analysys mason

Report for OPTA

# 2012 update of OPTA's fixed and mobile BULRIC models

*25 March 2013*

Response to operator consultation

**Ref: 35097-52**

www.analysysmason.com

# Contents

Analysys Mason Limited
St Giles Court
24 Castle Street
Cambridge CB3 0AJ
UK
Tel: +44 (0)845 600 5244
Fax: +44 (0)1223 460866
cambridge@analysysmason.com
www.analysysmason.com
Registered in England No. 5177472

# 1 Introduction

Onafhankelijke Post en Telecommunicatie Autoriteit (OPTA) has commissioned Analysys Mason to update its fixed and mobile bottom-up long-run incremental cost (BULRIC) models, to provide cost-based information for future wholesale termination regulation that OPTA may propose in the Netherlands. The original BULRIC models were updated to become the "v4 model", which was released for consultation in October 2012 so that industry could consult on the approach and implementation. Submissions were received from KPN, T-Mobile, UPC, Vodafone and Ziggo.

This document sets out how we have finalised the model inputs to derive the "v5 model" for OPTA. The remainder of this report is structured as follows:

- **Section 2: Market module** – In this section we review the comments received on the v4 market module and present our responses. We also consider whether changes are required to the inputs and calculations of the v4 market module.
- **Section 3: Network design** – In this section we review the comments on the v4 fixed and mobile modules that are related to network design, and present our responses. We also consider whether changes are required to the calculations in the v4 fixed and mobile modules.
- **Section 4: Costing** – In this section we review the comments on the v4 model related to costing, and present our responses. We also consider whether changes are required to the v4 model costing calculations.
- **Section 5: Process** – This section lists a number of comments that were received that we consider not to be of relevance to the model itself. Such comments are identified in this section for clarity only.

The report also contains two annexes:

- **Annex A** contains, for reference, a supplementary consultation note regarding the spectrum assumptions. This note was released to operators in December 2012, after the completion of the spectrum auction.
- **Annex B** contains a consideration of the responses and the final conclusions reached.

Note that throughout this report the names of the operators providing the comments are marked in such a way that OPTA will later be able to publish an anonymised version of the document.

> We have implemented a number of corrections or modifications to the v4 model based on operator feedback, to derive the v5 model. Analysys Mason and OPTA have finalised the inputs in the model as part of this process.

# 2 Market module

*Figure 2.1: Summary of comments related to the market module [Source: Analysys Mason, 2012]*

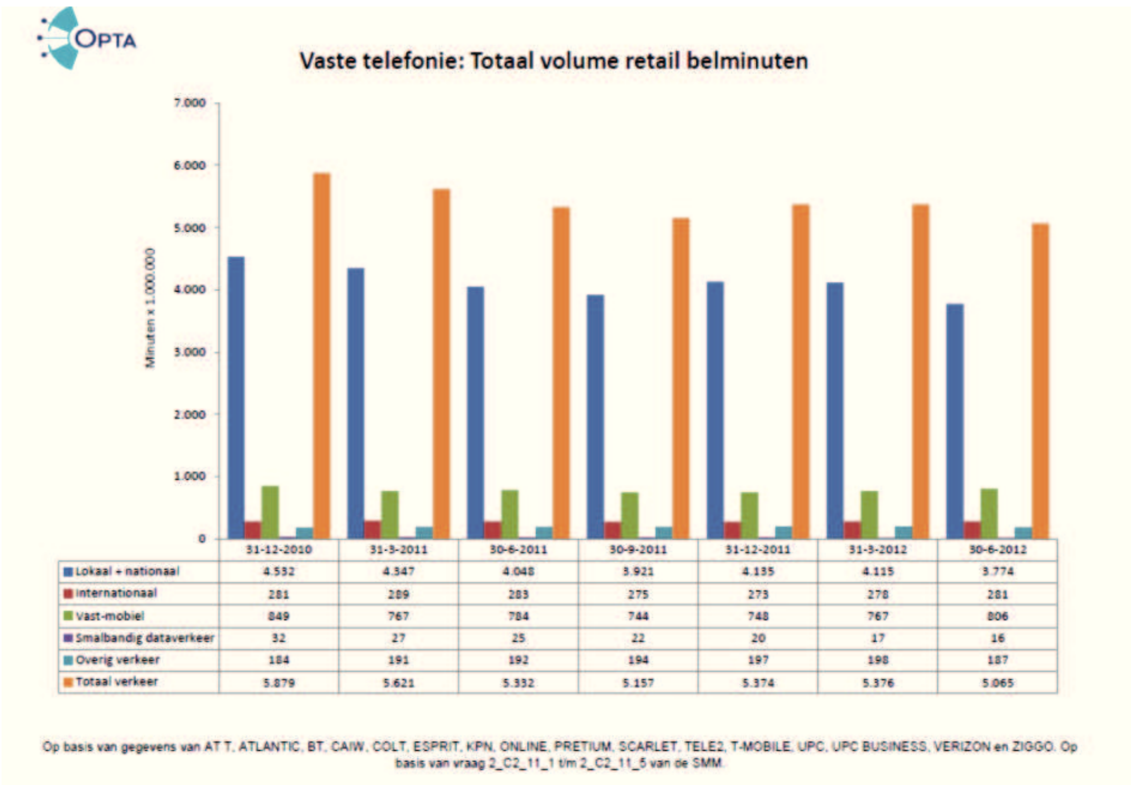
| Number | Issue |
|---|---|
| 1 | Traffic forecasts |
| 2 | VoIP traffic volumes |

## 2.1 Traffic forecasts

### 2.1.1 Comments by the operators

One operator [✂] "*questions the traffic developments that currently are included in the model*", stating that "*obvious current trends are insufficiently included*". The operator refers to OPTA's Q2 2012 Market Monitor[1], as shown in Figure 2.2, as evidence of a decline in fixed telephony minutes. The operator states "*it seems that Analysys Mason and OPTA foresee a change again in this trend in the near future, since the decrease of minutes is only temporarily in the modelled data*". It submits that "*it is insufficient to base such a changing trend on 'internal knowledge' that cannot be verified. It is not up to market parties to 'proof' why existing trends would not change, but to Analysys Mason and OPTA why these trends will not continue.*"

*Figure 2.2: Market Monitor figures for Q2 2012 [Source: OPTA, 2012]*




| | 31-12-2010 | 31-3-2011 | 30-6-2011 | 30-9-2011 | 31-12-2011 | 31-3-2012 | 30-6-2012 |
|---|---|---|---|---|---|---|---|
| Lokaal + nationaal | 4.532 | 4.347 | 4.048 | 3.921 | 4.135 | 4.115 | 3.774 |
| Internationaal | 281 | 289 | 283 | 275 | 273 | 278 | 281 |
| Vast-mobiel | 849 | 767 | 784 | 744 | 748 | 767 | 806 |
| Smalbandig dataverkeer | 32 | 27 | 25 | 22 | 20 | 17 | 16 |
| Overig verkeer | 184 | 191 | 192 | 194 | 197 | 198 | 187 |
| Totaal verkeer | 5.879 | 5.621 | 5.332 | 5.157 | 5.374 | 5.376 | 5.065 |

[1] OPTA, Public report mobile Q2 2012

Similarly, the operator [✂] states that in the mobile market, "*market realities recently show a decline of traditional SMS and voice usage on mobile networks. As shown in various reports (e.g. TelecomPaper*[2]*) the penetration of smartphones and the large acceptance of applications by the vast majority of smartphone users lead to rapidly changing communications patterns. The trend on SMS has shown a sudden and rather steep decline since early 2011, which trend is unlikely to be revised again. The same applies – later and so far less dramatic – to voice minutes*". The operator has "*not seen any convincing argument which would support a change in this trend, so shortly after it became apparent. The growing number of devices that are not primarily suitable for voice services, but do support the use of applications that can substitute voice calls – such as tablets – underline this presumption.*"

The operator [✂] concludes that with regards to the draft model, "*the modelling approach for voice is such that mobile volume forecasts are derived from the overall voice market developments subtracted with the fixed voice volumes. We suggest that this is changed in modelling the fixed and mobile voice markets separately, as there are no reliable forecast for the market as a whole, but there are much more insight in the separate markets.*"

A second operator [✂] states that "*the market is currently undergoing significant change as traditional voice and SMS services are increasingly displaced by data services*". With regards to the trends shown in the draft model, the operator highlights OPTA's Q2 2012[1] market statistics and KPN's Q3 SMS statistics.[3] It believes that "*in this context, it is surprising that AM is forecasting that total voice minutes will grow at an accelerated rate between 2011 and 2012 and remain at a growth rate above the growth rate from 2010 to 2011 until 2017. AM has offered no explanation for this accelerated growth rate and it is shown to be inconsistent with the actual market data of declining minutes and rapidly declining SMS messages for the first half of 2012.*"

This second operator [✂] "*believes that there is no basis for forecasting higher call minutes or SMS messages than that implied by the trend evident in the most recent data. As smartphone penetration increases and data-based alternatives to traditional voice and SMS services become more popular, voice volumes and SMS numbers may decrease at an even faster rate.*

*"Mobile data growth is also slowing. There is a significant risk of a sharper slowdown in data growth because: (i) later adopters of smartphones are likely to be much lighter users of data services than the early adopters; and (ii) WiFi coverage is widespread in the Netherlands including many trains and buses being equipped. Further, the effect of significant reductions in termination charges will be the increase to price of other mobile services including data services. This will act to further reduce the growth in mobile data volumes.*"

The second operator [✂] concludes that "*it is critical that demand forecasts used in the regulatory cost model minimize the risk of understating the target cost levels of the modeled operator. In this sense, they should differ from independent forecasts that aim to find a middle ground between optimistic and more conservative views and which fail to recognise that the harm from too low a*

2 http://www.telecompaper.com/research/dutch-mobile-consumer-q1-2012-operator-edition--880932

3 KPN, Third quarter results 2012, slide 22 and KPN_Factsheets_Q3_2012

*cost level is greater than slightly overestimating costs. This point has not been explicitly identified nor acknowledged by OPTA/AM. It is therefore essential that the forecasts OPTA/AM currently are using are corrected downwards to take into account both the recent downward trends and well as to guarantee recovery of target cost levels as set out under the selected costing methodology.*"

A third operator [✂] believes that the "*total data capacity forecasted growth seems conservative, however current market penetration does not reflect OPTA's market figures ('Structurele Marktmonitoring')*". It also believes that the "*forecasted growth of mobile devices such as smartphones (low end … high end), tablets and connected devices seems very conservative*" and that while "*forecasted bandwidth usage per device is implemented in the model, to improve the forecast AM needs to take into account the bandwidth per type of device.*"

### 2.1.2 Analysys Mason/OPTA response

There are a number of points raised with regards to traffic forecasts in the model and we address these in turn for voice, SMS and data traffic.

► *Voice traffic*

In the draft model we forecast total originated voice minutes across both fixed and mobile networks, since the intention was to derive a holistic forecast of the voice market. For fixed voice traffic, we used Analysys Mason Research forecasts[4] for the period to 2016, with no further decline after this year. Mobile voice minutes are sourced from OPTA historical market data to 2011, after which mobile traffic is derived as overall voice traffic minus fixed voice traffic. This approach resulted in an increase in mobile voice minutes, as shown in Figure 2.3 below.

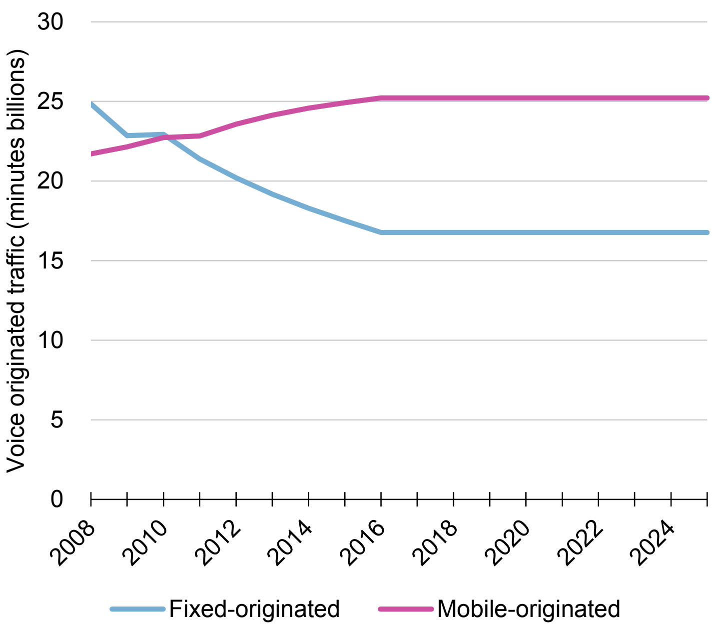



*Figure 2.3: Assumptions for fixed and mobile voice traffic in the v4 model [Source: v4 model, 2012]*

4 Source: Analysys Mason Research, *Fixed and mobile voice in WE: market sizings and forecasts, 2008–2016*

It has been suggested by one operator that 2016 is too early to assume a stabilisation in voice traffic. We observe that the rate of traffic decline is reducing at approximately 0.3% per annum and we have extended this trend out to 2030, where the fixed traffic growth rate reaches zero. Therefore, traffic will only stabilise at that point.

