchmark sources that have been used.

Any trend shown by additional quarterly data should be carefully compared with yearly trends since they suffer the impact of periodical market dynamics that might not affect long-run forecast (e.g. seasonality, competitive pressure, etc.).

The data reported by one party **[NOS]** (both the ones about 4Q 2014 at market level and the ones about the actual consumptions registered by the party itself) were not available at the time of the model development; furthermore, unit traffic projections appear in line with international benchmarks of comparable countries.

Regarding the comment by one party **[MEO]** stating that some factors are missing in the estimation of the data traffic volumes in the future years, the traffic forecast included in the model are based and validated on data and projections from third-parties which factor in all of the relevant trends which are likely to take place in the forthcoming years, including customer base migration to 4G (which includes also the substitution market) and Wi-Fi data traffic off-loading (increasing over time).

A similar answer can be provided for the comments on the voice traffic volume forecast: they were derived by combining the latest available data points provided by ICP-ANACOM, the data request respondents and third-party sources; the projections assumed appear aligned with other party forecast and international benchmarks.

With respect to the comment provided by one party **[MEO]** about the missing consideration of the OTT take-up, we remark that the projections factor in all of the relevant trends which are likely to take place in the forthcoming years, including OTT take-up, etc.; it is also true that the effective impact of some of them is hardly predictable: for instance, the effective take-up of WhatsApp call is hard to predict since, even if WhatsApp is a very popular OTT, it will depend also on other factors (e.g. the effective call quality and customer experience).

Historically, the voice traffic in Portugal has been growing more than in the benchmark countries, and the projections take this into consideration as well. However, in light of the comments received by one party [**MEO**] that deemed the voice traffic growth too aggressive, we have revised the voice traffic forecast downwards, in order to give a higher weight to the forecast for the benchmark countries (from third-party sources) and a lower weight to the historical evolution of the voice traffic in the Portuguese market. This update allows to better take into consideration the impact of "external" factors on the voice traffic evolution (e.g. OTT voice services) that are implicitly included in the third-party projections.

With respect to the comment by one party **[Vodafone]** about the impact of voice traffic evolution on the mobile termination pure LRIC, the answer encompasses two key concepts:

- Network dimensioning – Equipment (at least partially) dedicated to voice termination traffic is dimensioned according to the traffic that must be routed through it; the inclusion or exclusion of voice termination traffic can, in principle (even if to a reduced extent given the amount of the termination traffic out of the total network traffic), affect the overall dimensioning
- Pure LRIC – The comment made by the party about the predictability of the cost measure would apply in a LRAIC approach; however, this is not the case for pure LRIC as it cannot be predicted whether one incremental traffic unit leads to an increase of some equipment costs then leading to an overall increase of the unit cost; the unit cost would eventually decrease as long as the traffic amount increases without making any equipment scale again
- Pure LRIC cost-volume relationship – The article published in 2010 by Analysys Mason explains what the expected impact on the pure LRIC result is when it "is based on a single year/single service and especially a single technology". The model subject to consultation, conversely, aims at reflecting the Portuguese market technological situation, where 3G and 4G are being largely utilised by mobile network operators. As mentioned in the article quoted by the party "mobile operators will tend to upgrade their network to the most efficient technology (e.g. 2G, 3G or soon LTE) that will provide them with the lowest unit cost, given their traffic

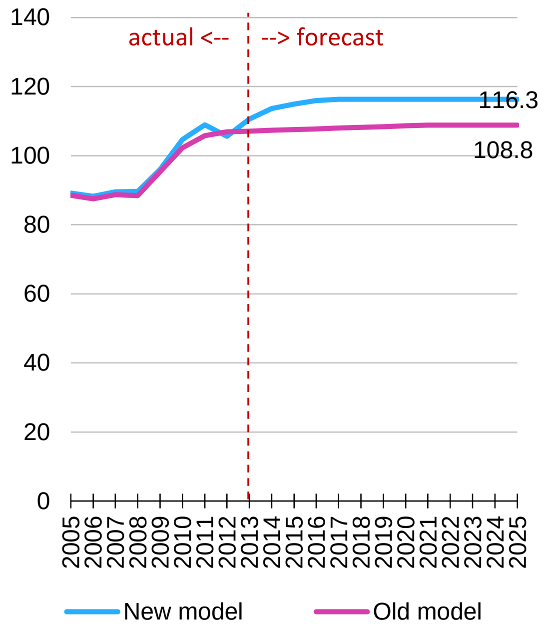
volume". As a consequence, the technological mix matters and an evolution towards more efficient networks is expected to reduce the costs scaling with wholesale mobile termination voice traffic.

As for the other services, SMS traffic volume projections have been based on and informed by three main sources, namely the actual data made available by ICP-ANACOM, the data provided by the respondents to the data request and international benchmarks. Moreover, SMS traffic contributes marginally to the mobile termination costs and alternative projections would have a negligible impact on the result calculated.

► *Conclusion*

We have revised the voice traffic forecast downwards, in order to give a higher weight to the forecast for the benchmark countries (from third-party sources) and a lower weight to the historical evolution of the voice traffic in the Portuguese market. Figure 2.5 is updated as follows.

Figure 2.5: Comparison of forecasts for minutes of usage [Source: Analysys Mason, 2015]



Incoming traffic from off-net

We have slightly revised the calculation of the incoming traffic from off-net as a percentage of outgoing traffic.

The model calculates the split of outgoing and incoming traffic separately:

- Outgoing traffic – Differently from the previous version of the model, the total traffic is now driven by the outgoing MoU, which was previously a back-calculation. This allows to better capture the impact of changing market shares of the operators. However, this update can be considered negligible and does not change the overall logic of the market model. The outgoing traffic is then calculated in two steps:

— The first step is the split of the total outgoing traffic by destination (to mobile, to international and to fixed networks). In line with what done in the previous model and the unpredictability of the traffic, the breakdown percentages of the split is maintained constant

— The second step is the calculation of the split of the outgoing traffic to mobile between on-net and off-net. This calculation is performed in a side model that takes into account the evolution of the market shares of the operator

- Incoming traffic – For the calculation of the total incoming traffic two changes were done.

— The first one is specular to the one done for the outgoing traffic: the total incoming traffic from off-net is now driven by the incoming MoU from off-net. Similarly to the previous model, the trend of the total traffic is assumed to be the same as the outgoing traffic, thus maintaining a stable ratio between outgoing and incoming from off-net over time. In the previous version of the model the incoming traffic from off-net represented 20.7% of total outgoing traffic and, in light of the considerations reported above, this percentage does not evolve over time. The split of the incoming traffic from off-net by origin (i.e. from other mobile, fixed and international networks) is also assumed to remain constant

— The second change is to add the incoming on-net traffic separately on top of the one incoming from off-net. In the previous model the calculation described above also included the on-net traffic, which is now excluded and added separately since it is already calculated in the outgoing calculations and does not need to be re-calculated.

These changes were done because it is more correct to assume that it is the ratio between outgoing on-net and off-net traffic depending from the market share, rather than the incoming traffic from off-net as percentage of outgoing traffic; indeed, the latter is driven by market considerations (for instance, it includes also voice traffic originated from fixed and international networks).

2.2.3 Breakdown of subscribers by generation and device type

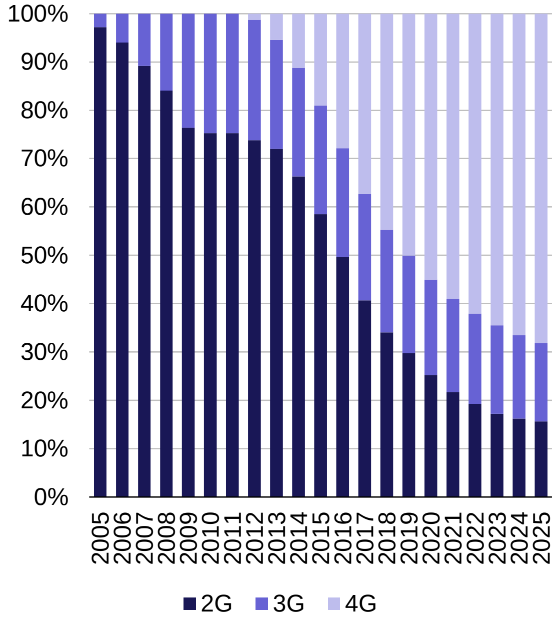


Figure 2.7: Share of subscribers split by technology [Source: Analysys Mason, 2015]

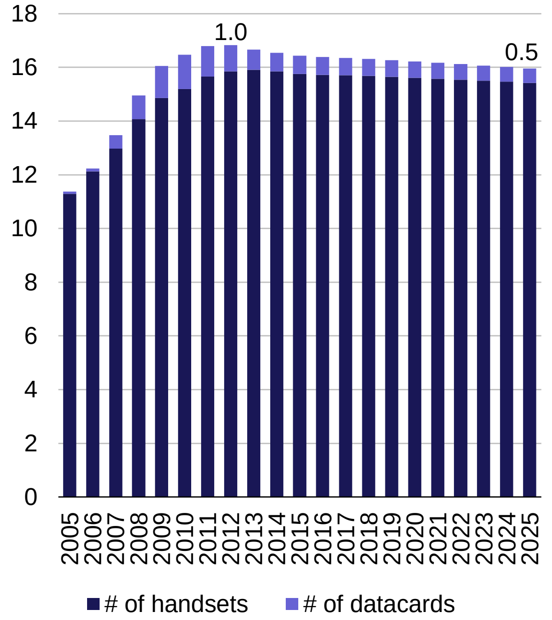
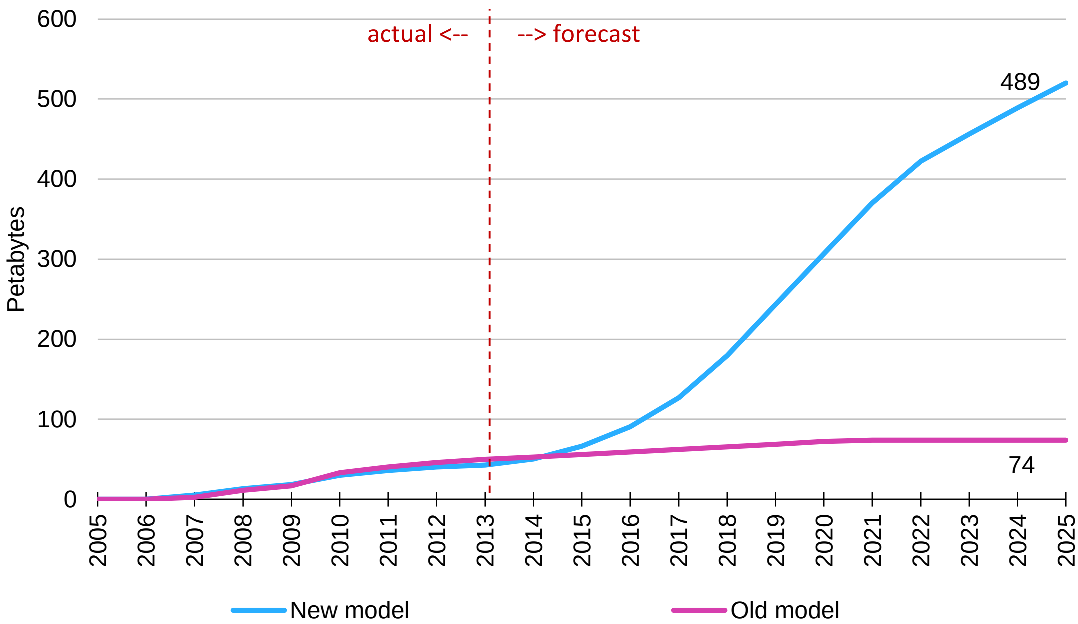


Figure 2.8: Split of SIMs between handsets and datacards / dongles [Source: Analysys Mason, 2015]

In light of the new data available and the launch of LTE in 2012, the new model includes a higher forecast of data traffic, compared to the old model (see Figure 2.9). The new projection is in line with benchmarks for the evolution of total mobile traffic projected by third-party analysts in Europe.

Figure 2.9: Comparison of data traffic projections [Source: Analysys Mason, 2015]



► *Stakeholder comments*

One party **[Vodafone]** thinks that the 4G services adoption expected in the model is too aggressive and unrealistic in light of the experienced 3G services adoption when it was launched, which furthermore was significantly subsidised at that time. Therefore, it considers that these assumptions should be reviewed downwards.

► *Analysys Mason response*

Regarding the comment about the 4G subscriber and traffic take-up forecast, inputs were requested as part of the data request process (namely, from Q9 to Q14); forecast were informed by the data received as a response to the data request and by international forecast, by looking at comparable countries that have already launched 4G services in the recent past. Take-up of 3G in Portugal was not taken into account in light of the significantly different market conditions at the time; for instance, if on one hand it can be true that 3G take-up was somehow encouraged by a number of parties, on the other hand nowadays telecoms services are generally more affordable and consumers are both more educated and more demanding towards high-speed mobile broadband. Indeed, 4G take-up is usually faster than what 3G used to be.

► *Conclusion*

The proposed approach is confirmed.

2.3 Loading parameters

2.3.1 Calculation of traffic carried by the networks

The model updates described in Section 2.2 enable calculation of the total traffic generated by 2G, 3G and 4G subscribers separately. However, the traffic generated by a 4G subscriber is not necessarily carried over the 4G network: instead, it may fall back onto 3G or 2G networks (as discussed in the concept paper). There are a number of reasons why traffic might fall back onto lower-generation networks:

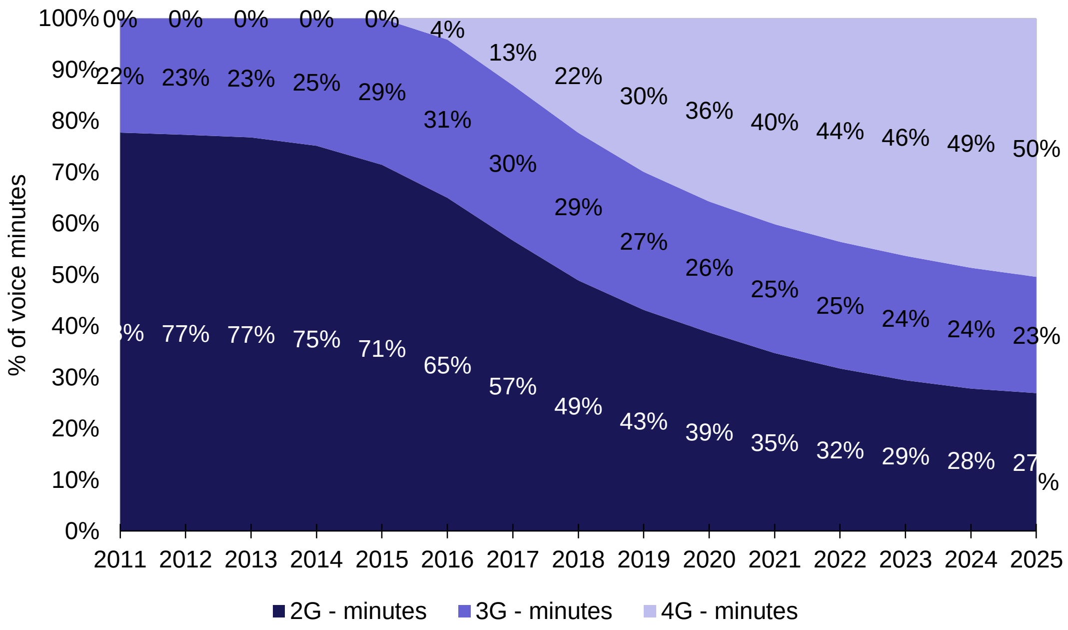
- **Coverage gaps** – There are coverage differences among the networks, with 2G able to provide an almost ubiquitous coverage layer to ensure the provision of basic voice services. For instance, whenever the signal reception is weak or absent a 4G subscriber will automatically connect to the strongest signal available, regardless of the technology of the SIM card installed
- **Device availability** – Mobile users may not have a handset which is capable of supporting a particular technology, despite having an enabled SIM installed; for instance, there still is a large share of 2G handsets in the market that is not able to connect to the 3G network, and most of the handsets that are sold today are not VoLTE capable
- **User experience / capex efficiency** – Mobile operators are interested in maximising the user experience offered to their customers. On the basis of their network loading operators might

decide that a certain share of traffic needs to fall-back on other networks in order to avoid over loading capacity constrained cells. This also allows limiting the capex required to increase capacity on the constrained network by better utilising the capacity already installed for other technologies.