From the OPTA market data,[5] we observe that mobile voice minutes are already relatively static, as shown in Figure 2.4 below. We have therefore revised the growth rate of total voice traffic so that mobile-originated traffic remains static while fixed-originated traffic declines. The results of the combination of our revised assumptions for total voice traffic and fixed-originated traffic can be seen in Figure 2.5 below.

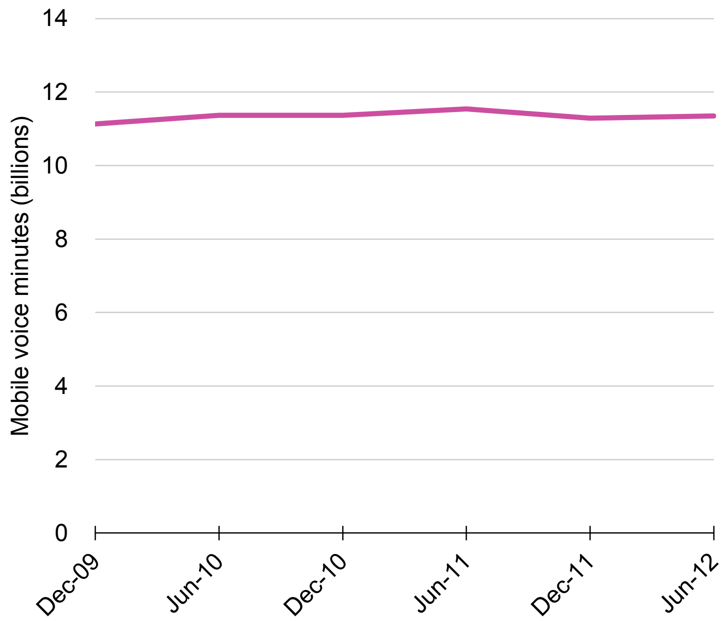



*Figure 2.4: Recent mobile voice minutes by half-year [Source: OPTA Market Monitor, 2012]*

5 Source: http://www.opta.nl/en/download/bijlage/?id=879

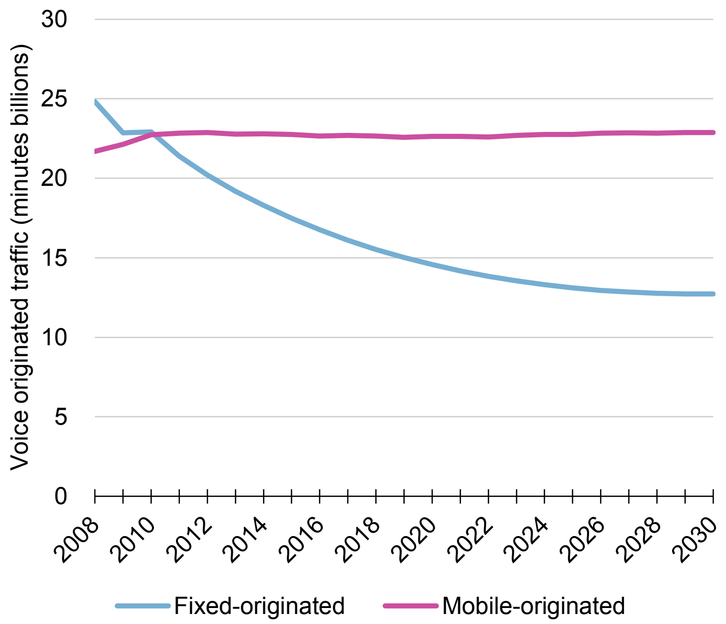



*Figure 2.5: Revised assumptions for fixed and mobile voice traffic in the v5 model [Source: v5 model, 2012]*

► *SMS traffic*

In the v4 model, we left the SMS traffic forecasts unchanged from the v3 model. We have since used OPTA Market Monitor data[6] to update our forecasts based on the historical SMS traffic. Several operators commented that SMS volumes have started to decline: between year-end 2010 and half-year 2012 SMS volumes have decreased at a compound annual growth rate (CAGR) of -19%. We have assumed this is the decline experienced between 2011 and 2012. We have then assumed the year-on-year decline reduces to zero by 2019, giving a revised SMS traffic forecast as shown in Figure 2.6.

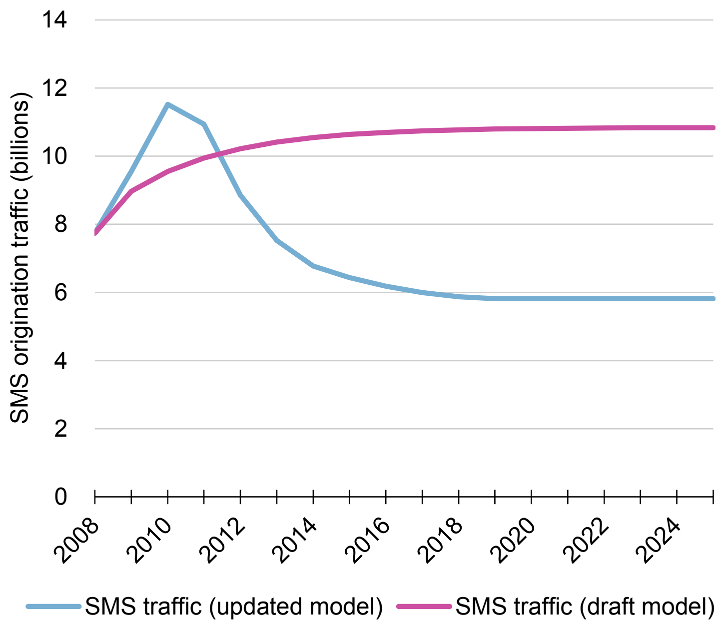



*Figure 2.6: Assumptions for SMS traffic in the v4 model and v5 model [Source: v4 and v5 models, 2012]*

6 See footnote 5.

► *Data traffic*

As noted in the responses, mobile data growth is slowing, with a continued reduction in growth rate expected. Our historical mobile data traffic inputs to the v5 model are based on data from the OPTA Market Monitor.[7] For the purposes of comparison, we have estimated mobile data traffic for 2012 as double the first-half 2012 volumes, and compared this value with the forecast in the v4 model. As can be seen (Figure 2.7), our estimates and the forecasts in the v4 model are almost identical. We believe that this demonstrates that our modelled growth rate is appropriate.

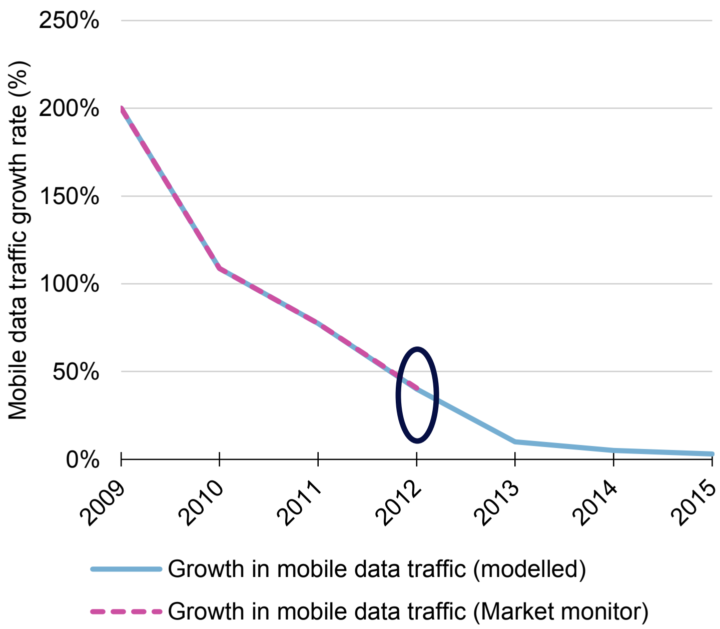
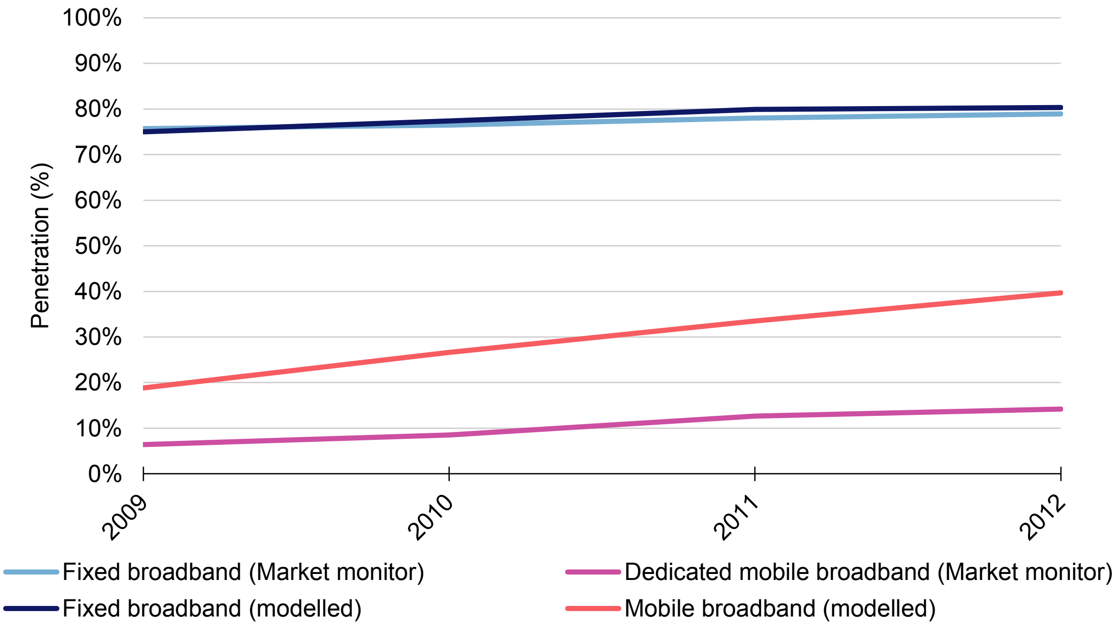



*Figure 2.7: Growth in mobile data traffic: v4 model compared with estimates based on market data [Source: v4 model, OPTA Market Monitor, 2012]*

We have also considered the comments made with regards to the market penetration of data connections (both fixed and mobile). As shown below in Figure 2.8, the estimates based on OPTA Market Monitor data and the forecast penetration in the v4 model are consistent. It is true that the modelled "Mobile broadband" connections are lower than the "dedicated mobile broadband connections" in the OPTA Market Monitor data – but this is because the model forecast includes *non-dedicated* mobile broadband connections. In particular, the mobile voice connections and mobile broadband connections are not assumed to be additive: they are instead used to derive mobile voice and data volumes separately. On this basis, we do not see a need to revise the penetration forecast, since the key input to the model is the data volumes (in megabytes), which is consistent with the OPTA Market Monitor data and – as demonstrated above – is following the developments in 2012 thus far.

7 See footnote 5.

*Figure 2.8: Fixed and mobile broadband penetration: v4 model compared with estimates based on market data [Source: v4 model, OPTA Market Monitor, 2012]*




## 2.2 VoIP traffic volumes

### 2.2.1 Comments by the operators

One operator [✂] refers to its earlier response which stated that *"the fixed traffic volumes over which the cost of the platform is recovered appear too low compared with the traffic volumes reported in the OPTA Market Monitor."*

### 2.2.2 Analysys Mason/OPTA response

We assume that the operator is referring to the following passage from section A of its submission from February 2010[8] that states:

[✂]

In the v4 model the forecasts for fixed-voice traffic volumes at the market level were taken from Analysys Mason Research.[9] We have compared these forecasts with estimates based on historical data from the OPTA Market Monitor,[10] as shown in Figure 2.9 below. This indicates that the model and the Market Monitor information are consistent.

8 [✂]

9 See footnote 4.

10 Source: http://www.opta.nl/en/download/bijlage/?id=880. 2012 inputs have been estimated based on the H1 2012 data available.

The volumes assumed to be carried on the modelled network are based on the N=2 assumption regarding the market share of the fixed operator. OPTA has previously refuted the claim by this operator [✂] that charges are best based on the actual costs of each individual operator, and sees no reason to change its position on this matter.

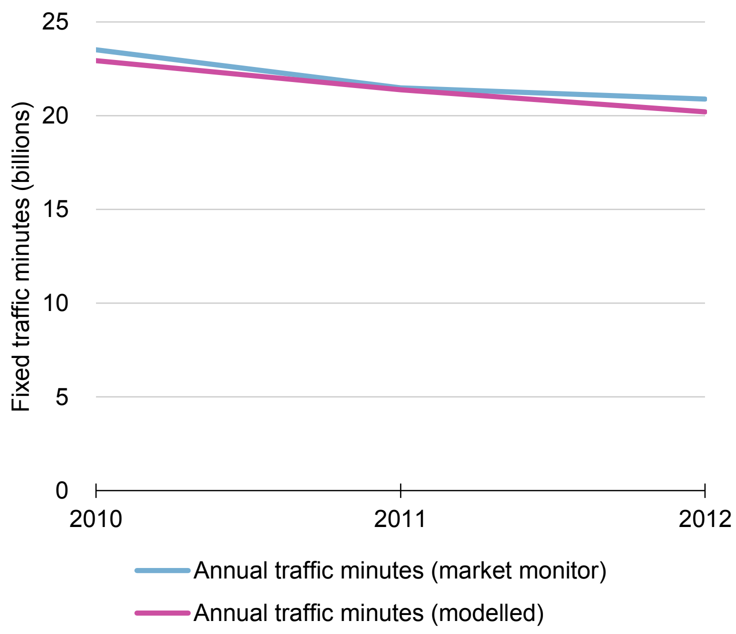



*Figure 2.9: Fixed-voice traffic: v4 model compared with estimates based on market data [Source: v4 model, OPTA Market Monitor, 2012]*

# 3 Network design

*Figure 3.1: Summary of comments related to the fixed and mobile modules [Source: Analysys Mason, 2012]*

| Number | Issue |
|---|---|
| 3 | Number of operators |
| 4 | Load-up of traffic onto the modelled network |
| 5 | Relationship between spectrum and allocation of cost |
| 6 | Network dimensioning |
| 7 | Modularity of network equipment |
| 8 | Reconciliation with operator data |

## 3.1 Number of operators

### 3.1.1 Comments by the operators

One operator [✂] believes that *"it is crucial that charges be set at a level of costs achievable by the operators. This will enable operators to recover their efficient costs, ensure that charges are efficiently set in line with costs and be consistent with the requirement of the Access Directive (Article 13) for regulators to allow operators "a reasonable rate of return on adequate capital employed, taking into account the risks involved". In this regard, it is important that costs be estimated with respect to an operator that has no more than the expected average market share. Clearly, it is impossible for all operators to achieve a higher than average market share. For the period of the next charge control, the most likely number of network operators in the Dutch market is at least four.*"

To support its conclusion, the operator [✂] cites "*the fact that there are five bidders participating in the current auction with two blocks specifically reserved for new entrants. The reservation of spectrum for new entrants reflects the view of OPTA that doing so would lead to at least one additional 'fully fledged competitor'.*

*"The results of the auction will also be known prior to the finalization of the model. Accordingly, OPTA will be in a position to know how many operators have acquired spectrum. OPTA could also seek information from these players in relation to the business case that underlies their spectrum acquisition.*"

The same operator [✂] refers to Analysys Mason's argument that a new operator could be a data-only operator (i.e. not in the mobile voice market), and a new entrant could use network sharing with an existing operator. Regarding this, the operator argues that "*costs should be based on what is the most likely scenario over the charge control period. If four or more operators acquire* *spectrum (particularly in the bands that have supported mobile operators*[11]*), then these operators would be expected to use this spectrum for the delivery of services. This situation is distinct from that of an MVNO which uses the network (and spectrum) of an operator. However, new entrants to the Dutch market are much more likely to offer a suite of voice and data services rather than only data services given: (i) most customers want both types of services; (ii) network equipment and most devices are designed to provide both type of services. Even in the unlikely event of a data-only operator this would be expected to reduce the volume of data demand available to the modelled operator.*

*"The acquisition of spectrum by four or more players should be taken as evidence of the likelihood of at least four networks. While it may be the case that a new entrant chooses to rely to an extent on sharing such as in rural areas or passive sites, an operator would not expend large sums of money on spectrum without the intention to use it. A report by HSBC noted that Tele2 and Ziggo/UPC are likely to bid in the current auction and that the cost of such an entrant providing coverage (rather than the more expensive cost of capacity) would be affordable: "Suppose Ziggo/UPC buy one block of 2×5MHz in the 800MHz band, the cost is unlikely to exceed the minimum price of EUR35m and given the geography of The Netherlands network deployment for coverage (rather than for capacity) is unlikely to be expensive".*[12]"

The operator [✂] suggests that "*limited network sharing could be taken into account in the model. For example, the AM model in the UK already incorporates passive site sharing. An even more straight-forward approach would be to simply reduce the market volumes in the existing model on the basis that new entrant(s) would capture some of these volumes.*

*"As to a reasonable assumption in relation to the speed with which an entrant would acquire share, we note that the European Commission's Termination Recommendation*[13] *states that: 'Drawing upon the ERG Common Position, it is reasonable to envisage a timeframe of four years for phasing out asymmetries based on the estimation that in the mobile market it can be expected to take three to four years after entry to reach a market share of between 15 and 20%, thereby approaching the level of the minimum efficient scale'.*"

With regards to Analysys Mason's argument that even if there is new entry, three should nonetheless still be considered the efficient number of operators for the Netherlands, the operator [✂] "*expects that prior to the finalization of the model, the outcome of the auction will show that in addition to the current operators there will be at least one additional party who has acquired spectrum on the basis of well-developed plans to roll out a network. Market conditions are changing including by the release of significant new spectrum itself as well as the growth in data volumes*".

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11 *In this regard, particular spectrum bands in the current auction are much more likely to enable competitive mobile network entry than the earlier 2.6 GHz auction.*

12 *HSBC, Ziggo – company report, 28 September 2012, p.10*

13 *EC Termination Recommendation, p.12*

The operator [✂] "*believes that weight should be attached to the willingness of additional parties to expend large sums of money acquiring licences as evidence of the likelihood of successful new entry.*

*"OPTA should also recognize the dynamic benefits that can be achieved by promoting a competitive market. A highly simplified, static model such as that of AM might indicate that one operator could supply services at lower cost than multiple operators. However, this does not mean that consumers would be better off over time if charges were set at a level so that only one operator could recover its costs. By enabling vigorous competition between multiple competing operators, consumers will gain the dynamic benefits of competition including a wide range of high quality services and operators developing new ways to reduce costs over time. As such, competition between multiple operators is expected and likely to deliver lower priced services over time, even if that requires charges to be set at a sufficient level to support multiple operators in the short-run. Accordingly, the efficient cost of termination should be assessed having due regard to dynamic efficiency rather than an estimate of static efficiency based on a highly simplified model."*

Finally, the operator [✂] argues that "*the European Commission's Recommendation states: 'To determine the minimum efficient scale for the purposes of the cost model, and taking account of market share developments in a number of EU Member States, the recommended approach is to set that scale at 20% market share…In case an NRA can prove that the market conditions in the territory of that Member State would imply a different minimum efficient scale, it could deviate from the recommended approach.'*[14]*"* The operator "*believes that were OPTA to retain the 33% market share assumption, it would be in conflict with both the actual situation in the Netherlands after the auction as well as the European Commission's Recommendation.*"

### 3.1.2 Analysys Mason/OPTA response

Given the expectation that voice volumes will be largely stable, and the fact that there are three operators currently serving the Dutch mobile voice market (consolidated from five operators serving the historically smaller mobile voice market) it is not clear that new entry and further division of the modelled mobile voice market into more than three players would be efficient. This supports our stated position that new entry will need to be supported by new technologies, new services and new data demand, and should not be supported by a four-player mobile voice market that would give rise to higher costs of voice. OPTA considers that dynamic competition offers greater benefits than somewhat increased economies of scale, which is why three players are assumed to be efficient for the mobile voice (termination) market. A conservative data forecast, and incorporation of a migration to LTE in the long-term also supports the adoption of a three-player market in the cost model calculation – any larger number of operators (in the absence of network sharing) would give rise to worse scale economies than are currently present in the Dutch mobile market, and likely to be present for the coming regulatory period.

[14] EC Termination Recommendation, p.12

In considering the efficient scale of operator for calculating termination costs, OPTA's position matter is consistent with that of other European NRAs:

- the Danish regulator has assumed 33% market share at the radio layer and 25% market share at the core (following the announcement of a joint venture in 2011 by Telenor and Telia)
- the Swedish regulator has assumed a 50% market share for the modelled GSM network, a 41% market share for the modelled UMTS network, and a 33% market share for the modelled LTE network (due to the various joint ventures operating in the country)
- the Belgian regulator assumes a 33% market share for the modelled hypothetical operator.

We believe that a 33% market share (N=3) continues to be reasonable and efficient since there is currently no evidence that a fourth *independent 2G or 3G mobile network* will establish itself as a *long-term operation in the Dutch mobile voice market*. In any case, a fourth operator, by stimulating competition, should aim to stimulate higher levels of traffic consumption in the market, rather than simply diluting the existing (forecast) usage across another infrastructure operator. Therefore, even if N was increased to 4, this would need to be accompanied by a commensurate increase in the demand forecasts. Therefore, the assumption of N=3 will be retained.

In regard to the comment [✂] quoted above, that "*even in the unlikely event of a data-only operator this would be expected to reduce the volume of data demand available to the modelled operator*", it should be noted that the modelled data forecast is conservative in the context of current usage growth: it assumes very little growth after 2012. As stated above, assuming a fourth (data-only, or data-focused) operator would still require a commensurate (and expected strong) increase in the assumed consumption of data megabytes, and the dilution of the megabytes carried by the modelled operator would therefore be negligible in our view.

## 3.2 Load-up of traffic onto the modelled network

### 3.2.1 Comments by the operators

One operator [✂] believes that Analysys Mason assumes that a hypothetical operator would, at the time of its launch, have a national network and an existing subscriber base. It argues that this "*fails to recognise that in reality operators experience a prolonged initial period of under-utilisation of assets which results in the need to recover higher costs in later years. [...] Economic depreciation should allow for operators to recover the costs of long-lived assets taking into account initial under-utilisation of those assets*."

The operator states that "*AM has not provided any reasoning to support its approach in Annex C.6 (p.31) and has simply repeated what its approach is*."

### 3.2.2 Analysys Mason/OPTA response

The respondent refers to Annex C.6, Discussion of operators responses to the draft model - 20 April 2010,[15] which contains the following passage:

"*We model a hypothetical existing operator which starts investing in 2004, but is not a new entrant. On launch (in 2006), the modelled hypothetical existing operator matches three aspects of the actual operators' networks:*

- *the average 3G coverage*
- *the average amount of 3G data traffic, including HSPA volumes*
- *the average 2G-3G migration.*

*Whilst it took many years since licensing to reach this situation, it is not reasonable to allow a higher voice termination rate because of the slow development or traffic take-up of the technology when we are modelling a rapid roll-out of the network for an operator launching a new network in 2006, and when we are not modelling the costs of the pre-2004 period.*"

Therefore, in particular, the hypothetical operator is *not* a new entrant with an instantaneous network and existing subscriber base: it is in fact an existing operator that is deploying a new network and migrating its existing subscriber base onto that network.

This discussion of network roll-out and traffic deployment is first raised as Concept 4 in Annex C.1[16] where it is argued that:

"*We believe that it would be most consistent and competitively neutral to adopt the same principle for rate of roll-out for both fixed and mobile networks, and that this should be based on Option 3. In this situation, we shall apply the same NGN roll-out principle to both fixed and mobile networks, and migrate existing traffic onto the network at a rate specified by:*

- *market developments from 1 January 2006 onwards (NGN launch date)*
- *the relative ease with which different types of customer and service volumes will move from the pre-existing to the modelled next-generation network.*

*We do not favour adopting the lowest-cost approach since in our opinion this cannot be considered as balanced or reasonable.*"

Additionally, we believe that an operator that had acquired demand at the historical rate in the market would have rolled out its network much more slowly, increasing its roll-out (especially in rural areas) as take-up increased – this slower roll-out would therefore develop in line with slower (historical) growth in traffic and would give rise to similar costs as in our rapid roll-out/rapid growth model.

[15] Source: http://www.opta.nl/nl/download/bijlage/?id=525

[16] Source: http://www.opta.nl/nl/download/bijlage/?id=539

## 3.3 Relationship between spectrum and allocation of cost

### 3.3.1 Comments by the operators

One operator [✂] seeks clarification on how the "*increase of spectrum relates to allocation of cost in a declining mobile voice market*". It states that "*both terminating and originating traffic show a decline in volume for mobile traffic, however increased 2/3G spectrum requirements seem to be allocated to voice services in the pure model.*"

### 3.3.2 Analysys Mason/OPTA response

We note that the increase in the allocations of 900MHz/1800MHz spectrum in the v4 model *does* lead to an increased cost allocation to voice in the Plus BULRAIC calculation of the v4 model. We have reconsidered the spectrum holdings in the context of the spectrum auction that was recently completed. On 14 December 2012, Agentschap Telecom concluded the multi-band frequency auction in which spectrum in six bands was auctioned (800MHz, 900MHz, 1800MHz, 1900MHz, 2100MHz and 2600MHz). Most licences were packaged in 5MHz blocks, with some being for paired spectrum. Before the auction, the situation among the operators was as follows:

- KPN had approximately 50% of the mobile market and 64.8MHz of GSM spectrum
- Vodafone had approximately 25% of the mobile market and 33.2MHz of GSM spectrum
- T-Mobile had approximately 25% of the mobile market and 83.6MHz of GSM spectrum (it should be noted that T-Mobile had acquired Orange's spectrum allocation in 2007/2008).

As part of the model finalisation previously described, the mobile BULRIC model reflects:

- a constant forecast for mobile voice traffic
- a conservative forecast for mobile data growth, reflecting the forecast for traffic carried on GSM/UMTS (above that, more data will be carried over LTE, but this is not modelled).