Therefore, we updated the model to allow the traffic routing over different networks with a migration profile that is set in the “Load_inputs” worksheet. The migration is separately set for the different traffic types:

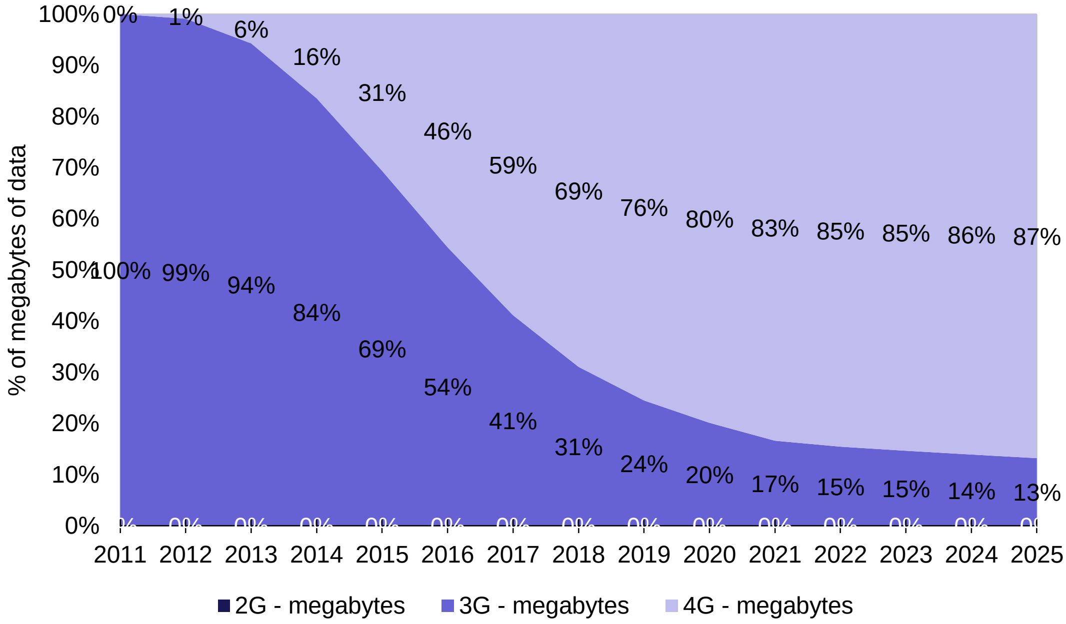
- voice traffic (as shown in Figure 2.10)
- messages (including SMS and MMS)
- low-speed data traffic (GPRS, EDGE, UMTS R99)
- high-speed data traffic (e.g. HSPA, LTE).

Figure 2.10: Share of voice traffic carried by each network generation [Source: Analysys Mason, 2015]



We have assumed that the voice traffic generated by 4G subscribers is carried by 2G and by 3G networks (respectively 55% and 45% of the total) until the launch of VoLTE, which is set to occur in 2016 in the base case. The fact that a higher share of voice traffic falls back onto the 2G network is due to its ubiquitous coverage. For more details on the migration to VoLTE, please see the Launch of VoLTE paragraph in Section 3.7. We are also assuming that 10% (stable over the modelling time period) of the voice traffic generated by 3G subscribers is downgraded to 2G, again because of the lower 3G population coverage.

Figure 2.11: Share of data traffic carried by each network generation [Source: Analysys Mason, 2015]



We have assumed that a certain percentage of the data traffic generated by 4G subscribers (30% in 2012, decreasing to 5% in 2021) falls back on to the existing 3G network, which serves as an additional capacity layer. This is caused by the fact that mobile operators will try to re-use capacity on their 3G networks once subscribers have begun migrating to 4G, in order to optimise the capital expenditure.

2.3.2 Other loading parameters

No change has been made to the mechanics behind all other loading parameters. However, the values of loading parameters have been updated using data provided by the operators, and can be found in the "Load_inputs" worksheet. In particular, as discussed below the changes have had an impact on the following parameters:

- percentage of traffic in the weekday and in the peak hour (busy-hour parameters)
- average call duration
- number of call attempts per successful call
- subscriber loading proportions.

Busy-hour parameters

Figure 2.12: Busy-hour loading parameters assumed in the model [Source: Analysys Mason based on operator data, 2015]

	Voice		SMS		Data	
Model	**New**	**Old**	**New**	**Old**	**New**	**Old**
% traffic in the weekday	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]
% traffic in the peak hour	[✂]	[✂]	[✂]	[✂]	[✂]	[✂]

► *Stakeholder comments*

One party **[Vodafone]** claims that the traffic ratio during weekdays should be higher than it is at the moment in the model. Vodafone proposes a new value **[BC]** [✂] **[EC]**.

► *Analysys Mason response*

With respect to one party's **[Vodafone]** comment about the voice busy hour parameter included in the model, this input is anonymised in the public version of the model, and then the value reported is not the one actually used to calculate the mobile termination cost. In any case, inputs were calibrated according to all the data received as a response to the public consultation and from international benchmarks internally available. **[BC]** [✂] **[EC]**.

► *Conclusion*

The proposed inputs are confirmed.

Average call duration

Figure 2.13: Average call duration assumed in the model, minutes [Source: Analysys Mason based on operator data, 2015]

Voice services	New model	Old model	% change
On-net calls	[✂]	[✂]	[✂]
Outgoing calls to other national fixed networks	[✂]	[✂]	[✂]
Outgoing calls to other national mobile networks	[✂]	[✂]	[✂]
Outgoing calls to international networks	[✂]	[✂]	[✂]
Incoming calls from other national fixed networks	[✂]	[✂]	[✂]
Incoming calls from other national mob. networks	[✂]	[✂]	[✂]
Incoming calls from international	[✂]	[✂]	[✂]
Roaming in origination	[✂]	[✂]	[✂]
Roaming in termination	[✂]	[✂]	[✂]

Call attempts per successful call

Figure 2.14: Call attempts per successful call assumed in the model [Source: Analysys Mason based on operator data, 2015]

Voice services	New model	Old model	% change
On-net calls	[✂]	[✂]	[✂]
Outgoing calls to other national fixed networks	[✂]	[✂]	[✂]
Outgoing calls to other national mobile networks	[✂]	[✂]	[✂]
Outgoing calls to international networks	[✂]	[✂]	[✂]
Incoming calls from other national fixed networks	[✂]	[✂]	[✂]
Incoming calls from other national mob. networks	[✂]	[✂]	[✂]
Incoming calls from international	[✂]	[✂]	[✂]
Roaming in origination	[✂]	[✂]	[✂]
Roaming in termination	[✂]	[✂]	[✂]

Subscriber loading proportions

We have updated the active packet data protocol (PDP) context per 2G and 3G subscriber on the basis of data provided by the operators.

Figure 2.15: Active PDP contexts per subscribers [Source: Analysys Mason, 2015]

	New model	Old model	% change
Active PDP contexts per 2G subscribers	[✂]	[✂]	[✂]
Active PDP contexts per 3G subscribers	[✂]	[✂]	[✂]

This parameter is used to dimension the GGSN core network equipment.

2.4 Definition of the geotypes and theoretical radii

All of the inputs calculated on a per-geotype basis, including the definition of the geotypes themselves, must be consistent among them. Consequently, we have updated all of these inputs according to two main principles:

- Availability of homologue benchmarks, with a closer look to regulatory models that have already included the 4G network
- Validation through third-party sources to double-check that the input values used in the model are sensible (i.e. inside the benchmark range).

Definition of the geotypes and traffic distribution

We have updated the population density thresholds for the definition of the geotypes according to available benchmarks; indeed, the definition of the geotypes is based on a number of factors, including conformation of the territory, availability of locations suitable for mobile sites, etc., which are approximated with the population density (which is an indirect proxy for the expected traffic in the area). These thresholds are – and must be – directly correlated with the updated cell radii values (see par. Theoretical coverage radius).

Figure 2.16: Comparison of the distribution of population across geotypes in the new and in the 2011 models [Source: Analysys Mason, 2015]

	Density threshold (pop/km^2)	% of population	Density threshold (pop/km^2)	% of population
	New model		Old model	
Dense urban	d > 14 000	1.7%	d > 7500	8.1%
Urban	1100 < d < 14 000	39.5%	280 < d < 7500	54.3%
Suburban	100 < d < 1100	40.9%	35 < d < 280	29.8%
Rural	d < 100	17.9%	d < 35	7.8%

In a similar manner, we have also updated the distribution of traffic by geotype in the *Radio access network elements and inputs* section of the "NwDes_Inputs" worksheet (see Figure 2.17). A distinction is now made between voice and data traffic in order to capture the impact of the take-up of mobile broadband (as a substitute for fixed broadband connections) in suburban and rural areas.

Figure 2.17: Voice and data traffic distribution by geotype [Source: Analysys Mason, 2015]

Geotypes	Voice traffic (new model)	Data traffic (new model)	Voice and data traffic (old model)
Dense urban	4.3%	3.4%	13.7%
Urban	54.4%	49.8%	57.8%
Suburban	31.0%	36.0%	23.3%
Rural	10.3%	10.9%	5.3%

Theoretical coverage radius

We have updated the theoretical radii of each spectrum band since the used radii have to be consistent with the definition of the geotypes (see Figure 2.18), and cross-checked that these figures are aligned with available benchmarks. This change can be seen in the *Radio network* section of the "NwDes_Inputs" worksheet. Of course, the model also includes radii for the new LTE bands (800MHz and 2600MHz), which are assumed to be around 120% and 78% of the 900MHz radius respectively.

Figure 2.18: Theoretical cell radius in kilometres assumed in the models by geotype and frequency band [Source: Analysys Mason, 2015]

Geotype	800MHz	900MHz	1800MHz	2100MHz	2600MHz
New model					
Dense urban	0.55	0.45	0.40	0.38	0.35

Urban	1.96	1.61	1.43	1.39	1.27
Suburban	5.42	4.46	3.95	3.84	3.50
Rural	6.01	4.95	4.38	4.31	3.89
Old model					
Dense urban	N/A	0.54	0.34	0.25	N/A
Urban	N/A	2.97	1.86	1.41	N/A
Suburban	N/A	4.45	2.78	2.12	N/A
Rural	N/A	6.24	3.90	3.00	N/A

The fact that the average theoretical 2G radii for urban and rural geotypes in the new model are smaller than those in the old model is consistent with the fact that these geotypes have a higher average density than in the old model. In contrast, the 3G radius has increased in suburban and rural geotypes. This is justified by the fact we revised upwards the 3G outdoor population coverage of the modelled operator (see the 3G outdoor population coverage paragraph in Section 2.5). An increase in coverage means that the incremental sites are more likely to be deployed in less dense areas, and are therefore expected to have a larger radius.

The scorched-node coverage coefficient (SNOCC) has also been updated in order to calibrate the model against the number of sites provided by the operators.

Figure 2.19: Scorched-node coverage coefficient (SNOCC) assumed in the models by geotype and frequency band [Source: Analysys Mason, 2015]

Geotype	800MHz	900MHz	1800MHz	2100MHz	2600MHz
New model					
Dense urban	0.54	0.57	0.59	0.59	0.61
Urban	0.59	0.62	0.65	0.65	0.67
Suburban	0.68	0.72	0.74	0.74	0.77
Rural	0.74	0.78	0.81	0.81	0.84
Old model					
Dense urban	N/A	0.62	1.00	1.00	N/A
Urban	N/A	0.68	1.00	1.00	N/A
Suburban	N/A	0.72	1.00	1.00	N/A
Rural	N/A	0.90	1.00	1.00	N/A

Average distance of the backhaul links by geotype

In accordance to the changes made on geotype definition threshold (and on the theoretical cell radii) we have updated also the average link distances in order to maintain the same average national value. Figure 2.20 below reports the comparison of the distribution of the backhaul links by length between the new and the old model.

Figure 2.20: Comparison of the distribution of backhaul links by length [Source: Analysys Mason, 2015]

Geotype	<10km	10–30km	30–50km
New model			
Dense urban	100%	-	-
Urban	93.0%	7.0%	-
Suburban	72.0%	27.0%	1.0%
Rural	55.0%	39.0%	6.0%
Old model			
Dense urban	100%	-	-
Urban	83.0%	17.0%	0.1%
Suburban	53.3%	45.5%	1.2%
Rural	36.0%	56.3%	7.7%

For the same reason, we have updated the share of self-provided backhaul links by geotype in order to keep the national share constant between the new and the old model.