It is clear that:

- T-Mobile has more GSM spectrum than its market share indicates and we are not forecasting any significant growth in GSM traffic in the coming years
- a constant forecast mobile voice market should not require additional amounts of spectrum to support it
- more spectrum in the 900MHz and 1800MHz bands (an additional 28MHz) is now licensed to the mobile market
- the existing incumbent operators are the only players holding 900MHz and 1800MHz frequencies.

We used the BULRIC model to calculate the amount of spectrum which delivers the most efficient (lowest) Plus BULRAIC per minute for voice traffic, taking into account that this approach intrinsically relies upon a given spectrum value in order that the trade-off between sites and spectrum costs can be computed. This curve (which can seen in Figure A.1 on page 47) suggests a range of approximately 2×5MHz to 2×15MHz of 1800MHz spectrum (in addition to 2×11.6MHz of 900MHz spectrum) would be cost-efficient at the old valuation of EUR0.30 per MHz per pop for an operator with 33.3% market share. In particular, this analysis indicates that assuming that such an operator has 33% of all 1800MHz spectrum may not be an efficient modelling choice.

This issue was released for consultation with operators in a separate note following the completion of the spectrum auction in December 2012. This note is included in Annex A, whilst a more detailed discussion of the issues is provided in Annex B. The conclusion reached was that the v5 model should assume that the generic operator has 2×11.6MHz of 900MHz and 2×18.2MHz of 1800MHz spectrum.

With regards to 2100MHz spectrum, since in the BULRIC model only the first carrier is allocated to voice and data traffic, and the subsequent carriers of spectrum are allocated only to data traffic, we do not consider that it is necessary to revise the amount of 3G spectrum used in the model for the purposes of calculating the cost of mobile termination.

## 3.4 Network dimensioning

One operator [✂] states that both its own analysis and that of its network service management provider "*suggest that the variability of modelled equipment quantities (and hence cost) in respect of different levels of volumes is not reflective of reality.*" It further states that "*since a key output of the model is the Pure LRIC calculation, which represents the "avoided cost" associated with the mobile voice call termination increment, it is imperative that the model accurately dimensions the network not only for full capacity, but also appropriately "flexes" network requirements for different levels of demand to the point where the "coverage network" is defined for the minimum level of capacity*[17]*. We note in this context that the model in its current form does not exhibit the inverse relationship between spectrum and network size (and hence cost) one would expect, in that the modelled equipment quantities are largely invariant to spectrum allocation*[18] *and, indeed, the increase in modelled spectrum holdings in the updated version of the Analysys Mason model appear to have no impact on modelled network size.*"

This operator's argument can be split into two parts: (a) definition of the coverage network, and (b) the busy-hour percentage. We consider these points in turn below, including further comments by other operators.

### 3.4.1 Comments by the operators – definition of the coverage network

In the view of another operator [✂] "*a key source of the error in the AM model is in the categorization of cell sites as built either for coverage or capacity*". The operator states that in its

17 We understand that some variability is established as a result of adjustments in parameters between the plus LRAIC and Pure LRIC model specifications, but consider that a greater level of variability of equipment and costs in respect of volume would be appropriate

18 By way of example, an increase in 3G spectrum from 2 x 10MHz to 2 x 20MHz shows no change in the dimensioned network size, with the only cost changes therefore being the amount paid for spectrum

network "*capacity needs have been the main driver of additional cell sites over recent years. While these cell sites have led to improved indoor call quality, the economic case for making much of this investment has been based on the need to meet higher traffic demands. In a world without termination many of these cell sites would not have been acquired.*

*"The draft model, however, fails to identify these cell sites as incremental to traffic because it is treating them as needed to meet indoor call coverage. In reality, a network that did not have to carry termination traffic would have far fewer sites than AM assumes.*"

The first operator [✂] had requested that its network service management provider "*conduct a study to provide information in respect of a "minimum call network" which we understand, in general terms, to be analogous to the coverage network defined within the Analysys Mason model.*[19] *The results of this study suggest that the modelled coverage network significantly overestimates the number of sites that would be required to provide a "coverage only" network.*"

*Figure 3.2: Coverage calculated for the operator's full network ('original') and for only a coverage network [Source: Response by operator [✂], 2012]*

[✂]

The operator [✂] continues, "*Relatedly, this study also suggests that the cell radii in the coverage network should be materially higher than those used in the model which, in turn, would mean (i) the coverage network would be smaller (i.e., have fewer cells) and, other things equal, (ii) the incremental capacity required (and hence costs incurred) in meeting full levels of demand would be larger. The table below shows the difference between the figures in the Analysys Mason model and those suggested by the study.*"

*Figure 3.3: Outdoor, 900MHz, prior to indoor and tessellation factor adjustments [Source: Response by operator [✂], 2012]*

| | Calculated radii for coverage network (km) | Current model radii (km) | Calculated number of cells for coverage network | Calculated number of cells in current model |
|---|---|---|---|---|
| Urban | [✂] | [✂] | [✂] | [✂] |
| Suburban | [✂] | [✂] | [✂] | [✂] |
| Rural | [✂] | [✂] | [✂] | [✂] |

The operator [✂] notes that the "*calculations are based upon the use of 2G technology (at 900MHz frequency) to provide the required coverage. We consider this to be appropriate given the inverse relationship between frequency and propagation (i.e., lower frequency means a larger cell radius, and hence fewer required sites and lower cost). However, we understand that, in contrast, the coverage network dimensioned in the Analysys Mason model largely reflects the use of 3G technology since the modelled number of sites is based upon consideration of the maximum sites*

19 [✂]

*required assuming dual 2G and 3G technology deployment. We consider this approach to be inappropriate, in that using 3G technology to dimension a coverage network is inefficient in that it requires sites – and hence cost – considerably in excess of the 2G alternative; we understand the existing methodology accepts that in a hypothetical, coverage only network would not use 1800MHz spectrum, and we consider that this logic extends to the use of 3G, with both being used to efficiently meet capacity requirements rather than to provide coverage.*

*"We also note that these results will still overestimate the number of cells required solely for coverage since the study undertaken … took a scorched node approach, in particular it looked only at the extent to which existing cell sites can be "removed" from the network while still maintaining the current levels of coverage. If instead the study had taken a "scorched earth" approach whereby both the location of the sites and other factors such as the antenna tower heights were not constrained by the current network topology then a lower number of required sites for the coverage network would result. Indeed the Analysys Mason model allows for this greater level of efficiency by removing reference to any existing network and allows for "new" site locations[20]. This would therefore be expected to result in fewer sites – and hence lower cost – compared with results of the study."*

### 3.4.2 Comments by the operators – busy-hour percentage

The first operator [✂] understands "*that the "busy hour percentage" figure used by Analysys Mason represents the average annual network busy hour. However, we consider there to be three factors which may suggest that this figure, as a basis for network dimensioning, understates the network requirements – and hence costs – for a given level of aggregate demand:*

1. *Demand on a cell-by-cell basis will be "peakier", i.e., the percentage of traffic in the busy hour will be higher for an individual cell than the national average, as a consequence of different cells experience peaks at different times of day. It is therefore appropriate to reflect this in the network dimensioning within the model, as this "peakiness" will, to some extent, be "dampened" when traffic across all cells is averaged over a 24 hour period and, to the extent this effect exists, will risk understating the network equipment required (and hence cost incurred) to meet total traffic. This is shown in the diagram below:*

   *Figure 3.4: Daily traffic profile of a sample of 15 cells in the operator's network [Source: Response by operator [✂], 2012]*

   [✂]

2. *Relatedly, we understand … that network dimensioning is also designed to reflect the fact that operators will seek to meet a measure of the peak demand in the busy hour, rather than the average during busy hour, and hence a larger network than implied by the current model input.*

[20] We note that the model employs a "Scorched Node Overlap Coverage Coefficient" ("SNOCC") 7which is described in the model as "...the effect of imperfect coverage site positioning on coverage area". However, to the extent that this is the sole purpose of the SNOCC, we consider there is a need for a further adjustment to allow for cell overlap to ensure call handover

3. *Monthly variability should also be considered, to ensure that the busy period of the year is taken when identifying the busy hour load on the network.*

In this context, data and analysis has been provided by the operator [✂] which, according to it, suggest that:

- *"Recognising peak demand on a cell-by-cell basis, as opposed to the network average, would require an increase in the modelled "busy hour percentage" from [✂].*
- *"Accounting for monthly variability results in an increase in peak demand on a cell-by-cell basis such that the "busy hour percentage" increases further, from [✂]."*

This data can be seen in more detail in Figure 3.5 below

*Figure 3.5: Busy-hour data [Source: Response of operator [✂], 2012]*

[✂]

### 3.4.3 Comments by the operators – conclusion

Adjusting the model to accommodate these changes suggested by the operators materially alters the outcome, as shown in the following table.

*Figure 3.6: Impact of changes suggested by the operators [Source: Response of operator [✂], 2012]*

| | Original result | Result post adjustment | Absolute difference | Relative change |
|---|---|---|---|---|
| Plus BULRAIC | 0.0216 | 0.0207 | -0.0009 | -4.3% |
| Pure BULRIC | 0.0125 | 0.0147 | 0.0021 | +16.9% |

The operator [✂] providing this analysis notes that "*in applying these amendments the modelled equipment quantities change materially; for example the modelled quantities of sites in the "full capacity" network reduces by c40% and, further, that the equipment quantities in the original model, adjusted for volumes provided by us [✂], are materially different to those deployed by the operator in reality. These results are therefore prior to any necessary recalibration exercise, and we recommend that such an exercise is conducted to ensure that the modelled equipment quantities are consistent with those which would be deployed by an efficient operator for a given level and mix of demand.*"

### 3.4.4 Analysys Mason/OPTA response

We have considered these two issues – the coverage network and the busy-hour percentage – as part of a single input recalibration of OPTA's BULRIC model made in order to reflect the sensitivity of the model to assumptions related to coverage, capacity and spectrum allocations. In the following, we (a) consider the increase in the busy-hour percentage suggested by the respondent, (b) consider the relevance of 3G coverage, (c) describe our recalibration exercise and (d) consider the relationship between spectrum and network size.

► *Busy-hour percentage*

The proposed mark-ups to the busy-hour inputs could be included in the model either by applying an explicit mark-up to the busy-hour proportion input, or by scaling the TRX utilisation factors. Since the effect described by the operator is related to the radio network only, and the mark-ups are not especially relevant to the calculation of the transmission network, we have followed the second approach and have included functionality to allow the inclusion of scaling factors to the TRX utilisation inputs. We have included two factors: (a) a factor to take into consideration consider cell busy-hour and seasonal variability (100%/150% = 67%), and (b) a factor of 80% to capture the effects referred to by the operator [✂] as “*daily variability, busy-hour variability, unforeseen peaks and spare capacity for traffic growth*”. These adjustments reduce the average TRX utilisations.

This new functionality can be found on the “Network_design_inputs” worksheet of the mobile module.

► *Relevance of 3G coverage*

We first of all note that the operator [✂] puts forward the view that its 3G coverage is for capacity only. However, in our opinion, the operator does provide 3G coverage for a nationwide UMTS/HSPA service. Its own website[21] includes a map showing the coverage of its 3G network. Therefore, we will continue to consider 3G coverage as relevant to the model.

21 [✂]

[✂]

*[✂] Figure 3.7:*

The radii quoted by the operator [✂] in Figure 3.3 (see page 17 above) are for outdoor GSM900 spectrum, corresponding to the inputs in cells D199:D201 in the "Network_design_inputs" worksheet of the v4 Mobile module. We have updated these in the v5 model with the radii suggested by the operator. Similarly, we have adapted the model to accommodate the operator's comments by setting the minimum TRX per sector to 1 (as opposed to 2 in the v4 model), performing a capacity-related calibration of additional TRX capacity and consequently removing the need for the explicit Pure BULRIC adjustment with regards to TRX per sector.

► *Recalibration exercise*

We have revisited the network design in order to determine a set of inputs that give results for 2G asset volumes (specifically for BTSs and TRXs) that correspond reasonably to actual operator asset counts (after, for example, adjustment for market share and busy-hour percentage).

Figure 3.8 below plots the market shares of 2G minutes of the three operators against their 2G spectrum allocations. As can be seen below, KPN and Vodafone demonstrate a similar relationship between 2G minutes and spectrum holdings, whilst T-Mobile, [✂], has considerably more 2G spectrum. Therefore, we have focused our recalibration efforts on the KPN and Vodafone cases, although we also consider the impact on the T-Mobile case. In particular, we have defined a 'KPN-like configuration' which can be used to calibrate the model at higher levels of traffic sensitivity, and a 'Vodafone-like configuration' which can be used to calibrate the model in the context of a low level of spectrum and a market share close to the "minimum efficient scale" as suggested by the EC Recommendation. For completeness, we have also set-up a 'T-Mobile-like configuration'.

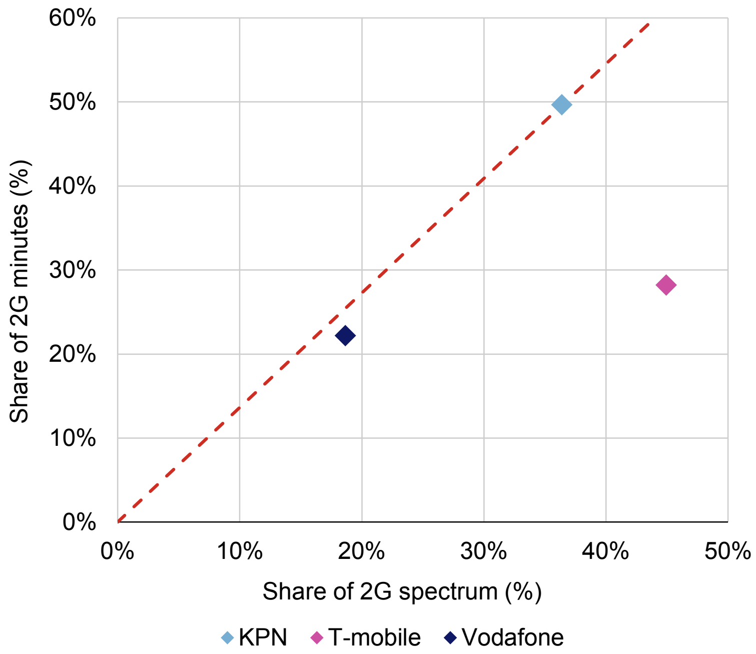



*Figure 3.8: Comparison of operator 2G minutes to 2G spectrum [Source: OPTA Market Monitor,[22], ECO report,[23] 2012]*

We have replaced certain hypothetical inputs with operator-specific values when recalibrating the operator-specific calculations. The inputs that we have adjusted are as follows:

- Market share of voice minutes – this is calculated from a combination of data on total network minutes supplied by the operators, and market-level data available in OPTA's Market Monitor
- Indoor population coverage – taken from operators' responses to our earlier data request
- Paired spectrum allocation – taken from the ECO report on the licensing of 'mobile bands'
- Number of 2100MHz carriers for voice – this is assumed to be 1 for Vodafone and 2 for KPN
- BTS sectorisation, network busy-hour percentage and migration profile – based on data from operators' responses to our earlier data request.

The first adjustment we have made is to revise the outdoor GSM900 cell radii to take into account the values suggested in the operator [✄] response discussed earlier (see Figure 3.3 on page 17). It will be recalled that the operator asserted that around 40% of its sites are for coverage purposes; using the model, we were able to produce a number of coverage sites corresponding to this figure by increasing each of the suggested radii by 0.1km. Therefore, the final outdoor GSM900 cell radii that we have used in our recalibration are those shown in Figure 3.9.

| | v4 model radii (km) | Radii suggested by respondent (km) | Radii used in calibrated model (km) |
|---|---|---|---|
| Urban | 2.2 | 2.4 | 2.5 |
| Suburban | 3.6 | 4.1 | 4.2 |
| Rural | 5.9 | 6.8 | 6.9 |

*Figure 3.9: Revised assumptions for outdoor GSM900 cell radii in the v5 model [Source: Analysys Mason based on operator [✄] response, 2012]*

[22] See footnote 10.

[23] http://www.ilr.public.lu/services_frequences/documents/mobile/ECO_Report_03.doc

We have then revisited particular network design inputs, in order to recalibrate the model so that both the KPN-like and Vodafone-like configurations generate BTS and TRX asset counts that are similar to the actual asset counts of these two operators. The inputs that have been revised are shown below.

*Figure 3.10: Revisions made to inputs on the "Network_design_inputs" worksheet of the v5 model [Source: v5 model, 2012]*

| Input | Cell reference | Description of revisions |
|---|---|---|
| TRX utilisation in terms of Erlangs | D567:G567 | Specified as a product of three utilisation factors: 75% (calibrated factors) and the two effects specified implied by the comments above i.e. 67% (1/150%) and 80% |
| GSM spectrum re-use limit | D288:D291 | Specified separately for 900MHz and 1800MHz. Values revised to be based on the assumed spectrum holdings in MHz, based on a lookup table |
| BTS utilisation for sites affected (unaffected) by borders | E572:E573 | Set to be 100% for sites unaffected by orders and 50% for sites affected by borders |
| Minimum TRX per sector | D295:G295 | Set to be 2 for micro/indoor; 1 otherwise |
| Maximum TRX per sector | D298:D299 | Specified separately for 900MHz and 1800MHz: both values set to 6 |
| Cell radius multipliers | E215:F215 | Adjusted for the rural geotypes in the 1800MHz and 2100MHz bands |
| Scorched node overlap coverage coefficient | E247:F248 | Adjusted for the suburban / rural geotypes |
| CK utilisation | N567:Q567 | Assumed to be the TRX utilisation with the 75% factor divided out |

These revisions make the following percentage differences calculated asset counts when the model is run under the different operator-specific configurations.

*Figure 3.11: Comparison of the actual asset counts and the bottom-up operator-specific calculations [Source: Operator data, v5 model, 2012]*

| | KPN-like configuration | T-Mobile -like configuration | Vodafone-like configuration |
|---|---|---|---|
| Total BTS in 2012 | [✂] | [✂] | [✂] |
| Total TRX in 2012 | [✂] | [✂] | [✂] |
| Total NodeB in 2012 | [✂] | [✂] | [✂] |

We therefore consider this recalibrated model to be more responsive to spectrum allocations and levels of voice traffic, since Vodafone and KPN are now well calibrated as regards both BTSs and NodeBs. Furthermore, Vodafone is well calibrated with regard to TRXs in the event of its smaller 1800MHz spectrum holdings, with T-Mobile also well calibrated with respect to TRXs.

At high levels of traffic (around 50%) the model over-deploys TRXs. However we believe this is likely to be due to increasing capacity saturation in the real network compared to the hard limits to

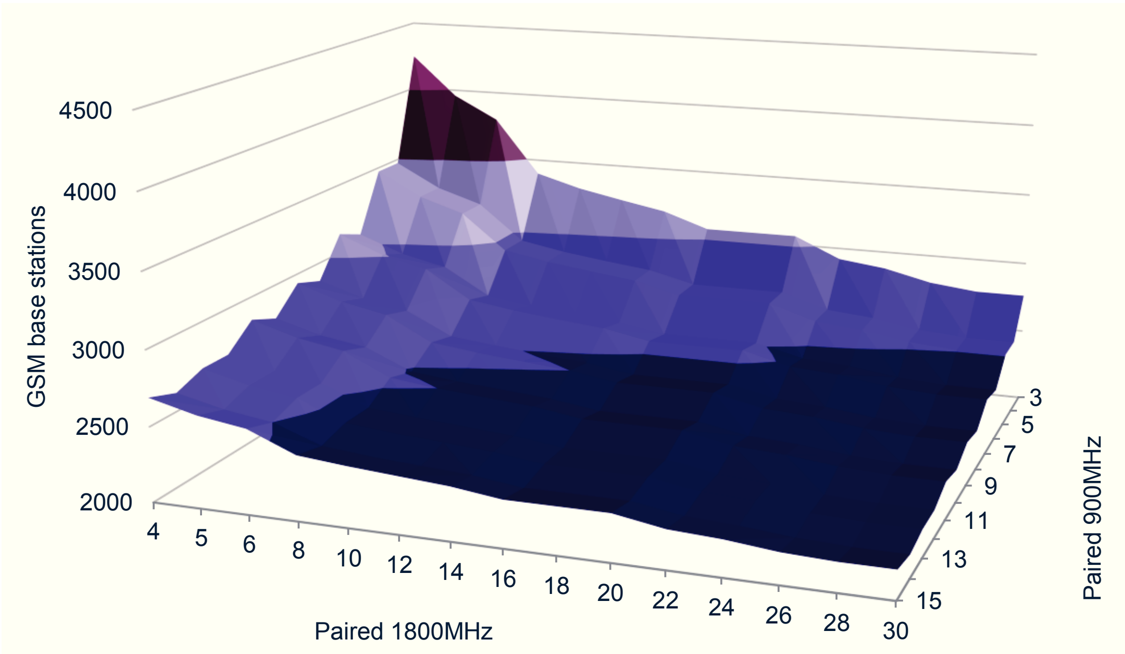
TRX capacity as modelled. At high traffic load, half-rate coding for voice calls may also become increasingly applied in congested areas.

► *Relationship between spectrum and network size*

As noted above, the v4 model displayed little sensitivity to the 900MHz/1800MHz spectrum allocations. As a result of our recalibration exercise, the v5 model now demonstrates increased sensitivity to these allocations. This is because the BTS capacity (in TRX terms) is now driven by the spectral capacity rather than the physical capacity. In the v4 model, the reverse was the case.

We illustrate this increased spectral sensitivity by showing the number of 2G BTSs calculated as required in the model for different amounts of 900MHz/1800MHz spectrum below. The resulting surface indicates the sensitivity to spectrum in the final model, with the number of sites required increasing as the spectrum holdings are reduced.

*Figure 3.12: Illustration of sensitivity to spectrum allocations in the v5 model [Source: v5 model, 2012]*




Therefore, we do not believe that spectrum should be avoided in the Pure BULRIC calculation in the v5 model. Avoiding spectrum will require more sites in the modelling state without terminated traffic as a result of this spectral sensitivity, which will lead to an increase in network costs that will *compensate the reduction in spectrum fees*. By not avoiding spectrum, the network design will now avoid GSM base stations, which will appear in the avoidable cost base.

## 3.5 Modularity of network equipment

### 3.5.1 Comments by the operators

According to one operator [✂], the modelling approach "*effectively develops two 'parallel' bottom up models – one dimensioned to full demand, and one dimensioned to full demand less volumes associated with mobile voice call termination. As a consequence, for the calculation of Pure LRIC to be accurate, it is essential that the modularity of all assets is accurately reflected in the dimensioning. It is not sufficient, as with plus LRAIC calculations, for assets and costs to be accurately specified for solely the minimum network and full network extremes but, instead, a robust cost volume relationship across the full breadth of output is required. Without this, avoided costs may be mis-stated, and in this regard, the Analysys Mason dimensioning risks systematically understating avoided costs since it fails to reflect the (full extent of) modularity in network equipment, network operating costs and support costs.*

*"In this context, we discuss below the implications of potential understatement of network equipment (and hence cost) modularity, and provide suggestions as to how such modularity could be included such that the model more accurately reflects our understanding of the modified principles being applied.*

*"At lower volumes, we would expect that it may be possible to install lower capacity units or to reduce the number of physical modular components (e.g., cards or racks) needed. A lack of recognition of such variability in respect of volumes therefore risks mis-stating avoided costs under the Pure LRIC convention. A number of network components have been identified whereby modularity in respect of volumes may be understated. The table below identifies these network components, and provides an indication of the extent to which costs may be variable with respect to output, along with a driver for the variability.*[24]"

*Figure 3.13: Variable element of costs [Source: Response by operator [✂], 2012]*

| Network component | Variable element of total cost (%) | Driver |
|---|---|---|
| VMS | 90% | Voice call volumes |
| HLR | 50% | Subscribers |
| Wholesale Billing System | 50% | Voice call volumes |
| AUC | 50% | Subscribers |
| EIR | 50% | Subscribers |
| MNP / Coin platform | 50% | Voice call volumes |
| Network Management System | 20% | Cell sites |

Adjusting the model to reflect this network modularity alters the outcome as follows:

24 *The variability of the cost with volume and the key drivers of these costs are indicative, having been derived from cost volume relationships for generic equipment in top down LRIC cost calculations.*

*Figure 3.14: Impact of suggested changes [Source: Response by operator [✂], 2012]*

| | Original result | Result post adjustment | Absolute difference | Relative change |
|---|---|---|---|---|
| Plus BULRAIC | 0.0216 | 0.0217 | 0.0001 | +0.4% |
| Pure BULRIC | 0.0125 | 0.0128 | 0.0003 | +2.1% |

### 3.5.2 Analysys Mason/OPTA response

We first note that the three assets listed above as scaling with subscribers (HLR, AUC and EIR) are irrelevant in our opinion to the Pure BULRIC calculation, since subscribers are unchanged with the removal of voice termination traffic. Therefore we do not see any need to revisit the HLR, AUC and EIR assets. We have reviewed the network design of the remaining four assets listed above, and summarise the relevant network calculations in Figure 3.15 below.

*Figure 3.15: Network design calculations [Source: Analysys Mason, 2012]*

<table>
<tr><th>Network component</th><th>Network design calculations</th></tr>
<tr><td>VMS</td><td><ul><li>Calculated as 'average subscribers in the network' / (' VMS subscriber capacity' × 'maximum VMS utilisation'), rounded up to the next integer</li><li>The v4 model includes a minimum VMS level of 2, and there will only be any variation in the number of VMS if this calculation gives an output of greater than 2<br>— this never occurs in the lifetime of the v4 model, and since it is subscriber-driven it will never appear in the avoidable cost of termination</li></ul></td></tr>
<tr><td>Wholesale Billing System</td><td><ul><li>Calculated as 'approximate call data records (CDRs) in the day'/ (' wholesale billing system daily CDR capacity' × 'maximum wholesale billing system utilisation', rounded up to the next integer</li><li>The v4 model includes a minimum wholesale billing system level of 1 and there is only any variation in the volume of wholesale billing system if this calculation gives an output of greater than 1<br>— the billing system reaches 3 units in the long term</li></ul></td></tr>
<tr><td>MNP / Coin platform</td><td>Set to 1 from 2006 onwards in the v4 model</td></tr>
<tr><td>Network Management System</td><td>Set to 1 from 2006 onwards in the v4 model</td></tr>
</table>

Therefore, only the wholesale billing system can respond to the removal of termination traffic, and thus possibly contribute to the avoidable cost of the service. This can be seen by looking at the "Avoided capex" and "Avoided opex" subsections on the "pureLRIC" worksheet of the Service Costing module.