Figure 2.21: Share of self-provided backhaul transit links [Source: Analysys Mason, 2015]

Geotypes	New model	Old model	Change (p.p.)
Dense urban	2.00%	10.00%	-8.0%
Urban	15.00%	30.00%	-15.0%
Suburban	85.00%	100.00%	-15.0%
Rural	100.00%	100.00%	-

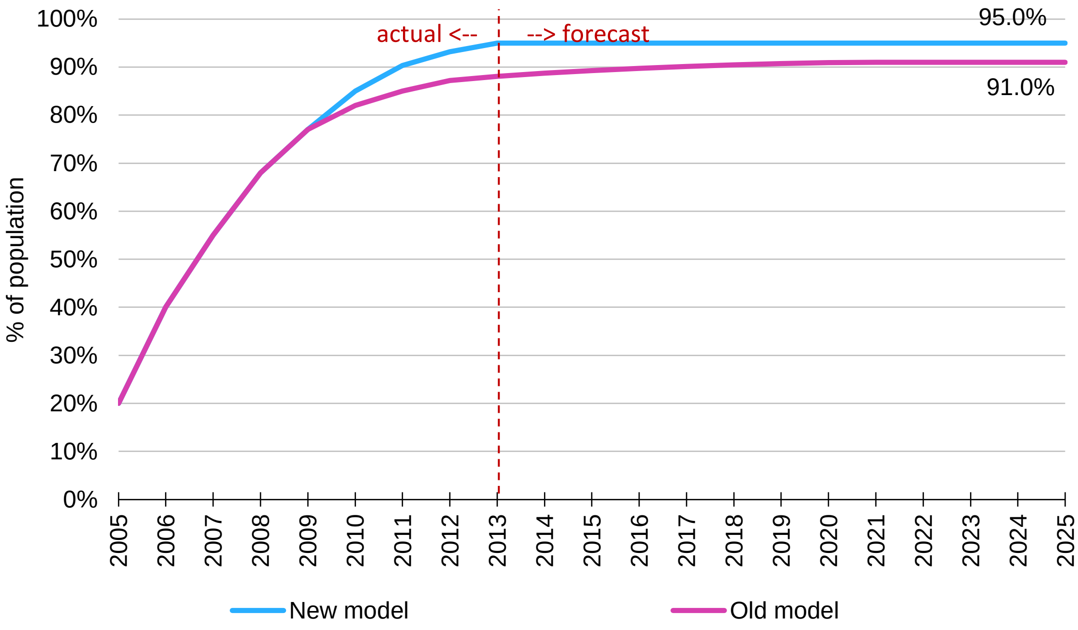
These updates can be found in the ‘Backhaul Last Mile Access (LMA)’ section of the “NwDes_Inputs” worksheet.

2.5 Network parameters and modelling updates

3G outdoor population coverage

We have updated the 3G population coverage, since data provided by the operators indicates that they have achieved a higher outdoor coverage of the population than previously expected (see Figure 2.22).

Figure 2.22: Comparison of UMTS 2100MHz outdoor population coverage [Source: Analysys Mason, 2015]



This update can be found in the ‘Coverage of population’ section of the “NwDes_Inputs” worksheet.

Indoor special sites: share of traffic carried, distribution of the cells and share of sites scaling with termination

The share of traffic carried by indoor special sites has remained broadly stable since the old model was developed, according to the data provided by operators. Some of them have pointed out that an increase can be expected in future in more densely populated areas; however, for conservative reasons we have kept the proportion of indoor traffic broadly stable, with almost negligible growth.

In the old model the indoor special sites were distributed across geotypes on the basis of the traffic distribution over time. However, indoor site deployment is likely to be skewed towards more densely populated areas, as stated by operators. In the new model we have assumed that the traffic carried by these indoor cells will follow the same distribution (see Figure 2.23).

Figure 2.23: Distribution of indoor special sites and indoor carried traffic across geotypes [Source: Analysys Mason, 2015]

Geotype	2G	3G	4G
Dense urban	20%	20%	20%
Urban	80%	80%	80%
Suburban	-	-	-
Rural	-	-	-

We have also updated the number of 2G and 3G indoor special sites; in particular, the number of 2G sites has been increased in light of new figures provided by the operators. To estimate the indoor site deployment of the modelled operator, we have used the ratio between the number of indoor special sites and the number of macro sites for 2G as a proxy; that is, [✂] indoor special sites per macro site.

The Portuguese MNOs exhibit similar ratios, which range between [✂] and [✂]. Moreover, both mobile operators have deployed a similar (slightly lower) number of 3G indoor sites compared to those for 2G. Therefore we have assumed the number of 3G indoor sites to be [✂] of the 2G sites we previously calculated.

According to their responses to the data request, operators do not envisage a significant deployment of special indoor sites in the future; as such, we have kept the number flat over the forecast period (as shown in Figure 2.24 and Figure 2.25).Figure 2.24: Comparison of the number of 2G indoor special sites [Source: Analysys Mason, 2015]

[✂]

Figure 2.25: Comparison of the number of 3G indoor special sites [Source: Analysys Mason, 2015]

[✂]

The old model assumed that 25% of 2G sites were not necessary when removing the termination traffic, based on benchmarks. We have revised this percentage by assuming that the indoor special sites scale with termination in the same proportion as macro sites, which are calculated separately for 2G, 3G and 4G (see Figure 2.26): the methodology change is justified on the basis that there is no reason to assume that special sites behave in a different manner than the macro ones with respect to termination any longer.

Figure 2.26: Share of indoor special sites that are assumed to scale with termination traffic [Source: Analysys Mason, 2015]

Model	2G	3G	4G
New model	5%	2%	-
Old model	25%	-	-

These updates can be found in the 'Radio access network elements and inputs' section of the "NwDes_Inputs" worksheet.

► *Stakeholder comments*

One party **[NOS]** has argued that the forecast number of micro/special sites is too high (approx. 800 by 2016), and that a lower number of them **[BC]** [✂] **[EC]** complemented by pico/femtocells is sufficient to carry even higher share of the total traffic, and then that the number of micro/special sites should be reduced **[BC]** [✂] **[EC]**.

Another party **[MEO]** commented instead on the fact that in light of the forecast increasing traffic it is not understandable why the number of micro/special sites stops growing from 2016-2017 onwards.

► *Analysys Mason response*

The responses received on this issues are somehow contradictory, some of which claiming for a lower number of micro/special sites and other ones for a higher one.

With respect to the objection of one party **[NOS]** regarding the number of micro/special sites, it is worth of remarking the following:

- As agreed in the previous iteration of the project, pico/femtocells are not included in the model: we did not feel to change the approach from the previous version of the model, as the complexity of including them would make the cost/benefit approach on the model inconvenient without any tangible benefit to the overall model accuracy (unrequired complexity vs. negligible benefit on accuracy)
- A higher number of micro/special sites is then deployed in order to ensure adequate indoor coverage and service quality
- The model inputs are calibrated on the basis of the data received by the operators.
- **[BC]** [✂] **[EC]** We would expect that operators with large(r) operations and high(er) population coverage also have a high(er) number of indoors and micro sites.

With respect to the comments requiring a higher number of sites to manage an increasing amount of traffic made by one party **[MEO]**, we remark the fact that the number of sites deployed is sufficient to manage the traffic at the steady state through the deployment of additional capacity (i.e. carriers) on the same physical site. Even though an increase in network traffic does not lead to more cost for sites, it could lead to more costs for carriers.

► *Conclusion*

The proposed approach is confirmed.

Sectorisation

We have updated the share of sites with one, two or more sectors on the basis of new data provided by the operators (see Figure 2.27). In line with what was done in the old model, we have assumed the same sectorisation across geotypes.

Figure 2.27: Comparison of the sectorisation by technology between the new and old models [Source: Analysys Mason based on operator data, 2015]

Technology	1 sector	2 sectors	3+ sectors
GSM 900MHz			
New model	[✂]	[✂]	[✂]
Old model	[✂]	[✂]	[✂]
GSM 1800MHz			
New model	[✂]	[✂]	[✂]
Old model	[✂]	[✂]	[✂]
UMTS 2100MHz			
New model	[✂]	[✂]	[✂]
Old model	[✂]	[✂]	[✂]
LTE 800MHz			
New model	[✂]	[✂]	[✂]
Old model	[✂]	[✂]	[✂]
LTE 1800MHz			
New model	[✂]	[✂]	[✂]
Old model	[✂]	[✂]	[✂]
LTE 2600MHz			
New model	[✂]	[✂]	[✂]
Old model	[✂]	[✂]	[✂]

These updates can be found in the ‘Radio access network elements and inputs’ section of the “NwDes_Inputs” worksheet.

2G BTS capacity

We have updated the maximum number of TRXs per sector from 6 to 10 on the basis of new data provided by the operators.

3G NodeB capacity

We have updated the channelisation of UMTS carriers and added additional HSDPA speeds (e.g. HSDPA10.1, HSDPA14.4 and HSDPA84.4). According to the new inputs received from the operators, they have rolled out HSPA+ (42.2Mbit/s using DC-HSDPA), while conversely there is no indication that HSDPA84.4Mbit/s will be rolled out in future; we have updated the model accordingly, i.e. to include HSDPA42.2Mbit/s but ignore HSDPA84.4Mbit/s.

Figure 2.28: Comparison of HSPDA42.2Mbit/s deployment by geotype [Source: Analysys Mason based on operator data, 2015]

Geotype	New model	Old model
Dense urban	2012	N/A
Urban	2013	N/A
Suburban	2015	N/A
Rural	N/A	N/A
Micro/indoor	2012	2013

Similarly, we have updated the activation year for the lower-speed HSDPA21.1Mbit/s, as shown in Figure 2.29.

Figure 2.29: Comparison of HSPDA21.1Mbit/s deployment by geotype [Source: Analysys Mason based on operator data, 2015]

Geotype	New model	Old model
Dense urban	2010	2010
Urban	2011	N/A
Suburban	2012	N/A
Rural	N/A	N/A
Micro/indoor	2010	2012

We have also updated the minimum and maximum number of channel elements that can be deployed on 3G NodeBs on the basis of data provided by the operators, as shown in Figure 2.30.

Figure 2.30: Comparison of the minimum channel elements deployment per carrier [Source: Analysys Mason, 2015]

Carrier	Minimum channels		Maximum channels	
	New model	Old model	New model	Old model
R99 (voice)	[✂]	48	[✂]	112
1.8Mbit/s	[✂]	32	N/A	N/A
3.6Mbit/s	[✂]	64	N/A	N/A
7.2Mbit/s	[✂]	64	N/A	N/A
10.1Mbit/s	[✂]	N/A	N/A	N/A
14.4bit/s	[✂]	N/A	N/A	N/A
21.1Mbit/s	[✂]	128	N/A	N/A
42.2Mbit/s	[✂]	128	N/A	N/A
84.4Mbit/s	[✂]	N/A	N/A	N/A
HSUPA	[✂]	48	N/A	N/A

As a consequence of these updates, the 3G network is more traffic capable in the new model than in the old one (for both voice and data).

Finally, in the new model we have adjusted the share of R99 channels which are sensitive to termination traffic from 25% to 0%.

All of these updates can be found in the 'Radio access network elements and inputs' section of the "NwDes_Inputs" worksheet.

Proportions of owned and third-party sites

We have updated the percentage of sites that are not owned by the hypothetical existing operator on the basis of new data provided by the operators (see Figure 2.31).

Figure 2.31: Comparison of the shares of owned and third-party sites in the old and new models [Source: Analysys Mason, 2015]

Site ownership	New model	Old model
Operator	[✂]	[✂]
Third party	[✂]	[✂]

This update can be found in the 'Radio access network elements and inputs' section of the "NwDes_Inputs" worksheet.

Access network elements capacity

We have updated the capacity drivers for the access network elements to take into account inputs received from the operators:

- BSCs: we have increased the minimum deployment from 2 to 8, and increased the capacity in terms of E1 incoming ports from 250 to 300
- RNC: we have increased the capacity of busy-hour traffic from 1600 to 2458Mbit/s
- MSCs: we have increased the minimum deployment from 4 to 7.

► *Stakeholder comments*

One party **[NOS]** does not understand why the number of MSCs is 7 (stable) and why the number of MGW keeps in increasing (from 7 to 15), even if the voice traffic gets to be broadly stable from 2018 onwards. For an operator launching its operations in 2005 a full-NGN network with just 2 sites should have been deployed. Furthermore, there should be significant room for improvement: **[BC]** [✂] **[EC]**. Finally, this hardware could support the IMS Core functionalities to provide VoLTE.

► *Analysys Mason response*

With respect to the number of equipment deployed, the new steady-state number is based on the data received during the data request; furthermore, there is a 1-year roll-out period (2004-2005) as in the previous iteration of the project. The modelled MGW is used for both 2G and 3G and manages both voice and data traffic. The decrease in 2G traffic is offset by the increase of 3G one.

Moreover, the number of MGW that is needed depends on the size of the operator: **[BC]** [✂] **[EC]**. Therefore, the difference in scale must be taken into consideration when comparing the number of equipment between two operators of very different size.

With respect to the hardware functionality, the choice of a more or less capable equipment is again depending on the predictions about the take-up of 4G services (including VoLTE), the technology available at moment of the initial deployment and the comparative unit costs between a somewhat more common solution and a more innovative integrated solution at a certain point in time.

Noteworthy, we have received opposite feedbacks from different respondents that suggest that the choice on what is the most suitable value for this parameter is not broadly recognised. **[BC]** [✂] **[EC]**

► *Conclusion*

The proposed approach is confirmed.

Backhaul and transmission

We have updated the number of sites that are connected per access point on the basis of new data provided by the operators, as shown in Figure 2.32.

Figure 2.32: Average number of radio sites connected to the upper-level access point, by technology [Source: Analysys Mason based on data provided by operators, 2015]

Technology	New model	Old model
2G	200	50
3G	200	180
4G	200	N/A

We have calibrated the model in order to capture the new data received from operators about the technologies used for their last-mile access (LMA). We have retained assumptions from the old model relating to the distribution of technologies by geotype; for instance, we assume fibre backhaul to be concentrated in more densely populated geotypes. The new model now includes the backhaul links to LTE sites.

Figure 2.33: Share of sites connected by radio technology, backhaul technology and by geotype [Source: Analysys Mason based on operators' data, 2015]

Geotype	Leased lines	Microwave	DSL	Fibre
New model				
2G				
Dense Urban	15.0%	20.0%	-	65.0%
Urban	20.0%	35.0%	-	45.0%
Suburban	20.0%	60.0%	-	20.0%
Rural	38.0%	60.0%	-	2.0%

Geotype	Leased lines	Microwave	DSL	Fibre
Indoor / micro	100.0%	-	-	-
3G				
Dense Urban	15.0%	5.0%	-	80.0%
Urban	15.0%	30.0%	-	55.0%
Suburban	20.0%	40.0%	-	40.0%
Rural	20.0%	60.0%	-	20.0%
Indoor / micro	100.0%	-	-	-
4G				
Dense Urban	3.0%	2.0%	-	95.0%
Urban	5.0%	15.0%	-	80.0%
Suburban	15.0%	30.0%	-	55.0%
Rural	36.0%	60.0%	-	4.0%
Indoor / micro	100.0%	-	-	-

Old model				
2G				
Dense Urban	15.0%	10.0%	-	75.0%
Urban	20.0%	35.0%	-	45.0%
Suburban	20.0%	60.0%	-	20.0%
Rural	28.0%	70.0%	-	2.0%
Indoor / micro	100.0%	-	-	-
3G				
Dense Urban	15.0%	5.0%	-	80.0%
Urban	20.0%	30.0%	-	50.0%
Suburban	20.0%	55.0%	-	25.0%
Rural	28.0%	70.0%	-	2.0%
Indoor / micro	100.0%	-	-	-

These updates can be found in the ‘Transmission’ section of the “Nw_Des_Inputs” worksheet.