We have adapted the "pureLRIC" worksheet of the Service Costing module such that the capex/opex contributions of the relevant assets to the Pure BULRIC can be viewed on an asset-by-asset basis. On the "Results_mobile" worksheet in the Service Costing module, we have also included new functionality to include a contribution of the BULRAIC of termination from a chosen list of assets within the Pure BULRIC of termination. We note that this is not the Plus BULRAIC i.e. common cost mark-ups are excluded. For asset "A", this contribution is calculated using the following formula:

*BULRAIC per minute for "A"* × *Proportion of the asset cost assumed to be traffic variable*

The v5 model includes a contribution for each of the four assets specified above in Figure 3.15. In order to capture this effect for the network management system, this asset has been removed from the common cost base. For the values of "Proportion of the asset cost assumed to be traffic variable", we use the operator-provided [✂] data in Figure 3.13. These contributions are assumed to sit within the 'high' Pure BULRIC case (as described in more detail in Section 4.1).

## 3.6 Reconciliation with operator data

### 3.6.1 Comments by the operators

One operator [✂] believes that "*the AM model is a highly simplified approximation of costs that might be incurred by a hypothetical operator and that cannot practically take into account all the real-world constraints on network design in practice (such as in relation to the availability of site locations). Accordingly, there is no basis to believe that the cost level estimated by the draft model is closer to the efficient level of costs than the actual costs incurred by operators. Unless the model is calibrated so that it reflects the actual costs incurred by operators, it will carry a large risk of preventing operators from recovering their efficiently incurred costs.*

*"AM has compared some of the model's results with operator data in the Presentation for Industry Group of 18 October 2012. This data shows that the draft model is:*

- *Underestimating the number of 2G mobile base stations of all operators;*
- *At the lower end of the range of operator data for 3G base stations;*
- *In the lower end of the range of operator data for macro sites;*
- *At the bottom of operator data for total CAPEX; and*
- *At the lower end of operator data for total OPEX.*

*"Given that the model is supposed to be estimating the costs that would be incurred by an operator serving a 33% market share, these comparisons raise serious concerns that the model is significantly underestimating costs. We believe that it will be important for adjustments to be made to the model so that they do not lie below the average of the operator data (and after making adjustments for market share differences). Ensuring that costs are not below the average of the operator data is important as individual operators may have less of one type of asset and more of another. To simply take the lowest value from different operators would result in an overall cost estimate that is unlikely to be achievable in practice.*"

The operator [✂] uses confidential data on its urban cell radii and growth in site numbers to support its argument that the reconciliation of the model with operator data needs to be revisited:

*"One source of the difference between the model's results and operator data is likely to be the assumption of the effective radius of a 3G cell in urban area of 400 metres. This is much greater than urban cell radii in our network. Accordingly, this may help explain why the model is estimating a number for 3G base stations at the lower end of the range of operator data.*

*"We believe that reconciliation is also important in assessing the reasonableness of the Pure BULRIC estimates. For example, the model estimates that site numbers would increase by only 8% between 2009 and 2012 despite the increase in overall traffic over this time. [✄]"*

### 3.6.2 Analysys Mason/OPTA response

As shown in the response to Section 3.4, we have recalibrated the radio network asset counts for all three operator-specific calculations. We have then undertaken a similar exercise in terms of comparison of the modelled and actual operating expenditures.[25]

We have been able to consider opex for both the KPN-like calculation and the Vodafone-like calculation, so as to get closer agreement with both the KPN-like calculation and the Vodafone-like calculation. We have included an additional mark-up on the opex assumptions for all radio network assets and all core network assets of 60% and 45% respectively. We have reduced the level of business overheads, as described in Section 4.6. We have also introduced negative year-on-year opex cost trends for radio network assets, core network assets and site assets. These trends are required since operator data indicates that total opex, in real terms, is either static or falling year-on-year.

The outcome of the revision of the modelled opex and the operator data is shown in Figure 3.16 below. The difference in opex levels for KPN and Vodafone has made it difficult to obtain close agreement for both calculations. The model currently slightly over-estimates the opex in the Vodafone-like calculation and slightly under-estimates the opex in the KPN-like calculation.

| Percentage difference | KPN-like calculation | T-Mobile - like calculation | Vodafone-like calculation |
|---|---|---|---|
| Total opex | [✄] | [✄] | [✄] |

*Figure 3.16: Comparison of bottom-up operator-specific calculations [Source: Operator data, v5 model, 2012]*

Due to the lack of cumulative capex data from operators, we have been unable to construct a comparison similar to that for opex in Figure 3.16.

Using our revised model, we have assessed the impact of different market shares on the assets and costs mentioned by the operator. We have specifically looked at the asset volumes and cost levels for an operator with 20%, 30% and 50% market share.

25 During this opex reconciliation exercise, we identified that the "expenditure_flag" named range in the Fixed module and Mobile module was effectively leading to one year where no opex was incurred for particular assets when they were being shut down prior to the end of the modelling lifetime. We have replaced this named range with a "capex_flag" for the capital expenditure calculations and an "opex_flag" for the operating expenditure calculations that addresses this.

► *Assets*

We have compared the asset volumes deployed by the operator in 2012 taken from the "Full_Network" sheet of the Mobile module when the draft model is run for operators with 20%, 30% and 50% market share. The results of this comparison are illustrated below in Figure 3.17.

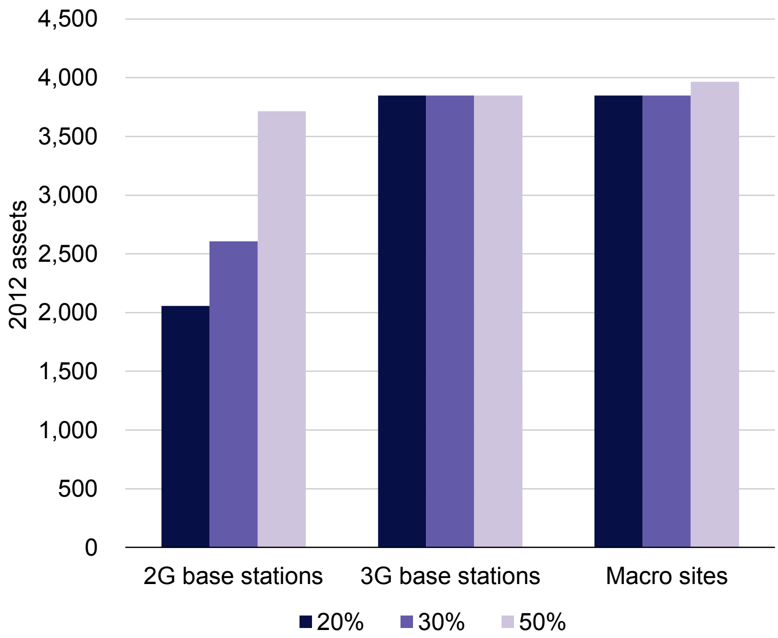



*Figure 3.17: Asset volumes in 2012 under three different market shares [Source: v5 model, 2012]*

► *Costs*

We used the same methodology to find the capex and opex outputs of the Mobile module over time under the three market share assumptions.

We considered the impact of market share on cumulative capex, as shown in Figure 3.18 below. By the end of the investigated period (2020), the difference in market share from 20% to 30% equates to approximately an 8% increase in cumulative capex. Similarly, the difference in market share from 20% to 50% equates to approximately a 25% increase in cumulative capex.

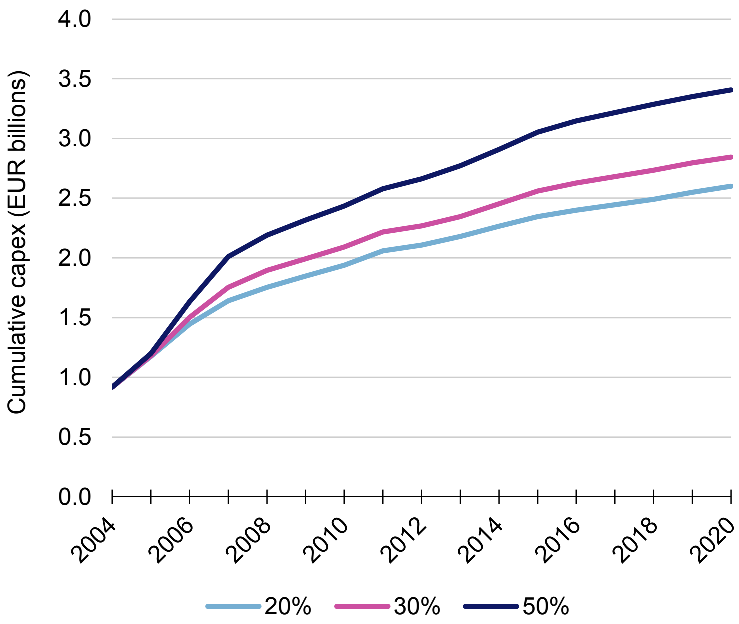



*Figure 3.18: Cumulative capex under three different market shares [Source: v5 model, 2012]*

Finally, we also looked at the impact of market share on opex per annum as shown in Figure 3.19. We find that in 2018 the impact of a move in market share from 20% to 30% is an approximately 10% increase in opex, while a similar move from 20% to 50% market share results in an approximately 40% increase in opex.

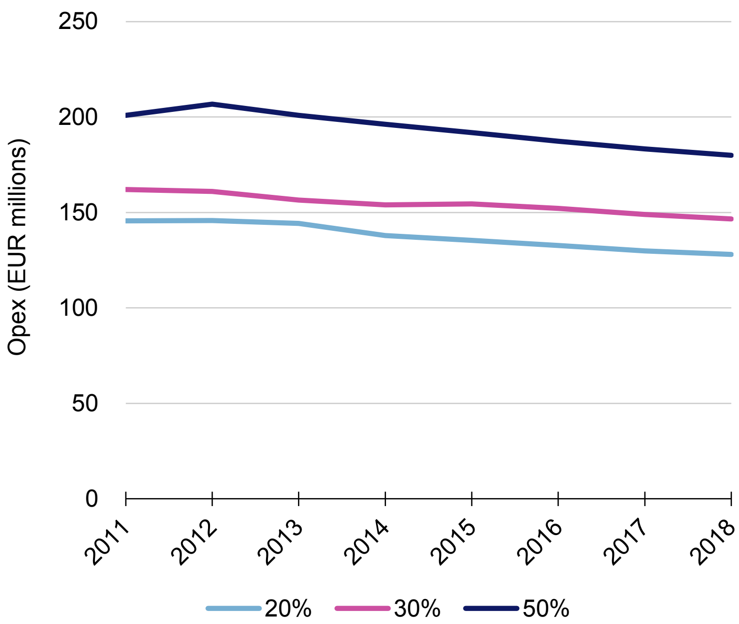



*Figure 3.19: Opex under three different market shares [Source: v5 model, 2012]*

# 4 Costing

*Figure 4.1: Summary of comments related to the Service Costing module [Source: Analysys Mason, 2012]*

| Number | Issue |
|---|---|
| 9 | Range of values for mobile termination rate |
| 10 | VoIP costs |
| 11 | Interconnection costs |
| 12 | Mark-up mechanism |
| 13 | Rationale for allocation of costs |
| 14 | Treatment of business overhead costs |
| 15 | Pure BULRIC calculation |
| 16 | Treatment of parameter values |

## 4.1 Range of values for the mobile termination rate

### 4.1.1 Comments by the operators

One operator [✂] points out that the *fixed* Pure BULRIC model indicates the range of the termination rates calculated. The operator believes that it would be useful for the *mobile* model to also show the range of values output, as "*this gives a good indication of how sensitive the model is to different assumptions regarding the degree to which underlying costs are believed to vary with traffic*".

The operator goes on to say that "*the discussion held during IG2 seems to suggest that the currently calculated termination rate for mobile voice services forms the upper bound of such a range*". It states that it "*would be very interested to know what a lower bound of the range looks like and how this compares with the range for fixed voice services.*"

### 4.1.2 Analysys Mason/OPTA response

First of all, we observe that as a result of the recalibration described above (Section 3.4.4), the 2G and 3G radio network designs in the v5 model are more traffic-sensitive for network capacity, but taking into account the inverse relationship between spectrum and capacity means that the revised model is now sensitive to both levels of traffic in the network and spectrum holdings. As a result, we have removed the adjustments related to the minimum TRXs per sector and minimum channel elements per NodeB from the Pure BULRIC calculation. As a result of the spectrum sensitivity in the v5 model described in Section 3.4, we have removed the adjustment to the 1800MHz spectrum allocation. The remaining adjustments have been retained, i.e.:

- UMTS cell loading (for cell breathing relaxation)
- proportion of GSM special sites deployed.