► *Stakeholder comments*

One party **[NOS]** deems that the percentage of 2G sites backhauled with leased lines in dense urban and urban geotypes (respectively 15% and 20%) is overestimated in light of the significant investments in fibre backhauling. **[BC]** [✂] **[EC]**. NOS recognises the estimation being potentially biased by data provided by other player **[BC]** [✂] **[EC]**, which in the past has deployed a significant number of micro-sites backhauled with fibre before realising it was not a profitable strategy.

► *Analysys Mason response*

One party [NOS] finds the share of 2G leased lines-backhauled sites in dense urban and urban geotypes as overestimated. The estimation of the breakdown percentages is calibrated according to the data provided by the respondent to the data request, when available; alternatively, it has been carried out based on the data of the previous iteration of the project and on internally available benchmarks.

► *Conclusion*

The proposed approach is confirmed.

HSPA backhaul capacity requirements

We have improved the methodology used to calculate the capacity requirements for HSPA backhaul links. In the old model the requirement was derived only from the peak capacity available on the site; however, the capacity requirement is also influenced by commercial considerations, since the upgrade to newer releases increases the speed as well as the capacity needed. The new model dimensions the E1-equivalent circuit requirement on the basis of the actual traffic transported, also taking into account the channel elements (CE) maximum utilisation in order to ensure the resilience of the links.

These updates can be found in the '3G radio network' section of the "Nw_Des_Inputs" worksheet.

Maximum utilisation

We have also updated the maximum utilisation of the main network elements by calibrating them on the basis of the data received from the operators.

[✂]

Figure 2.34: Comparison of maximum utilisation for major network elements [Source: Analysys Mason based on model calibration, 2015]

► *Stakeholder comments*

One party **[NOS]** commented on the updated values, highlighting significant discrepancies with respect to the data provided during the data request process.

► *Analysys Mason response*

With respect to the response by one party commenting about the discrepancies between the provided utilisation factors and the ones included in the model, we remark that the utilisation factor inputs reported in the public version of the model are tweaked to anonymise and protect confidential inputs provided by the operators.

► *Conclusion*

The proposed approach is confirmed.

2.6 Cost inputs

The results in the new model are shown in real 2013 EUR terms, and so the unit costs have been updated accordingly. Therefore, in the "Asset_input" worksheet the inputs have been replaced with the 2013 values in order to keep the unit costs unvaried from the old model, unless any update was required. In this section of the report we provide an overview of the unit cost changes between the new and the old model, both in real 2013 EUR terms.

Capex costs

In the following paragraphs we highlight the main updates related to unit capex.

► *Radio sites and base stations*

As shown in Figure 2.35, we have revised downwards the unit capex for the acquisition of radio access network elements, on the basis of the data provided by the operators and our benchmarks from other Western European regulatory cost models. For the physical sites we have maintained a positive forecast cost trend (even in light of a decrease in actual values) since the main components of these costs are labour and building materials, which are forecast to be stable or slightly increase in real terms in the future.

Figure 2.35: Radio sites and base stations – comparison of unit capex and of cost trends assumed in the new and old models [Source: Analysys Mason based on operator data and international benchmarks, 2015]

Asset	2013 unit cost (real 2013 EUR)		Cost trend (year-on-year % change)	
	New model	Old model	New model	Old model
Own macro site location	[✂]	[✂]	1.0%	1.0%
Third party macro site location	[✂]	[✂]	1.0%	1.0%
Third party indoor site location	[✂]	[✂]	1.0%	1.0%
Macro BTS 1-sector	[✂]	[✂]	-5.0%	-3.0%
Macro BTS 2-sector	[✂]	[✂]	-5.0%	-3.0%
Macro BTS 3-sector	[✂]	[✂]	-5.0%	-3.0%
Indoor / special BTS	[✂]	[✂]	-5.0%	-3.0%
Macro NodeB 3-sectors	[✂]	[✂]	-5.0%	-3.0%
Indoor / special NodeB	[✂]	[✂]	-5.0%	-3.0%
Site upgrade – 2G to 3G	[✂]	[✂]	-5.0%	-3.0%
RNC base unit	[✂]	[✂]	-10.0%	-10.0%

We have also updated the cost trends for the base-station asset items (e.g. BTS, NodeB, eNodeB).

These updates can be found in the “Asset_input” worksheet.

► *Backhaul links and other leased lines*

In the new model we have revised upwards the 2013 unit costs for the backhaul links. It is worth of noting that forecast cost trends are informed by similar benchmark (of forecast) and not by historical series.

Figure 2.36: Backhaul links and other leased lines – comparison of unit capex and cost trends assumed in the new and old models [Source: Analysys Mason based on Portugal Telecom’s ORCA reference offer, 2015]

Asset	2013 unit cost **(real 2013 EUR)**		Cost trend **(year-on-year % change)**	
	New model	Old model	New model	Old model
Fibre LMA	[✂]	[✂]	-3.0%	-8.0%
Leased E1 LMA Dense Urban	[✂]	[✂]	-3.0%	-8.0%
Leased E1 LMA Urban	[✂]	[✂]	-3.0%	-8.0%
Leased E1 LMA Suburban	[✂]	[✂]	-3.0%	-8.0%
Leased E1 LMA Rural	[✂]	[✂]	-3.0%	-8.0%
Leased E1 LMA Indoor	[✂]	[✂]	-3.0%	-8.0%
Self-provided ULL E1	[✂]	[✂]	-3.0%	-8.0%
Leased E1 - Remote BSC/PCU to MSC/SGSN	[✂]	[✂]	-3.0%	-8.0%
Leased STM1 - Remote BSC/PCU to MSC/SGSN	[✂]	[✂]	-3.0%	-8.0%
Leased E1 - MSC to MSC/VMS	[✂]	[✂]	-3.0%	-8.0%
Leased STM1 - MSC to MSC/VMS	[✂]	[✂]	-3.0%	-8.0%

We have reduced the unit capex of the traffic aggregation switch used for fibre backhaul links from EUR[✂] to EUR[✂], in line with more up-to-date benchmarks[5] for asset types which meet the specific needs in that part of the network more closely (in terms of capacity and capabilities). However, on the basis of our experience, the other cost inputs (e.g. fibre, installation and trench cost) have not declined to the extent that was assumed in the old model. As a consequence, the average fibre LMA cost per unit has increased in real 2013 EUR terms between the old and the new model. This update can be found in the “Asset_input” worksheet.

We have also updated leased-line pricing according to the latest available Reference Offer from Portugal Telecom.[6] As a consequence, the unit capex of leased segments has increased compared

5 The new value has been benchmarked against the switches of other regulatory models.

6 Portugal Telecom’s Reference Offer, “ORCA_Anexo3_Precos_v17_31mai2013”, available at http://ptwholesale.telecom.pt/GSW/UK/Canais/ProdutosServicos/OfertasReferencia/ORCA/RLLO.htm.

to what was expected in the old model for 2013. These updates can be found in the 'Transmission' section of the "NwDes_Inputs" worksheet.

In light of the above considerations, we have also made a downward adjustment to the unit capex reduction trend that is applied to the transmission assets.

Opex costs

We have revised the operational expenditure (opex) per unit in a similar way to that described for capex. Noteworthy, we have decreased the share of indirect costs from [✂]% to [✂]% on the basis of the cost data observed in our benchmarks for the 2012.

► *Radio sites and base stations*

We have updated the opex per unit for some of the radio sites and base-station assets on the basis of our benchmarks from other Western European regulatory cost models.

Figure 2.37: Radio sites and base stations – comparison of unit opex and cost trends assumed in the new and old models [Source: Analysys Mason based on operator data and international benchmarks, 2015]

Asset	2013 unit cost (real 2013 EUR)		Cost trend (year-on-year % change)	
	New model	Old model	New model	Old model
Own macro site location	[✂]	[✂]	-	-
Third party macro site location	[✂]	[✂]	-	-
Third party indoor site location	[✂]	[✂]	-	-
Macro BTS 1-sector	[✂]	[✂]	-12.0%	-12.0%
Macro BTS 2-sector	[✂]	[✂]	-12.0%	-12.0%
Macro BTS 3-sector	[✂]	[✂]	-12.0%	-12.0%
Indoor / special BTS	[✂]	[✂]	-	-
Macro NodeB 3-sectors	[✂]	[✂]	-	-
Indoor / special NodeB	[✂]	[✂]	-	-
Site upgrade – 2G to 3G	[✂]	[✂]	-2.0%	-2.0%
RNC base unit	[✂]	[✂]	-	-

These updates can be found in the "Asset_input" worksheet.

► *Backhaul links and other leased lines*

We have validated the leased-line pricing on the basis of Portugal Telecom's Reference Offer.[7] Similar to what has happened to the unit capex, the 2013 operational expenditure per link has increased between the old and the new model. The cost trend has been updated accordingly.

7 Portugal Telecom's Reference Offer, "ORCA_Anexo3_Precos_v17_31mai2013", available at http://ptwholesale.telecom.pt/GSW/UK/Canais/ProdutosServicos/OfertasReferencia/ORCA/RLLO.htm.

Figure 2.38: Backhaul links and other leased lines – comparison of unit opex and of cost trends assumed in the new and old models [Source: Analysys Mason based on Portugal Telecom's ORCA reference offer, 2015]

Asset	2013 unit cost **(real 2013 EUR)**		Cost trend **(year-on-year % change)**	
	New model	Old model	New model	Old model
Fibre LMA	[✂]	[✂]	-%	-%
Leased E1 LMA Dense Urban	[✂]	[✂]	-5.0%	-15.0%
Leased E1 LMA Urban	[✂]	[✂]	-5.0%	-15.0%
Leased E1 LMA Suburban	[✂]	[✂]	-5.0%	-15.0%
Leased E1 LMA Rural	[✂]	[✂]	-5.0%	-15.0%
Leased E1 LMA Indoor	[✂]	[✂]	-5.0%	-15.0%
Self-provided ULL E1	[✂]	[✂]	-5.0%	-15.0%
Leased E1 - Remote BSC/PCU to MSC/SGSN	[✂]	[✂]	-5.0%	-15.0%
Leased STM1 - Remote BSC/PCU to MSC/SGSN	[✂]	[✂]	-5.0%	-15.0%
Leased E1 - MSC to MSC/VMS	[✂]	[✂]	-5.0%	-15.0%
Leased STM1 - MSC to MSC/VMS	[✂]	[✂]	-5.0%	-15.0%

In line with the assumptions taken for the backhaul links, we have decreased the cost trend of the regional and national backbone links.

Figure 2.39: Regional and national backbone links – comparison of unit opex and of cost trends assumed in the new and old models [Source: Analysys Mason, 2015]

Asset	**2013 unit cost (real 2013 EUR)**		**Cost trend (year-on-year % change)**	
	New model	Old model	New model	Old model
Regional backbone access points STM1	[✂]	[✂]	-5.0%	-15.0%
Regional backbone access points STM4	[✂]	[✂]	-5.0%	-15.0%
Regional backbone access points STM16	[✂]	[✂]	-5.0%	-15.0%
Regional backbone access points STM64	[✂]	[✂]	-5.0%	-15.0%
Regional backbone distance (km)	[✂]	[✂]	-5.0%	-15.0%
National backbone access points STM1	[✂]	[✂]	-5.0%	-15.0%
National backbone access points STM4	[✂]	[✂]	-5.0%	-15.0%
National backbone access points STM16	[✂]	[✂]	-5.0%	-15.0%
National backbone access points STM64	[✂]	[✂]	-5.0%	-15.0%
National backbone distance (km)	[✂]	[✂]	-5.0%	-15.0%

These updates can be found in the 'Transmission' section of the "NwDes_Inputs" worksheet.

► *Core network*

We have refined the logics underlying the network management system ('NMS') from two points of view to make it more in line with the current deployments of the Portuguese operators; more specifically, we have:

- updated (namely reduced) the cost to make it more in line with the actual costs reported by the Portuguese operators
- increased the number of "logical units" in order to take into account the deployment of LTE and the launch of VoLTE.

Figure 2.40: Network management system – comparison of unit opex and of cost trends assumed in the new and old models [Source: Analysys Mason, 2015]

Asset	2013 unit cost (real 2013 EUR)		Cost trend (year-on-year % change)	
	New model	Old model	New model	Old model
Network management system (HW)	[✂]	[✂]	-	-
Network management system (SW)	[✂]	[✂]	-	-

► *Stakeholder comments*

One party **[NOS]** commented on the updated cost trend values, stating that some of them appear now more reasonable (e.g. the one for BTS and eNodeBs) while other ones does not look aligned with its available data (e.g. the one for transmission equipment); according to this party, a significant decrease of the core network hardware cost would also be foreseeable.

Another party **[Vodafone]** has commented on the capex and opex downward cost trends, which are deemed to be 'unrealistic and unreasonable'. According to the party, operating costs cannot decrease more than capital expenditure given their nature; furthermore, the best proxy for opex cost trend would be inflation, which would already be a conservative assumption.

Finally, the unit cost of some network equipment (e.g. the SBC) appear underestimated, especially in light of the inclusion of state-of-the-art features (e.g. to manage VoLTE) which are currently costly.

Also another party **[MEO]** reported that in its opinion cost trends does not look credible as it is unlikely that such decrease trends go on in the long run, as it would inevitably lead to a network quality decrease, to a lower degree of technological evolution and to a higher number of network faults. Therefore, it proposes to assume either flat or inflation cost trends.

► *Analysys Mason response*

The respondents have submitted comments about both the unit capex values and about the cost trends (for both capex and opex), some of which are in contradiction among them (i.e. some parties claim for higher values and other ones for lower ones). Inputs about the cost items were requested during the data request process (namely Q76 to Q92); the model inputs have been calibrated according to the data provided by the data request respondents and validated through international benchmarks; all of these data are confidential by nature. **[BC]** [✂] **[EC]**.

► *Conclusion*

The proposed approach is confirmed.

2.7 Regulatory fees

To be consistent with the bottom-up model recently developed by Analysys Mason and ICP-ANACOM for fixed core networks in Portugal, the new mobile model now includes a cost for regulatory fees. In the interests of consistency and simplicity we have adopted the same methodology followed in the fixed model, which is in line with ICP-ANACOM's calculation of the regulatory fees charged to the major telecoms operators (by revenue).

Indeed, Tier-2 operators (with revenue higher than EUR1.5 million) pay a variable regulatory fee T_2, which is a percentage of their revenue; i.e. $T_2 = t_2 \times R_2$, where t_2 is the fee rate (expressed as a percentage of revenue) and R_2 is the relevant revenue, which excludes VAT, sales of terminals (equipment), transactions between entities of the same group and revenue from the universal service. t_2 is calculated by ICP-ANACOM and is worth 0.5999% for the year 2014. In light of the actual values, a long-term value of 0.6% for t_2 appears reasonable (see Figure 2.41).

The mobile termination cost calculated by the new model is marked up by t_2 to also take into account the regulatory fees, i.e. $Termination\ cost_{with\ regulatory\ fees} = Termination\ cost \times (1 + t_2)$.

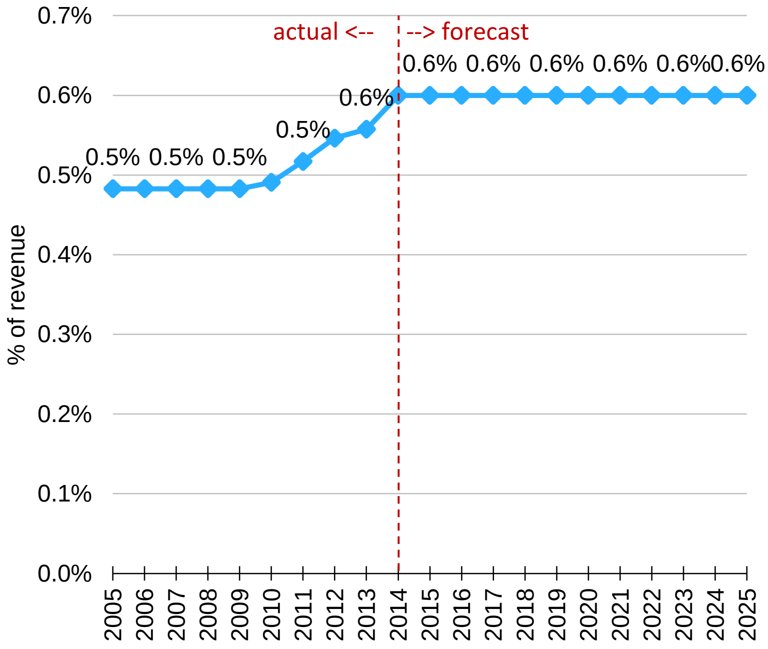


Figure 2.41: t_2 *forecast for calculation of the regulatory fees included in the model [Source: Analysys Mason, 2015]*

► *Stakeholder comments*

One party **[Ar Telecom]** alerts the fact that the regulatory fees cost input assumes a long-term rate of 0.6% when this value has not been reached in the last 6 years of history.

Since electronic communication operators have been forced to optimise their cost structures, the same pressure on costs should be expected by the Authority, including the Governor. The party, therefore, deems necessary to assume a downward trend of regulatory costs, supported by a plan of progressive increase of efficiency.

► *Analysys Mason response*

The regulatory fees have been calculated using the standard methodology adopted in previous years and already implemented in the model developed by Analysys mason and ICP-ANACOM to calculate the fixed termination rate.

► *Conclusion*

The proposed approach is confirmed.

2.8 WACC

We have updated the WACC following the same methodology used in the old model. Figure 2.42 compares the WACC components between the new and the old version of the model.

Figure 2.42: Comparison of WACC components [Source: Analysys Mason, 2015]

WACC	New model	Old model	Source
Risk-free rate, nominal	3.91%	4.80%	ECB, Eurostat
Equity premium	5.75%	6.02%	Average between the data from Aguirreamalloa and Linares and from Damodaran
Beta (relevered for gearing and tax)	1.57	0.81	Calculation
Unlevered beta	0.69	0.53	Average of mobile operators' beta (Mobistar, Telenor ASA, TeliaSonera AB, Vodafone, Mobile Telesystems) extracted from Reuters[8] and Financial Times[9] websites
Nominal cost of equity (post-tax)	12.92%	9.67%	Calculation
Nominal cost of equity (pre-tax)	17.82%	13.62%	Calculation
Nominal cost of debt (pre-tax)	4.84%	6.14%	Calculation
Debt premium over risk-free rate	0.93%	1.34%	Benchmark of debt premiums adopted by other Western European telecoms regulators
Gearing D/(D+E)	56.19%	33.93%	Average 2010–2014 gearing of Western European mobile operators (Mobistar, Telenor ASA, TeliaSonera AB, Vodafone, Mobile Telesystems) sourced from Financial Times and Morningstar
Debt over equity (D/E)	128.28%	51.36%	Calculation
Marginal tax rate	27.50%	29.00%	Tax rate for 2015, DG Orcamento[10]
Nominal WACC (pre-tax)	10.52%	11.08%	Calculation
Inflation rate	1.70%	1.73%	2015–2025 average based on Euromonitor
Real pre-tax WACC	**8.68%**	**9.19%**	**Calculation**

► *Stakeholder comments*

One party **[NOS]** agrees with the overall implementation approach.

Another party **[Vodafone]** claims that the inputted value is too low; as a reference point, it should be higher than the one used for the regulation of the fixed operations for a number of reasons:

8 See http://www.reuters.com/finance/stocks/.

9 See http://markets.ft.com/research/Markets/Overview.

10 State Budget 2015; see http://www.dgo.pt/politicaorcamental/Paginas/OEpagina.aspx?Ano=2015&TipoOE=Proposta%20de%20Or%C3%A7amento%20do%20Estado&TipoDocumentos=Lei%20/%20Mapas%20Lei%20/%20Relat%C3%B3rio.

- The need of mobile operators of maintaining three network generations in operation at the same time
- The intrinsic risk undertaken by mobile operator when acquiring the spectrum licences with significant upfront payments (and on-going spectrum fees to be paid)
- The need for significant upfront capex to be incurred in order to build the networks.

Another party **[MEO]** reports two main comments about the WACC:

- The value of the WACC cannot be stable over a 45-year time period
- Different sources (with respect to Euromonitor) should be used to estimate the forecast inflation rate in the time horizon, e.g. PwC and Ernst&Young.

► *Analysys Mason response*

One party **[NOS]** agrees with the overall implementation approach.

With respect to the comments submitted by one party **[Vodafone]** claiming a too low assumed value, the methodology used to estimate the WACC is a widely accepted one and in light of the information received and of the context updates we did not deem it was the case of changing it. Furthermore, we deemed as still appropriate also the benchmark sample from which inputs were sourced, which we have updated with the latest available data points.

The issue about different values of the WACC over time raised by one party **[MEO]** has been already debated in the previous iteration of the process; while a constant WACC for 45 years is indeed not realistic, it cannot be reasonably expected to calculate the WACC for each of the 45 years. We remark that the model shall ensure that it produces coherent and consistent results for the next regulatory period. This entails that the calculation of the WACC will need to take into account information available about this period, typically 2-3 years. To avoid additional errors and complexity, we will aim to the implementation of simple WACC calculations that combine a rigorous approach with a simple methodology that takes into account the economic reality of the country and allows a transparent verification of calculations.

Finally, Euromonitor is a third-party authoritative source for macroeconomic inputs (both actual and forecast), which was already accepted in the previous iteration of the process, and there was nothing at our knowledge preventing us in keeping in using its inputs to inform our models. Moreover, the update Euromonitor's projections have been benchmarked against the forecast from EIU that is consistent with the data used in the model.

► *Conclusion*

The proposed approach is confirmed.

2.9 Other updates

The other relevant model updates are presented in this section.

Annual spectrum licence fee

We have updated the price per MHz for the spectrum licence fees in line with the related document that ICP-ANACOM sent to Analysys Mason;[11] see Figure 2.43.

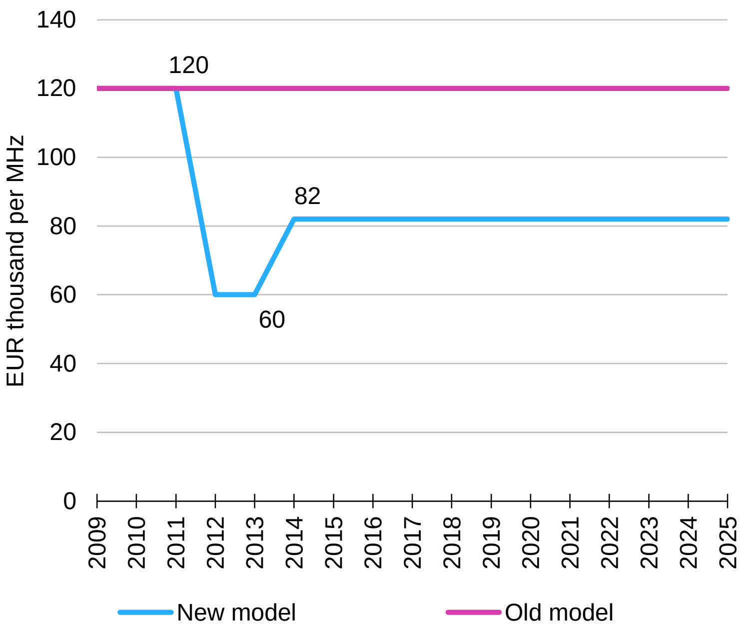


Figure 2.43: Comparison of the spectrum licence fee per MHz to be paid by mobile operators [Source: Analysys Mason on ICP-ANACOM, 2015]

In the previous model the above mentioned license fee was multiplied by 2 for every MHz of spectrum beyond 35MHz. This rule has been removed from the model, since it does no long apply as we understand from our conversations with ICP-ANACOM.

These updates can be found in the 'Spectrum and licence fees' section of the "NwDes_Inputs" worksheet.

Real 2013 versus real 2011 results

The results that were shown in real 2011 EURcents in the old model are shown as real 2013 EURcents in the new model.

11 Artigo 2, Alteração ao Decreto-Lei n.º 287/2007, de 17 August 2013.

3 The inclusion of 4G in the model

This section describes all the changes we have made to the model to include 4G services, 4G network, 4G spectrum bands, etc.

3.1 Inclusion of new services (retail and network)

We have added the services provided over the 4G network homologous to those already provided over the 2G and 3G networks. However, even though 4G data services have been offered since 2012, it will only be possible to offer voice services over 4G once the mobile operators have rolled out their voice over LTE (VoLTE) platform; we have assumed the commercial launch of VoLTE to take place in 2016. We discuss the topic in more detail in the Launch of VoLTE paragraph of Section 3.7.

New network services included in the model
4G On-net calls
4G Outgoing calls to other national fixed networks
4G Outgoing calls to other national mobile networks
4G Outgoing calls to international
4G Incoming calls from other national fixed networks
4G Incoming calls from other national mobile networks
4G Incoming calls from international
4G Roaming in origination
4G Roaming in termination
4G On-net SMS
4G Outgoing SMS to other networks
4G Incoming SMS from other networks
4G Data (LTE)

Figure 3.1: 4G network services [Source: Analysys Mason, 2015]

3.2 4G-capable spectrum holding and spectrum upfront payment

LTE spectrum holding and re-farming of the 1800MHz spectrum band

The 2011 spectrum auction assigned LTE-capable spectrum in three bands, i.e. 800MHz, 1800MHz and 2600MHz.[12]

12 ICP-ANACOM, “Information on multi-band spectrum auction”, available at http://www.anacom.pt/render.jsp?contentId=1106646#.VIr2UzHF_pV.

As shown in Figure 3.2, the three MNOs were awarded similar spectrum lots, with Vodafone obtaining the largest amount of spectrum in total, thanks to additional lots in the 900MHz and 2600MHz bands (the latter including an unpaired TDD lot).

Spectrum bands	MEO	Vodafone	NOS
800MHz	2×10MHz	2×10MHz	2×10MHz
900MHz	-	2×5MHz	-
1800MHz	2×14MHz	2×14MHz	2×14MHz
2600MHz	2×20MHz	2×20MHz 25MHz TDD	2×20MHz

Figure 3.2: Outcome of the 2011 spectrum auction in Portugal [Source: ICP-ANACOM, 2014]

In light of these results we have assumed a spectrum holding for the modelled operator as shown in Figure 3.3, with an amount of LTE-capable spectrum similar to that actually awarded to existing Portuguese MNOs.

Figure 3.3: Paired spectrum holding assumed for the modelled operator [Source: Analysys Mason, 2015]

	800MHz	900MHz	1800MHz	2100MHz	2600MHz
Old model	-	2×8MHz	2×6MHz	2×20MHz	-
New spectrum assigned in 2011	2×10MHz	-	2×14MHz	-	2×20MHz
Spectrum holding from 2012	2×10MHz	2×8MHz	2×20MHz	2×20MHz	2×20MHz

The spectrum in the 800MHz band is modelled to provide the primary coverage layer for LTE, whereas the 2.6GHz and the 1.8GHz ones are modelled to provide primary and secondary capacity overlays respectively.

We have modelled the re-farming of the GSM 1800MHz spectrum to LTE in 2018; indeed, this spectrum has already been used to provide LTE services by Portuguese MNOs (some on selected sites, others on all sites). However, the re-farming of GSM spectrum to LTE is subject to the migration of voice traffic from 2G to other networks; indeed, the capacity provided by the GSM 900MHz coverage layer alone is insufficient to carry the modelled operator's 2G traffic, and so the operator would need to make additional investments to increase the capacity installed (i.e. by deploying additional sites). Therefore, we consider the launch of VoLTE as a key enabler of spectrum re-farming. The spectrum is re-farmed at the beginning of 2018 because this is the first year in which the share of total voice traffic carried on the 2G network falls below 50%.

► *Stakeholder comments*

One party **[NOS]** claimed that a hypothetical efficient operator would have chosen different coverage layers for 4G, using 1800MHz as a secondary coverage layer (once freed up by GSM) and 2600MHz as tertiary coverage layer, **[BC]** [✂] **[EC]**.

Similarly, another party **[Vodafone]** states that it is unrealistic the fact that the 1800MHz spectrum refarming is supposed to take place in 2018. After the investment the operators made in networks and spectrum allocation in 2012 in order to enable the use of iPhone 5 in LTE mode, the party **[Vodafone]** claims the refarming should take place before 2018.

► *Analysys Mason response*

With respect to the different approach to the coverage layers reported by one party **[NOS]**, we deem to remark the fact that the approach adopted in the model is one among the possible ones, and that the effective degree of efficiency depends on the relative costs between the incremental number of sites needed if the 2600MHz spectrum is used as secondary coverage layer (instead of the 1800MHz one) vs. the spectrum re-farming costs that an operator would incur if it wanted to use the 1800MHz spectrum as secondary coverage layer, being this spectrum currently occupied by GSM (as stated by the party itself).

The possibility of re-farming spectrum from GSM to LTE depends on several operators' specific characteristics:

- Operator size/number of subscribers – Given a certain spectrum holding, the larger the number of subscribers and the traffic volume on the network, the later an operator will be able to re-farm bands, since more spectrum will be needed to support the service continuity to the existing subscriber base
- Spectrum holdings – A higher quantity of GSM-capable spectrum (e.g. 900MHz) in the low frequency bands could potentially allow an operator to free the 1800MHz earlier than competitors since the traffic could be carried more easily using GSM900. **[BC]** [✂] **[EC]**
- Handset subsidy strategy – An operator that is more aggressive on handset subsidies is likely to be able to migrate its subscriber base to 3G and to 4G earlier than other ones, thus being also able to free bands earlier. Moreover, handset subsidies are easier to control in postpaid-based markets, while the majority of SIMs in Portugal is prepaid. **[BC]** [✂] **[EC]**

For the reasons stated above, there is no an efficient choice in absolute terms, i.e. a choice that can be deemed as 'efficient' for an operator is not necessarily said to be 'efficient' as well for another one.