We have added additional functionality to the v5 mobile model to enable the calculation and display of the lower bound for the mobile Pure BULRIC, as requested by the operator. This output is calculated in the same manner as for the Pure BULRIC results, with the changes in network design removed and the additional BULRAIC contributions described in Section 3.5 also removed. This gives a lower bound for the Pure BULRIC for mobile termination, analogous to that illustrated in the fixed model. The low and high bounds are shown in Figure 4.2 below.

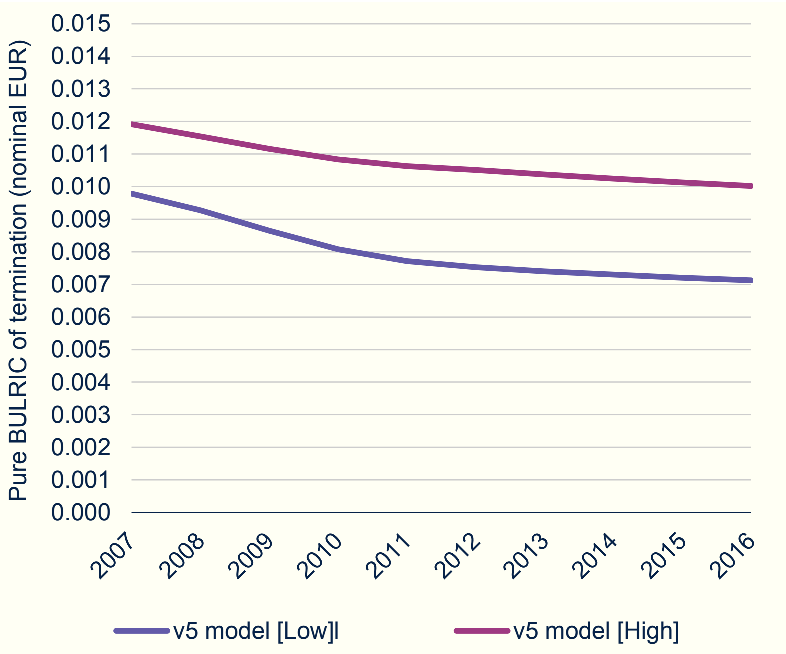



*Figure 4.2: Low and high cases for the mobile Pure BULRIC [Source: v5 model, 2012]*

## 4.2 VoIP costs

### 4.2.1 Comments by the operators

One of the operators [✂] agrees that "*the cost input of OPTA's calculations is in conformity with our answers to OPTA's data request*", but it argues that *"[✂] These capital expenditures are not included in OPTA's calculation*"

The operator [✂] has "*already mentioned the 40% utilisation that Analysys Mason uses in the model for the other assets. OPTA reacted on that issue in the definitive FTA-MTA 3b decision, and said that for VOIP software 100% utilisation is used in the model. But that is a misleading statement, because the VOIP software is not modelled in the Analysys Mason model, but just input, one figure of 5 euro/subscribers/year. The actual calculation Analysys Mason made can be seen as an additional model. One can conclude that Analysys Mason doesn't use an utilisation of 40% (but about 80%), which is (according to Analysys) in general needed for a qualitative network."* The operator refers to slides 80 and 92 of the Analysys Mason IG2 presentation of 10 October 2010.

The same operator [✂] also claims that OPTA neglects its "*argument that a migration from NSN to ALU means a simultaneous use of two platforms for some time. So the low cost alternative is not an alternative in a long run cost model*".

### 4.2.2 Analysys Mason/OPTA response

The two slides referred to by the operator, which we believe are included in Annex C of our presentation dated 20 April 2010[26] (and not 10 October 2010 as stated by the respondent). They are reproduced in the figures below.

*Figure 4.3: Slide 80 from Annex C.3 [Source: Analysys Mason, 2010]*

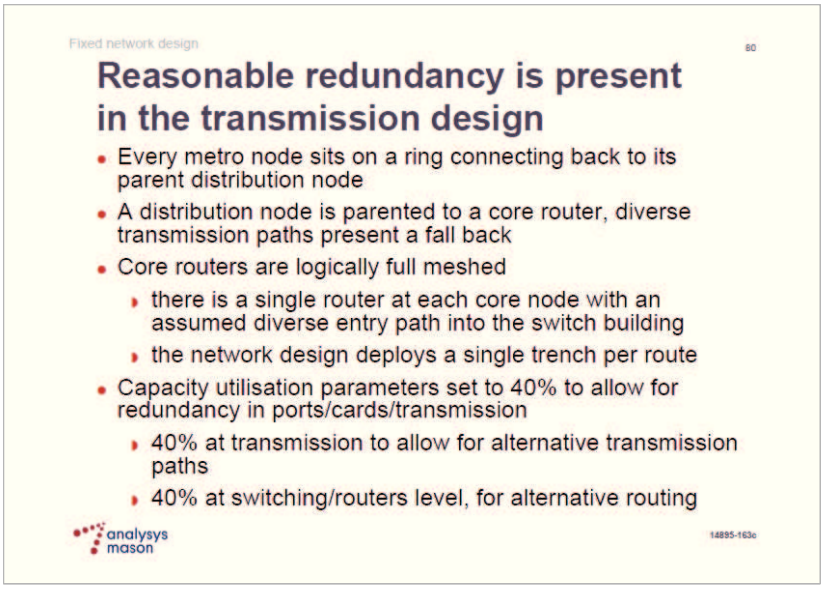
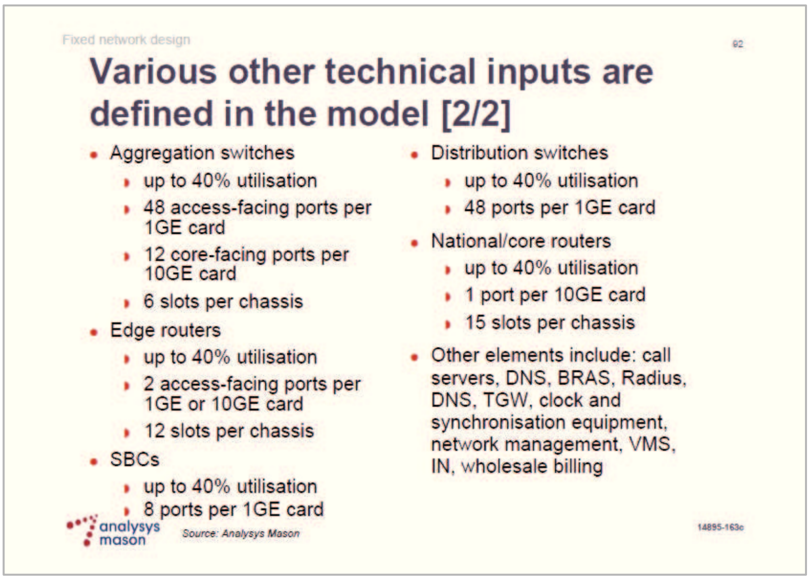



*Figure 4.4: Slide 92 from Annex C.3 [Source: Analysys Mason, 2010]*




The VoIP subscriber licence asset in both the v3 and v4 BULRIC model does not have a utilisation factor. However, as the respondent notes, the external cost benchmark calculation undertaken by

26 Source: http://www.opta.nl/nl/download/bijlage/?id=525

Analysys Mason in preparing the v4 model *does* assume an 80% utilisation factor. In the slides referred to, the 40% utilisation factors mentioned are intended to capture an over-booking effect that is very specific to the modelled IP Ethernet core network (there is an over-booking factor of 2, which leads to a utilisation factor of ½ × 80% = 40%). However, this over-booking effect is not relevant to the VoIP system, and therefore we believe the use of an 80% factor is appropriate.

Regarding the comment on the [✂] case, we have included an additional EUR[✂] of new capex in the [✂] calculation, assuming a lifetime of five years. This increases the average value of the VoIP system cost-per-minute benchmark.

We have also revisited the Plus BULRAIC VoIP system cost-per-minute benchmark and identified some instances where costs included in the benchmark were already being captured in the existing modelled assets, and therefore should be removed from the calculation. A mark-up for business overheads[27] was also included to make the calculated value directly comparable with the Plus BULRAIC from the model. After these adjustments, the calculated cost-per-minute value was EUR0.296 cents. The input on the Controls worksheet in the Fixed workbook was kept as 75%, which still provides close top-down agreement between the Plus BULRAIC from the final model in 2012 and the value of EUR0.296 cents.

A similar revision of the Pure BULRIC VoIP system cost-per-minute benchmark was also undertaken. In particular, where a list of assets for the VoIP system were provided by operators, it was reconsidered in detail which assets were likely to driven by traffic (e.g. routers, gateways, etc.), driven by subscribers (e.g. VMS servers) or fixed costs (e.g. HSS). Only traffic-driven assets were then included in the calculation. This led to a Pure BULRIC VoIP system cost-per-minute benchmark of EUR0.105 cents (compared with the range of EUR0.12–EUR0.14 cents as derived for the purposes of the v4 model in October 2012). The proportion of the "CN: VoIP software per subscriber" asset Plus BULRAIC that was assumed to be traffic-driven, and therefore relevant to the Pure BULRIC, was then reduced from 100% to 76% in order to get close top-down agreement between the Pure BULRIC from the final model in 2012 and this benchmark value of EUR0.105 cents. This adjustment was implemented on the Results_fixed worksheet of the Service_costing workbook.

Regarding the final comment, since we are modelling the network of a hypothetical efficient operator, rather than that of [✂], the efficient choice would *not* be to [✂].

## 4.3 Interconnection costs

### 4.3.1 Comments by the operators

One operator [✂] states that, as in the earlier model "*some cost elements are underestimated. This applies especially to two issues:*

27 The mark-up was assumed to be 4.2%, corresponding to the mark-up assumed in the model in 2012.

- *Monthly on-going costs. The total number of labour capacity in the model for the monthly on-going activities is assumed to be equal to 1.1 fte (with 5 interconnecting operators). We have identified all the mobile interconnection labour capacity in our organisation*[28] *and came to a total number of 2.15 fte (with 3 interconnecting operators, including ourselves) which is a significant difference in costs. In the cost model only billing related costs have been calculated. Service related costs (i.e. monitoring/reporting, maintenance), necessary for the service availability and quality were not included. Furthermore the hourly rate for future planning meetings and dispute resolution is [✄] euro. We consider tariffs for these two activities to be more likely to be near [✄] euro since in most of the dispute cases (external) legal capacity is needed.*
- *The number of hours for direct interconnects (772.5 in the model) seems too low, even if already slightly increased compared to the previous model)*".

### 4.3.2 Analysys Mason/OPTA response

The revised hourly rate is based on an average of hourly rate information provided by multiple operators. We therefore believe that it is representative of the actual hourly rates incurred.

We reject the comment regarding the hours for direct interconnections, since we received a directly opposite comment from one operator [✄] in the responses to the draft model during the original development of the BULRIC models. The respondent stated that "*monthly activities charges are lower than assumed and clearly for both sides of the interconnection and should therefore be halved*".

## 4.4 Mark-up mechanism

### 4.4.1 Comments by the operators

One operator [✄] "*re-affirms its view that any regulation of MTA should be set on the basis of efficient Ramsey pricing*"

A second operator [✄] states that "*the BULRIC model identifies, through a series of calculations and inputs, the portion of costs which are deemed to be common by each asset category and operating cost type. These common costs are then, for the purposes of the Plus LRAIC calculation, used to determine a "mark-up" which is applied on a service-by-service basis. However, we note that this approach appears to be inconsistent with the Pure LRIC calculation, which is determined on the avoided cost principle rather than relying in any way on exogenously identified common costs. In this way, it appears there is a "disconnect" between the Pure LRIC and the Plus LRAIC calculations which potentially undermines the comparability of the two sets of outputs.*

*"Furthermore, irrespective of how common costs are identified or calculated, it is often the case that mark-ups for such are applied on a sequential and 'targeted' basis, recognising the fact that*

28 Note: for details, please refer to this operator's response document.

*some costs are common (i.e., used to support more than one increment or service), but only to a subset of increments or services (i.e., some costs are 'more common' than others. In addition to the potentially subjective identification of common costs referred to above, there also exist costs which are separately identified as common to either the 2G or 3G networks, as distinct from those which are technology agnostic. In such circumstances, i.e., where different costs have different extents to which they are common, adherence to the principle of cost causality typically sees the sequential allocation of costs, such that the mostly broadly allocated costs are allocated last in a sequence or 'cascade'.*

*"In order to consider a more objective approach, we have eliminated any exogenously determined common costs (i.e., by setting the common costs identified in the model to zero), thereby allowing, to the extent that common costs exist in respect of a given asset or operating cost item, to be allocated to services on the basis of the associated 'direct' (or incremental) costs. This approach, broadly in keeping with a Fully Allocated Cost (FAC) methodology, does not affect the total economic costs, but does impact the service (total and, hence, plus LRAIC) costs by virtue of a distributional effect: where no common costs are exogenously determined, all costs are distributed at the network element level, whereas any exogenously identified common costs are distributed as a mark-up at the service level.*

*"We consider this FAC approach will yield a result which more closely adheres to the principle of cost causality, since any common costs are, effectively, allocated to network elements and hence the distribution occurs at a more targeted, granular level than the existing approach. By way of example, the modelled plus LRAIC costs for the "subscriber" increment are 1.2m euros, which is 25% higher than under the approach we consider above. We note that radio network common costs in the model are 50%+ of total common costs, suggesting that, under the existing Analysys Mason approach, an additional 0.6m euros of radio network costs is allocated to subscriber services on a proportional basis.*

*"As noted above, the identification of common costs under the Plus LRAIC approach is, we understand, distinct and unrelated to the Pure LRIC calculations. Hence, amending the model as suggested above affects solely the Plus LRAIC calculations, with the impact on results shown in the table below*"

*Figure 4.5: Impact of suggested changes [Source: Response by operator [✂], 2012]*

| | Original result | Result post adjustment | Absolute difference | Relative change |
|---|---|---|---|---|
| Plus BULRAIC | 0.0216 | 0.0243 | 0.0027 | 12.3% |
| Pure BULRIC | 0.0125 | 0.0125 | 0 | 0% |

### 4.4.2 Analysys Mason/OPTA response

OPTA has previously rejected the application of Ramsey Pricing, as described (most recently) in paragraph 626 of its 2010 market analysis.[29]

We observe that when the BULRIC models were originally developed, an FAC approach was implemented in Sections 4 and 6 of the "ED" worksheet in the Service Costing module. However, we do not agree that this is an appropriate methodology to use for the costing of termination.