Noteworthy, the refarming strategy was part of the data request (Q73, "Spectrum refarming, sites redeployment") and the party **[Vodafone]** did not provide any information on its plan to re-farm the 1800MHz band (same as the other operators).

► *Conclusion*

The proposed approach is confirmed.

LTE spectrum costs

The latest spectrum auction awarded all the spectrum lots at the reserve price. We have therefore assumed the same upfront payments for the modelled operator and a 15-year licence duration, as shown in Figure 3.4.

Figure 3.4: Upfront spectrum licence payment and licence duration assumed for the modelled operator [Source: Analysys Mason, 2015]

	800MHz	900MHz	1800MHz	2100MHz	2600MHz	Total
Upfront payment (EUR million)	90	-	11	-	12	113
Licence duration (years)	15		15		15	

We have also modelled the spectrum management fees for the new frequencies. To calculate the amount to be paid, we have used the same methodology as that used in 2009 for the 3G spectrum. These fees comprise an annual licence worth EUR82 000 per year from 2014 and a fee equal to EUR0.02 per subscriber per year, as in the old model.

3.3 4G network population coverage

We have used operator data to inform our assumptions on the 4G outdoor population coverage (with 800MHz as the primary coverage layer), which is projected to reach 97% by the end of 2019.

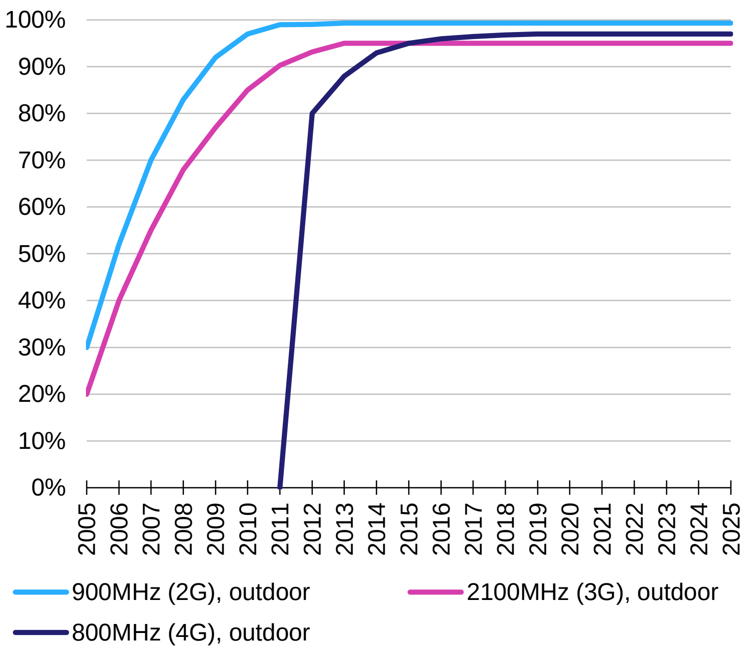


Figure 3.5: Outdoor population coverage of the modelled operator by network generation [Source: Analysys Mason based on operator data, 2015]

4G coverage is likely to exceed that for 3G, given the use of a lower-frequency band as the primary layer (800MHz for 4G, versus 2100MHz for 3G). However, the achieved coverage might be lower if the operator decides not to launch VoLTE, since voice services would require a more ubiquitous coverage.[13]

The cell radii of the LTE capable spectrum bands have been derived from and validated with available benchmarks.

Indoor special sites

We have assumed that the number of 4G indoor special sites will converge with the number of 2G special sites (which are deployed for indoor coverage).

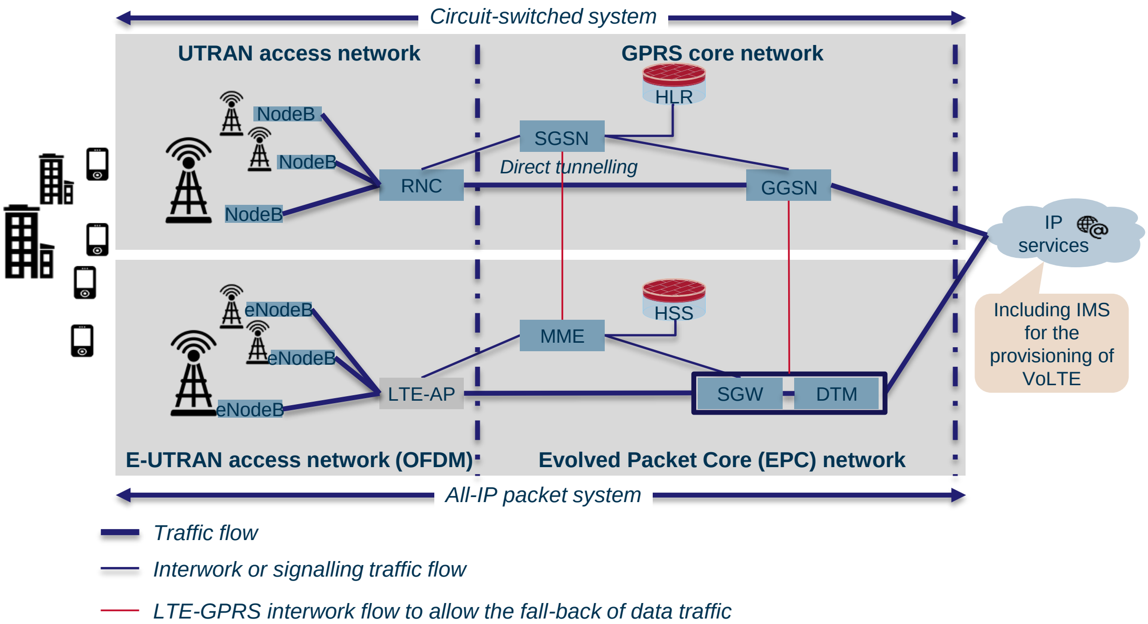
3.4 The LTE network

We have modelled a theoretical LTE network in accordance with international best practice,[14] which appears in line with the networks actually rolled out by Portuguese operators.

Figure 3.6 illustrates the main components of the all-IP LTE network we have modelled:

- E-UTRAN (orthogonal frequency division multiplexing (OFDM)) access network
- evolved packet core (EPC) core network.

Figure 3.6: Illustration of the modelled LTE network and the relationship with the legacy GPRS infrastructure [Source: Analysys Mason, 2015]



13 This option is not modelled explicitly.

14 Telecom Italia, *Notiziario Tecnico: speciale LTE, perché? Sostenibilità, tecnologie e uso delle nuove reti*, Q3 2013. (URL http://www.telecomitalia.com/content/dam/telecomitalia/it/archivio/documenti/Innovazione/MnisitoNotiziario/2013/2-2013/NT2-2013.pdf); Alcatel-Lucent, *Introduction to Evolved Packet Core* (URL http://www3.alcatel-lucent.com/wps/DocumentStreamerServlet?LMSG_CABINET=Docs_and_Resource_Ctr&LMSG_CONTENT_FILE=White_Papers/Intro_EPC_wp_0309.pdf); Alcatel-Lucent, *The LTE Network Architecture* (URL)

In the following sections we provide an overview of the equipment and dimensioning rules followed in the model.

3.5 E-UTRAN radio access network

Coverage layer

The number of assets required for coverage is derived using the same dimensioning rules as for 2G and 3G networks, with the only difference being that 4G has three spectrum bands available.

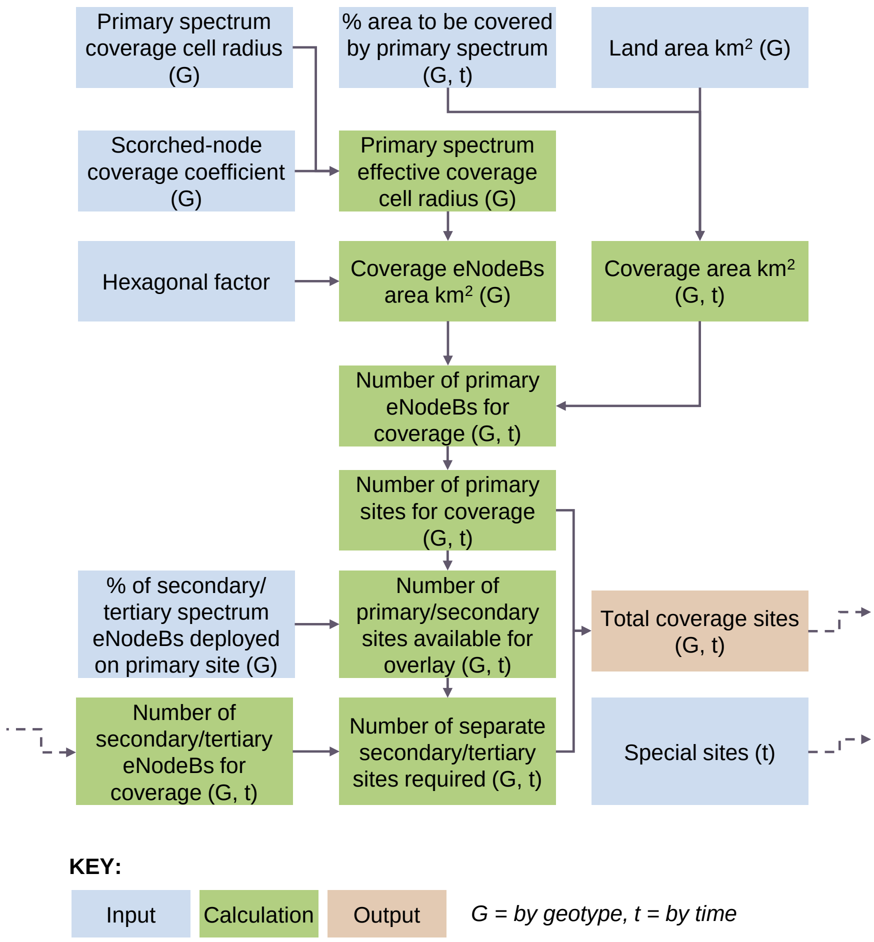


Figure 3.7: Calculation of the number of 4G sites required to provide the target outdoor coverage of the population [Source: Analysys Mason, 2015]

Capacity overlays

We have calculated the number of LTE capacity-driven sites through a two-step internationally validated approach which firstly calculates the number of eNodeBs and eventually the number of carriers needed to carry the assumed volume of 4G traffic. Both steps are described below.

► *eNodeB requirements*

We have assumed six LTE upgrades (as shown in Figure 3.8). Each incremental step allows the operator to increase both the speed offered to the customers and the throughput (capacity).

Figure 3.8: LTE upgrades used in the model [Source: Analysys Mason, 2015]

Peak speed in Mbit/s	Modulation	MHz paired spectrum	MIMO configuration
37.0	64 QAM	2×5MHz	2×2
75.6	64 QAM	2×10MHz	2×2
152.7	64 QAM	2×20MHz	2×2
229.8	64 QAM	2×30MHz	2×2
306.9	64 QAM	2×40MHz	2×2
604.5	64 QAM	2×40MHz	4×4

Note: The peak speed achievable has been calculated assuming a 10% guard band, 7 OFDMA symbols in a timeslot and a 15kHz subcarrier size.

Supported by the data provided by Portuguese MNOs, we have assumed that the modelled operator is deploying the following carrier configurations across all geotypes:

- a 2×10MHz carrier in the primary spectrum band (800MHz)
- a 2×20MHz carrier in the secondary spectrum band (2600MHz)
- a 2×20MHz carrier in the tertiary spectrum band; this carrier is assumed to be deployed only if needed to fulfil excess in traffic demand
  - of course, the availability of 2×20MHz spectrum in the 1800MHz band is subject to its re-farming from GSM.

We have made some assumptions regarding the deployment period of each upgrade, as shown in Figure 3.9 for the coverage and additional capacity layers respectively.

Figure 3.9: Years in which the LTE upgrades are deployed by geotype [Source: Analysys Mason, 2015]

Upgrade (Mbit/s)	Dense urban	Urban	Suburban	Rural	Micro / indoor
37.0	2012	2012	2012	2012	2012
75.6	2012	2012	2013	2013	2012
152.7	2013	2014	2016	2020	2013
229.8	2016	2018	2020	2024	2016
306.9	2018	2020	2022	N/A	2018
604.5	N/A	N/A	N/A	N/A	N/A

This is consistent with the data provided by operators in Portugal. The main Portuguese MNOs have a basic configuration of around 70Mbit/s and have already started deploying the 150Mbit/s upgrade on some sites following the commercial launch of LTE-Advanced in 2013.

The other main inputs to the eNodeB capacity calculation used in the model are summarised in Figure 3.10.

Figure 3.10: Description of other main inputs used in the eNodeB calculation [Source: Analysys Mason, 2015]

Name	Value assumed	Description
Effective Mbit/s as a proportion of peak Mbit/s (average throughput)	25%	For example, the peak rate might be c. 12Mbit/s, but the effective rate over the cell area is c. 3Mbit/s
Coverage frequency	800MHz – primary spectrum	Frequency assumed to be used to deploy coverage eNodeBs in all geotype
Capacity frequency	2600MHz – secondary spectrum; 1800MHz – tertiary spectrum	Remaining frequencies available for 4G services. The tertiary spectrum band is only deployed if the demand exceeds the capacity available in primary and secondary spectrum bands

The ratio between the effective throughput achieved and the peak speed is a key input in the model, since it drives the capacity of the network. MNOs provided quite different responses to the data request on this issue. Based on their response, the percentage should range between [✂]% and [✂]%. Our assumption is closer to the lower bound of the range provided, and has been validated through the internally available benchmarks.

In order to validate the value we have assumed, we benchmarked it against other Western European regulatory models.

In terms of methodology, we firstly calculated the busy-hour (BH) Mbit/s per coverage site by accounting for the carriers' maximum utilisation factor and average throughput. We then calculated the maximum bitrate across all carriers, multiplying the total number of carriers (coverage and capacity) available by the capacity per carrier (capacity per sector multiplied by the average number of sectors). This capacity depends on the evolutionary step adopted by the modelled operator on both the coverage and capacity layers (see Figure 3.8). As a consequence, the capacity per available carrier increases over time as the modelled operator upgrades its LTE technology.

We then calculated the number of eNodeB macrocells required to carry the BH throughput using the following formula:

$$eNodeBs\ macrocells = eNodeBs\ required\ for\ coverage \times \left[\left(\frac{BH\frac{Mbit}{s}\ per\ coverage\ eNodeB}{Maximum\ bitrate} - 1\right)\right]$$

By definition, the total number of eNodeBs required is the sum of those previously calculated for coverage plus the demand capacity-driven ones calculated in this step, as shown in Figure 3.11.

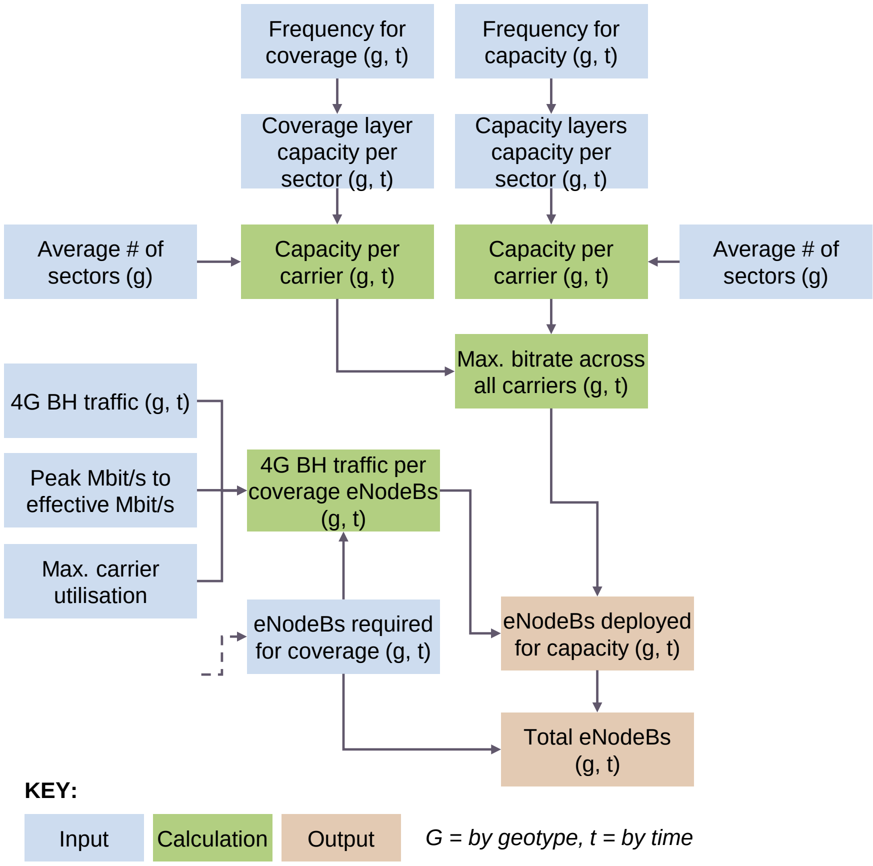


Figure 3.11: Calculation of eNodeB requirements [Source: Analysys Mason, 2015]

► *Carrier requirements*

We firstly calculated the BH Mbit/s per eNodeB (including both coverage and capacity eNodeBs this time), again accounting for the carriers' maximum utilisation factor. For each cell type, we then determined whether deploying one carrier per eNodeB would be sufficient to carry this BH throughput (by cross-checking the BH Mbit/s per eNodeB with the maximum bitrate of a carrier). If one carrier was not sufficient, we then sequentially checked whether deploying an additional carrier per eNodeB would be sufficient. The functionality has been included in the model to repeat this process for up to a maximum of three carriers. The first two iterations are mandatory, since the model assumes that the deployment of the first two carriers is driven by commercial decisions. Conversely, the third and last carrier is deployed only if the capacity provided by the previous ones is insufficient to cope with the traffic demand.

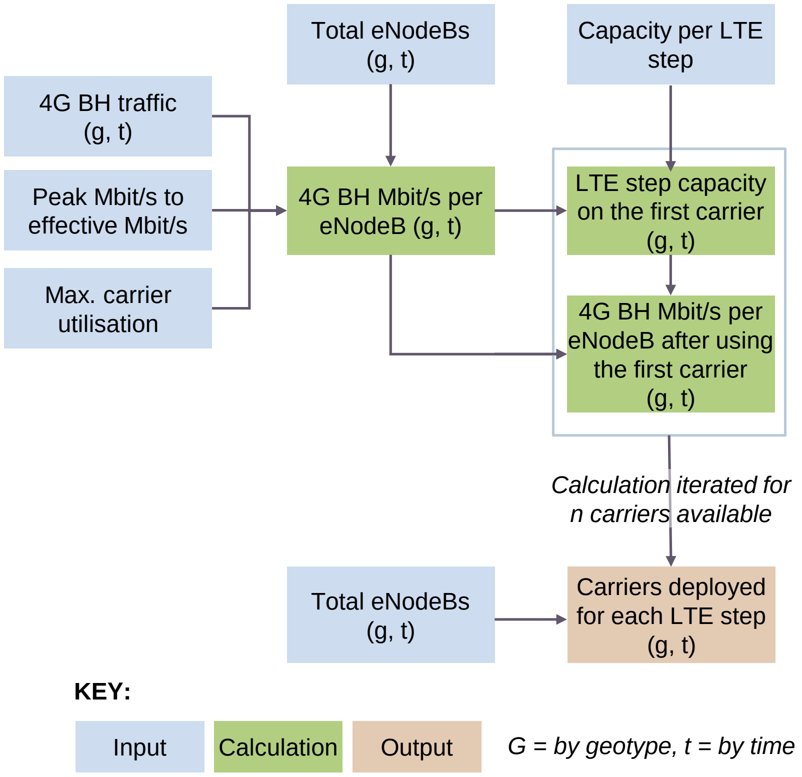


Figure 3.12: Calculation of LTE carrier requirements [Source: Analysys Mason, 2015]

We then summed up the total number of carriers across all LTE upgrades available. The planning period was then factored into the output, with the final results by cell type aggregated into tables of macro/microcell carriers by geotype over time.

Calculation of physical sites

Although the methodology has not changed from that used for the old model, the addition of 4G technology complicates the calculation of the number of physical sites required in the access network. We have derived the degree of co-location of the different mobile technology generations on the basis of the following drivers:

- share of 2G sites capable of hosting 3G
- share of 2G sites capable of hosting 4G
- share of 2G sites without 3G capable of hosting 4G
- share of 3G sites without 2G capable of hosting 4G.

We have assumed that, as far as possible, mobile operators roll out the incremental technology on top of already existing physical sites in order to optimise their capital expenditure. Radio sites can have a number of technological configurations:

- 2G only
- 3G only
- 4G only
- 2G + 3G
- 2G + 4G

- 2G + 3G + 4G
- 3G + 4G.

The total number of physical locations required by the radio access network is the sum of all the configurations above.

Transmission

The dimensioning of the backhaul transmission follows the same rules used for links connecting HSPA sites. Please see the Backhaul and transmission paragraph in Section 2.5 for more details on the technology split used.

LTE-AP

LTE does not require the equivalent of the RNC (for 3G) or BSC (for 2G). The functionalities of this equipment are distributed between the eNodeB (in the access network) and the MME (in the core network), effectively removing one network layer. Nonetheless, we have assumed the existence of an aggregation hub (“LTE-AP”) where the 4G backhaul links converge to aggregate the traffic into more capable links connecting to the regional and national backbone. We have assumed that the LTE-AP has additional functionalities and features, including multiplexing, an optical distribution frame (ODF).

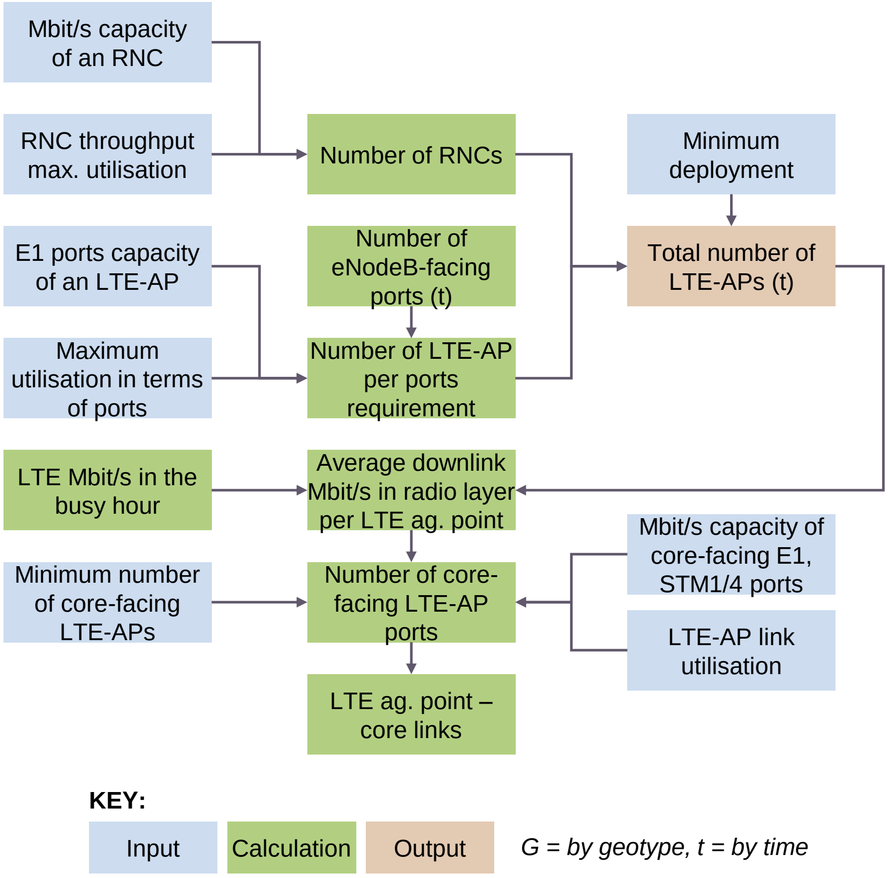
The LTE-APs are assumed to be co-located with RNCs and BSCs.

The deployment of the LTE-AP is illustrated in Figure 3.13, and is driven by:

- the maximum number of E1 ports connected, assuming a maximum utilisation (estimated to be 5000 with a [✂]% maximum utilisation)
- the minimum number of LTE aggregation points deployed in the network for resilience
- the number of RNC locations.

The total number of LTE aggregation points is the highest of these three values.

Figure 3.13: LTE-AP dimensioning [Source: Analysys Mason, 2015]



Similarly to what happens for the RNCs and BSCs, the number of incoming ports (eNodeB-facing ports) are directly derived from the number of backhaul E1 links, including all technologies.

The LTE-AP links facing the core network are either E1 or STM1/4 and are dimensioned based on the average LTE downlink throughput, taking into account a utilisation factor that reflects, among other things, the need for redundant ports and links.

Due to the lack of data provided by Portuguese operators, the unit opex and capex of this equipment has been derived from a benchmark of other European country models (where it is generally defined as “high-speed transmission hub”). It should be noted that the unit costs used in the model assume that the LTE-AP includes multiplexing capabilities and an optical distribution frame (ODF) to connect all the fibre backhaul links.

3.6 Dimensioning of backhaul transmission

The backhaul transmission dimensioning follows the same rules already used for the 2G and the 3G networks.

3.7 Core network and servers

4G core network

The inclusion of a 4G radio network requires the modelling of a 4G core network, which is assumed to be an evolved packet core (EPC)[15] one. This is an industry-standard architecture used to carry the data traffic from 4G eNodeBs and is in line with the 4G network diagram provided by the operators. We modelled four main assets:

- *Serving gateway (SGW)* – The primary function of this equipment is to manage the user-plane mobility and act as a demarcation point between the RAN and the core network. It serves as a local mobility anchor, meaning that packets are routed through this point for intra E-UTRAN mobility and for mobility through other generations (2G/3G)
- *Data traffic manager (DTM)* – This equipment includes any other systems that handle data traffic. Among others these include:
  - *packet data network gateway (PDN-G)* – This equipment, generally co-located with the SGW, serves as an anchor point towards the external packet data network. It supports policy enforcement features, packet filtering and charging support
  - *policy and charging rules function (PCRF)* – This equipment manages the policy and rule functions
- *Mobility management entity (MME)* – This equipment performs the signalling and control functions to manage the user equipment access to network connections, the assignment of network resources and the management of the mobility states to support tracking, paging, roaming and handovers. The MME also provides the control plan functionalities (similarly to the SGSN in a GPRS core network)
- *Home subscriber server (HSS)* – This equipment is the 4G equivalent of the home location register (HLR).

The main inputs used in the calculation are described in Figure 3.14 below.

Figure 3.14: Description of inputs used in the LTE core network calculations [Source: Analysys Mason, 2015]

Name	Description
Server capacity	The capacities of the core assets dimensioned in their respective units
Minimum roll-out	The minimum number of equipment that must be deployed
Server redundancy	A value of 2 means that for each equipment deployed there is also a spare one
Server minimums	The minimum number of equipment that must be deployed

[15] Alcatel-Lucent, *Introduction to Evolved Packet Core*. (URL: http://resources.alcatel-lucent.com/?cid=133461)

The equipment deployed in the 4G core network is calculated according to the specific demand drivers, along with the assumed capacity and utilisation. Figure 3.15 illustrates the calculations.

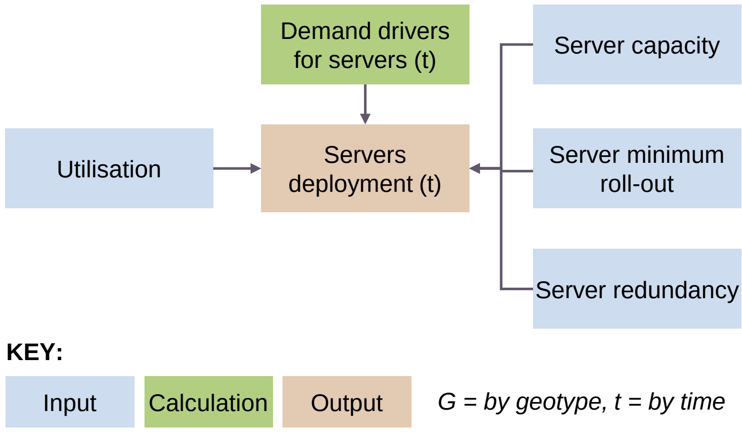


Figure 3.15: Calculation of 4G core network assets [Source: Analysys Mason, 2015]

Figure 3.16 provides a summary of the inputs used for 4G core network assets. All of these inputs can be found in the 'Core network elements' section of the "NwDes_Inputs" worksheet.

Figure 3.16: Specifications of the 4G core network elements [Source: Analysys Mason, 2015]

Asset	Capacity	Minimum roll-out	Redundancy	Max. utilisation	Source
MME (Hw and Sw)[16]	12 500 000 SAUs	2	1	[✂]	Operator data
SGW	40 000Mbit/s	2	1	[✂]	Analysys Mason
Data traffic manager	30 000Mbit/s	2	1	[✂]	Analysys Mason
HSS	1 000 000 4G subscribers	1	1	[✂]	Operator data

For MME dimensioning, we have assumed that 50% of 4G users are simultaneously active on the network, as for 3G in the 'Subscribers loading proportion' section of the "Load_inputs" worksheet.

Launch of VoLTE

As discussed in the concept paper, the model includes VoLTE because it is an efficient technology that has now been rolled out by several MNOs. Some Portuguese operators wrote that there is no information about the possible launch of the service, whereas others stated that launch of VoLTE is planned, but did not disclose any information on when it is supposed to occur.

On the basis of the status of VoLTE deployment in other Western European countries (see Figure 3.17), we have assumed that the modelled operator launches this service in 2016.

16 Hardware and software.

Figure 3.17: Status of VoLTE in selected Western European countries [Source: Analysys Mason Research, 2014]

Operator	Country	Status	Expected launch year
Swisscom	Switzerland	In deployment	2015
H3G	United Kingdom	In deployment	2015
EE	United Kingdom	In deployment	2015
Bouygues	France	In deployment	2015
E-Plus	Germany	In deployment	N/A
T-Mobile	Germany	In deployment	2014
Telefónica	Germany	In deployment	N/A
Vodafone	Germany	In deployment	2014
KPN	Netherlands	Trialling	July 2014
Tele2	Netherlands	In deployment	N/A
Tele2	Sweden	In deployment	N/A
TeliaSonera	Sweden	In deployment	N/A
Telefónica	Spain	Trialling	N/A
Vodafone	Spain	In deployment	N/A

The rate of adoption of VoLTE services largely depends on the availability of capable handsets. Most of the devices currently available in the market do not support VoLTE, as this is only included as a feature in high-end handsets. However, we expect this functionality to start being embedded in mid-range handsets during 2015. At that point, the rate of adoption of VoLTE will then depend on how much mobile operators are willing to push (subsidise) new handsets.

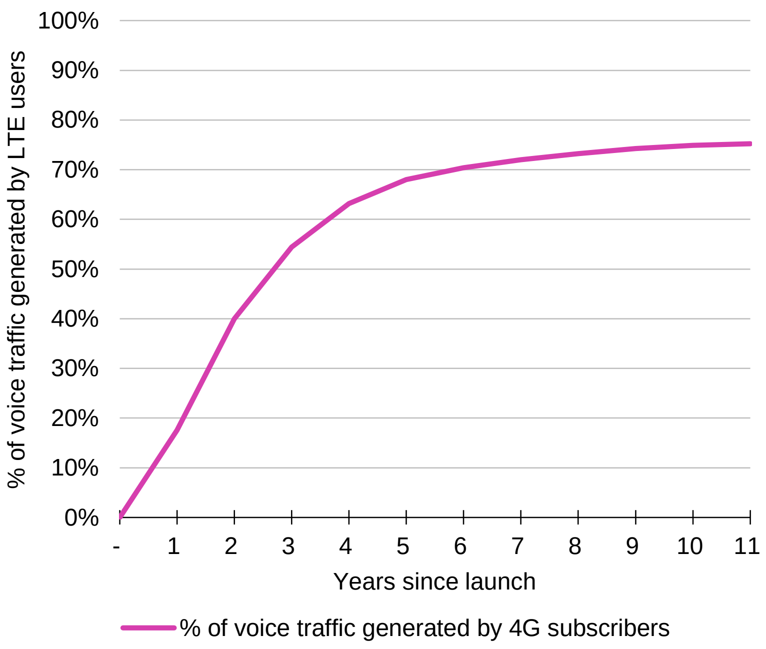


Figure 3.18: Share of voice traffic generated by 4G subscribers that is VoLTE [Source: Analysys Mason, 2015]

The model assumes that the share of 4G subscribers voice traffic migrated to VoLTE reaches around 40% two years after commercial launch (i.e. in 2018).

There are very few international data points to indicate how quickly the migration to VoLTE might occur. Most of these data points come from South Korea, which is at the forefront of LTE adoption and was one of the first countries worldwide to launch VoLTE. For example, LG U+ launched LTE in March 2012 and had migrated around 50% of its subscriber base to LTE within 2.5 years.[17] The Korean operator LG U+ launched VoLTE in July 2013 and managed to migrate 50% of its LTE subscribers to the new voice services technology within less than two years.

However, the South Korean case may not be considered as a valid benchmark for Portugal, since the country's MNOs have direct access to local handset manufacturers, which is a key lever for accelerating the adoption of VoLTE-capable devices. In addition, MNOs in South Korea have provided heavy subsidies on LTE handsets (to the extent that raised regulator's concerns and had to pay a hefty fine).

Nevertheless, Portuguese operators might enjoy some latecomer advantages, since they could benefit from previous successful experiences in other countries.

VoLTE network

Once a VoLTE platform is deployed, voice and data can both be provided over the 4G network, under the control of the network operator.

VoLTE requires an IP Multimedia Subsystem (IMS) to be deployed in the core network. The IMS core is composed of:

- the call server (CS), which contains the voice service functions CSCF, ENUM and DNS[18,19]
- the session border controllers (SBCs)
- the telephony application servers (TASs), which must be deployed to manage voice services (with the TASs in particular managing capabilities such as call forwarding, call wait and call transfer).

The IMS core assets are summarised in Figure 3.19 below.

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17 LG U+, *VoLTE as Key Success Factor*, 2014

18 Call session control function, E.164 number mapping and domain name system, respectively.

19 The CSCF, ENUM and DNS are not explicitly modelled; they are contained within the call server (CS) and as such are treated as a single asset.

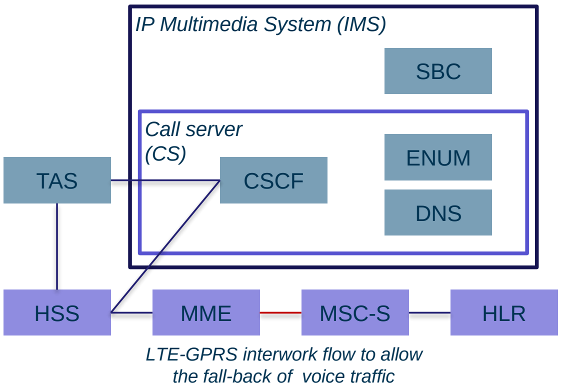

Figure 3.19: Appearance of an IP Multimedia System [Source: Analysys Mason, 2015]

The VoLTE platform must also communicate with the 4G data platform (via the MME/SGW), meaning that upgrades to existing assets are required. In particular, the MSC–S must be enhanced so that:

- calls can connect to the IMS domain via the MSC–S, to continue to provide the voice service if a 4G user is within the coverage of the 2G/3G circuit-switched networks rather than the coverage of the 4G network
- calls can be handed over from the 4G network to the 2G/3G networks.

A separate converged HLR/HSS can also be deployed to manage data on the 4G subscriber base, keeping the legacy HLR unchanged. Upgrades to the network management system (NMS) may also be required to support VoLTE.

The main inputs used in the VoLTE network calculation are outlined in Figure 3.20.

Figure 3.20: Description of inputs used in the VoLTE network calculation [Source: Analysys Mason, 2015]

Name	Description
Capacity driver	Quantity that is used to dimension the number of assets required
Server capacity	The capacities of the core assets dimensioned in their respective units
Server minimums	The minimum number of equipment that must be deployed
Server redundancy	A value of 2 means that for each equipment deployed there is also a spare
4G voice call data rate	The data rate required for VoLTE calls in the radio network. The model assumes a value of 12.65kbit/s, based on the specification of the Adaptive Multi-Rate Wideband (AMR-WB) standard

The calculation structure for VoLTE assets in the updated model is the same of the one adopted for the 4G core network, as shown in Figure 3.15. The servers deployed within the VoLTE network are calculated according to their demand drivers, along with their specifications and utilisation. The planning period is then factored into the output.

Figure 3.21 summarises the inputs for the VoLTE assets modelled, namely their assumed capacities, minimum numbers and redundancies. These inputs can be found within the 'Core network elements' section of the "NwDes_Inputs" worksheet.

Figure 3.21: VoLTE asset dimensioning inputs [Source: Analysys Mason, 2015]

	Capacity	Minimum	Redundancy	Maximum utilisation	Source
SBC (Hw and Sw)	2000 BH voice Mbit/s	1	2	[✂]	Analysys Mason
Call server (Hw and Sw)	2 000 000 BHCA	1	2	[✂]	Analysys Mason
TAS	25 000 subscribers	1	1	[✂]	Analysys Mason

► *Stakeholder comments*

One party **[Vodafone]** claims that the model should have taken into account the cost of SR-VCC, a network element used in the provision of the VoLTE service.

Another party **[MEO]** reports that the proposed network diagram misses the following elements:

- SCC-AS Service Centralization & Continuity AS
- PCRF Policy Charging and Rules Function
- DRA Diameter Relay Agent
- SPR Subscription Profile Repository.

► *Analysys Mason response*

The functionalities and the related costs of the SR-VCC are included in the IMS network elements.

Also the elements reported by another party are actually included in other network assets, namely:

- SCC-AS is included in the IP Multimedia System
- PCRF is included in the Data Traffic Manager (DTM) element
- DRA is included in the IP Multimedia System
- SPR is included in the HSS.

► *Conclusion*

The proposed approach is confirmed.

3.8 Features of LTE-specific assets

The LTE network has been modelled as an additional layer on top of the existing network, as discussed in the concept paper. Therefore, there are a number of additional equipment items a mobile operator must deploy in order to offer the service to its customers. In this section we provided an overview of the dimensioning rules we followed. In this subsection, we provide additional information regarding the features of the deployed assets. In the “Asset_input” worksheet we have updated the asset list in order to capture all relevant elements (see Figure 3.22 below).

Figure 3.22: New 4G-specific assets included in the model [Source: Analysys Mason, 2015]

Asset	Lifetime	Planning period	2013 capex (EUR)[20]	2013 opex (EUR)[21]	Asset type
Macro eNodeB	10	3	[✂]	[✂]	RAN
Indoor special eNodeB+distributed antenna	10	3	[✂]	[✂]	RAN
Site upgrade – 2G/3G site facilities for 4G	10	9	[✂]	[✂]	RAN
LTE-AP	10	9	[✂]	[✂]	BSC/RNC
Data traffic manager	8	3	[✂]	[✂]	LTE core network
MME – hardware	8	3	[✂]	[✂]	LTE core network
MME – software	8	3	[✂]	[✂]	LTE core network
SGW	8	3	[✂]	[✂]	LTE core network
HSS	8	3	[✂]	[✂]	LTE core network
Call server – hardware	8	3	[✂]	[✂]	VoLTE core network
Call server – software	8	3	[✂]	[✂]	VoLTE core network
TAS	8	3	[✂]	[✂]	VoLTE core network
SBC – hardware	8	3	[✂]	[✂]	VoLTE core network
SBC – software	8	3	[✂]	[✂]	VoLTE core network
VoLTE upgrade – HLR	8	3	[✂]	[✂]	VoLTE core network
VoLTE upgrade – MSC-S	8	3	[✂]	[✂]	VoLTE core network
VoLTE upgrade – NMS	8	3	[✂]	[✂]	VoLTE core network
4G upfront licence fees	15	-	[22]	[✂]	4G licences
4G frequencies management fees	1	-	[23]	[✂]	4G spectrum fees
LTE step for: 37.0	10	3	[✂]	[✂]	Base-station equipment
LTE step for: 75.6	10	3	[✂]	[✂]	Base-station equipment
LTE step for: 152.7	10	3	[✂]	[✂]	Base-station equipment

20 Includes a mark-up of [✂]% for indirect costs.

21 Includes a mark-up of [✂]% for indirect costs.

22 This represents the lump sum assumed to be paid by the hypothetical existing operator; see Section 3.2 for further details.

23 This represents the annual fee paid on a per-MHz basis; see Section 3.2 for further details.

Asset	Lifetime	Planning period	2013 capex (EUR)[20]	2013 opex (EUR)[21]	Asset type
LTE step for: 229.8	10	3	[✂]	[✂]	Base station equipment
LTE step for: 306.9	10	3	[✂]	[✂]	Base station equipment
LTE step for: 604.5	10	3	[✂]	[✂]	Base station equipment

Cost trend

We have applied to the LTE-specific assets the same cost trends that were assumed in the old model for their 2G/3G equivalents, as shown in Figure 3.23.

Asset	Capex	Opex
Macro eNodeB	-5%	-
Indoor special eNodeB+distributed antenna	-5%	-
Site upgrade – 2G/3G site facilities for 4G	1%	-2%
LTE-AP	-10%	-
Data traffic manager	-4%	-5%
MME – hardware	-4%	-5%
MME – software	-	-
SGW	-4%	-5%
HSS	-4%	-2%
Call server – hardware	-4%	-5%
Call server – software	-	-
TAS	-4%	-
SBC – hardware	-4%	-5%
SBC – software	-	-
VoLTE upgrade – HLR	-4%	-
VoLTE upgrade – MSC-S	-4%	-
VoLTE upgrade – NMS	-4%	-
4G upfront licence fees	-	-
4G frequencies management fees	-	-
LTE upgrade 1	-6%	-
LTE upgrade 2	-6%	-
LTE upgrade 3	-6%	-
LTE upgrade 4	-6%	-
LTE upgrade 5	-6%	-
LTE upgrade 6	-6%	-

Figure 3.23: Year-on-year cost trend in the model for 4G-specific assets [Source: Analysys Mason, 2015]

3.9 Routeing factors

The routeing factors applied to the 4G assets follow the same methodology as that adopted for all other assets. Figure 3.24 shows the factors used for 4G radio access elements, while Figure 3.25 shows the routeing factors for the core network elements (including VoLTE).

Figure 3.24: Routeing factors for 4G radio access network elements [Source: Analysys Mason, 2015]

Network element	4G on-net voice min	4G out voice min	4G in voice minute	4G SMS	LTE Mbytes
Radio equipment	2 × (1 + RT)	1 + RT	1 + RT	~0.0003	1.68
Backhaul	2 × (1 + RT)	1 + RT	1 + RT	~0.0003	1.68
LTE-AP	2 × (1 + RT)	1 + RT	1 + RT	~0.0003	1.42
4G spectrum license	2 × (1 + RT)	1 + RT	1 + RT	~0.0003	1.68

upfront payment					
4G spectrum license fees	2 × (1 + RT)	1 + RT	1 + RT	~0.0003	1.68

Figure 3.25: Routeing factors for the EPC assets and VoLTE servers [Source: Analysys Mason, 2015]

	4G on-net voice min	**4G out voice min**	**4G in voice min**	**4G SMS**	**LTE Mbytes**
DTM	2 × (1 + RT)	1 + RT	1 + RT	~0.0003	1.68
MME	2 × (1 + RT)	1 + RT	1 + RT	~0.0003	1.68
SGW	2 × (1 + RT)	1 + RT	1 + RT	~0.0003	1.68
HSS	1	-	1	1	-
Call server	2	1	1	1	-
TAS	2	1	1	1	-
SBC	2	1	1	1	-