In particular, we also believe that the shared network common costs are common to both the subscriber increment and the traffic increment – i.e. there is a subscriber service that should be allocated a share of network common costs. Such a network service must exist in a mobile operator's network, since operators do not sell traffic to the customers of competing networks in the Netherlands. This indicates the presence of a subscription requirement in order to originate or terminate calls on an exclusive network basis.

## 4.5 Rationale for allocation of costs

### 4.5.1 Comments by the operators

One operator [✂] wishes more clarity on the rationale for the allocation of costs between different technology generations, and argues that "*all investments in the 2/3G network that are not directly related to voice should not be allocated to these voice services e.g.:*

- *increased coverage for data services (3G) if 2G coverage for voice is available and sufficient*
- *replacement of old 2/3G equipment with new 4G ready equipment.*

*"Allocation of common costs such as sites, transmission and dark fiber that are reused/redeployed by 4G services should be allocated to these services as well. If existing 2/3G mobile operators are building 4G networks they will reuse these assets, which currently are fully allocated to 2/3G.*"

A second operator [✂] states that "*the model in its current form appropriately dimensions the network in respect of the busy hour but allocates costs to services on the basis of annual volumes. To the extent that different services (e.g., data and voice) contribute equally (i.e., exhibit the same proportions of traffic) to both the busy hour and the annual volumes, both approaches would yield the same result. However, intuitively, it is expected that voice services would be expected to represent a greater proportion of traffic in the busy hour when compared with total annual traffic, for example since voice traffic patterns across the day exhibit higher peak to mean ratios than equivalent data profiles (i.e. subscribers tend to use data services across more hours of the day than voice) and indeed the Analysys Mason model recognises that fact in its busy hour traffic inputs.*"

29 See http://www.opta.nl/nl/download/publicatie/?id=3180

*Figure 4.6: Ratio of voice and data under different allocation methods [Source: Response by operator [✂], 2012]*

| | Traffic allocation | Busy-hour allocation |
|---|---|---|
| Voice | [✂] | [✂] |
| Data | [✂] | [✂] |

This second operator also notes that "*although downstream (i.e., retail) pricing structures are complex and reflect competition and consumer preferences, charges for voice services are higher on a 1Mbps basis than for data services. This is in keeping with this broad principle of cost causality whereby the fact that voice places a greater proportional demand on the busy hour to which the network is dimensioned results in higher charges, on a unit basis, for such services.*

*"In recognition of the above, we consider that the Analysys Mason model would better reflect the principles of cost causality by both dimensioning the network and allocating costs in respect of busy hour demand. The results of amending the model to account for this are shown in the table below."*

*Figure 4.7: Impact of suggested changes [Source: Response by operator [✂], 2012]*

| | Original result | Result post adjustment | Absolute difference | Relative change |
|---|---|---|---|---|
| Plus BULRAIC | 0.0216 | 0.0258 | 0.0042 | +19.2% |
| Pure BULRIC | 0.0125 | 0.0125 | 0 | 0% |

### 4.5.2 Analysys Mason/OPTA response

With regard to the comments of the first respondent, we would make the following points:

- The model does not deploy extra NodeBs for data services, but only for Release-99 traffic (i.e. voice and non-HSPA data). In order to carry the modelled HSPA data, sufficiently fast upgrades are assumed to be activated on these (3G) NodeBs.
- In the BULRIC model, 2G/3G equipment is not assumed to be replaced with 4G-ready equipment: the negative price trends are assumed to capture the modern equivalent asset prices for 2G/3G equipment. However, after 2016, the model assumes that an increasing proportion of mobile traffic is being carried by next-generation technologies (i.e. 4G) until the 2G/3G network is shut down entirely in 2019.
- Regarding the treatment of future technology generations in the model, we refer to slide 1 of Annex C.6 of the original model documentation,[30] which describes how all technology-specific expenditures are recovered from the volumes carried using each technology during the period to 2019. The remaining technology-agnostic ('enduring') assets can be used to support traffic carried on future technology generations, and thus continue to have their costs

30 See http://www.opta.nl/nl/download/bijlage/?id=525

recovered beyond 2019. In the case of the mobile BULRIC model, assets such as sites, transmission and dark fibre are all considered to be enduring, and thus are implicitly assumed to be recovering some of their costs from future technologies (which would include 4G/LTE).

In response to the comments of the second respondent, we do not believe the suggested approach to be reasonable in the context of the objectives of the BULRIC models. Their objective is to calculate the costs of wholesale voice minutes, not to calculate the costs of a busy-hour interconnection Erlang. The approach suggested by the respondent is therefore inconsistent with this objective. It is also inconsistent with the service which is being sold on the wholesale market (that service being interconnection minutes throughout the day).[31]

## 4.6 Treatment of business overhead costs

### 4.6.1 Comments by the operators

One operator [✂] states that "*The model includes 'business overhead' operating costs of circa 30 million euros*[32] *which are, as modelled, invariant to service volumes. As a consequence, the 'avoided costs' identified for Pure LRIC calculation do not include any business overhead cost, suggesting that such costs – which we understand represent the cost associated with central functions such as HR, finance, legal and the CEO's office – would be the same regardless of the level of volumes or, generalising, the 'size' of the business. We consider that such costs are, instead, variable with volumes to some extent; for example, a business that, say, halves in size (in keeping with the 'avoided cost' calculation approach of Pure LRIC) is unlikely to require the same number of staff in its central functions, or indeed pay its heads of such functions (such as the CFO) the same remuneration. In keeping with this intuitive outcome, we have provided a comparison of business overhead costs (defined for the purposes of analysis as those costs – termed 'support costs' in our management accounts – which are unrelated to technology or network operations) which shows a positive relationship between business overhead costs and service volumes, as the figure below shows.*[33]"

*Figure 4.8: Relationship between business overhead costs and service volumes [Source: Response by operator [✂], 2012]*

[✂]

Adjusting the model to these changes alters the outcome as follows:

31 If the MNOs were instead deciding to sell interconnection busy hour Erlangs (analogous to capacity based interconnection, 'CABIS'), then indeed a traffic LRAIC increment based on busy hour load would be appropriate. In such a circumstance, wholesale buyers would be able to terminate traffic outside of the busy hour at no additional cost because they would be purchasing peak BHE interconnection.

32 The modelled figure is 30 million euros, minus c0.5 million euros for "Interconnection (4FTE)" operating costs

33 *This is a high-level analysis to demonstrate the positive relationship between support costs and volumes*

*Figure 4.9: Impact of suggested changes [Source: Response by operator [✂], 2012]*

| | Original result | Result post adjustment | Absolute difference | Relative change |
|---|---|---|---|---|
| Plus BULRAIC | 0.0216 | 0.0216 | 0 | 0% |
| Pure BULRIC | 0.0125 | 0.0145 | 0.0020 | +15.9% |

The operator further states that "*In addition to amending the model to reflect the variability of business overhead costs in respect of service volumes, it is also appropriate to consider whether the absolute amount of business overhead costs included in the model is consistent with a "real world" operator of similar scale. [✂] has provided us with its actual "support" costs (defined as above, and amounting to [✂] euros for the financial year 2012*[34]*) which, adjusted to account for the modelled volumes (i.e., consistent with an operator with 33% market share) suggests that modelled business overhead costs should be [✂] euros. We have modelled the effect of increasing this value, in conjunction with the 'variability adjustment' discussed above, and the impact on the results is shown below.*"

*Figure 4.10: Impact of suggested changes [Source: Response by operator [✂], 2012]*

| | Original result | Result post adjustment | Absolute difference | Relative change |
|---|---|---|---|---|
| Plus BULRAIC | 0.0216 | 0.0216 | 0 | 0% |
| Pure BULRIC | 0.0125 | 0.0173 | 0.0048 | +38.2% |

Another respondent [✂] considers that the assumed proportion of costs as fixed common costs in the model in 2012 (41%) is "*implausibly high. For example, OFTEL has previously noted that: "In Oftel's LRIC model of mobile network costs there are relatively small common costs, comprising only about 3-5% of total network costs" and Oftel also states that "in practice, however, there are few sources of economies of scale and scope in mobile networks (apart from short run modularity effects). Consequently, common costs between incoming and outgoing traffic are relatively small."*[35]"

### 4.6.2 Analysys Mason/OPTA response

We observe that no operator has explicitly split out mobile network business overheads in its top-down data submission, which limits what investigations have been possible. We have revisited the business overheads in connection with our reconciliation of the opex, as described in Section 3.6. In order to get a reasonable level of agreement between both the KPN-like and Vodafone-like model configurations, we have reduced the level of business overheads from EUR30 million to

34 *[✂]*

35 *Oftel, Network common costs, 2002, §2 and §4.*

EUR5 million. Therefore, a greater proportion of the modelled opex is now variable (i.e. it scales with the network size).

With regard to the operator comment regarding the proportion of costs that are common, we must emphasise that the proportion calculated using the BULRIC model by the respondent includes the minimum coverage radio network and minimum core network for the Netherlands. We do not believe that this is an appropriate comparison to make with the Ofcom statement, which instead assumes a minimum network consisting of "*a network management system and of acquiring, preparing and leasing the number of sites needed to meet the coverage requirements.*[36]" By setting the values in cells I45:BF194 of the "Network_common" worksheet in the Mobile module to zero (with the exception of rows 45, 46, 68, 69 and 147), the model can calculate an minimum network cost as a proportion of total cost that is equivalent to that used in the Ofcom approach. In the v4 model, this proportion is found to be 13.5% of total costs. Nevertheless, the range derived from the Ofcom work is still for an operator in the UK, rather than the Netherlands.

We would also note that in the UK, Vodafone (which also operates in the Netherlands) stated in a public policy paper[37] that the size of fixed and common costs in a mobile business was large – Vodafone quoted a figure of 23% in the policy paper it submitted, but in fact we believe the value is likely to vary between 15% and 40% depending on the assessment methodology used. The v5 model, as a result of the recalibration, produces a proportion of 33% in 2012, which is within this range.

## 4.7 Pure BULRIC calculation

### 4.7.1 Comments by the operators

One operator [✂] states that a "*Pure LRIC calculation is, as discussed above, defined by the 'avoided cost' principle, i.e., by determining those costs which are avoided as a result of lower demand resulting from the 'removal' of a traffic increment. The Analysys Mason model appropriately recognises that lower capacity requirements would result in a requirement for fewer sites, and as a consequence, less site-specific network equipment. In keeping with the EC's Recommendation and Analysys Mason's conceptual framework, we consider that all avoided costs associated with the defined increment should be recognised when determining the Pure LRIC, irrespective of whether such costs are directly used to provide the 'removed' service increment. This should include those costs, such as HSDPA equipment, which are used to provide data services but which are a site dependent (and hence fewer sites require less equipment) since this reflects the avoided cost principle and an alternative method of deployment (e.g., by cell) would lead to an inefficient or impractical network deployment and higher network costs*."

Adjusting the model to these changes alters the outcome as follows:

36 See http://www.ofcom.org.uk/static/archive/oftel/publications/mobile/ctm_2002/network_costs.pdf

37 See http://www.vodafone.com/content/dam/vodafone/about/public_policy/policy_papers/public_policy_series_1.pdf

*Figure 4.11: Impact of suggested changes [Source: Response by operator [✂], 2012]*

| | Original result | Result post adjustment | Absolute difference | Relative change |
|---|---|---|---|---|
| Plus BULRAIC | 0.0216 | 0.0216 | 0 | 0% |
| Pure BULRIC | 0.0125 | 0.0127 | 0.0002 | +1.5% |

### 4.7.2 Analysys Mason/OPTA response

Currently in the BULRIC model, in a particular year all NodeBs in a geotype are assumed to use the same HSPA speed (namely the lowest speed that can accommodate the average busy-hour Mbit/s per NodeB). For example, if the average busy-hour Mbit/s per NodeB in a geotype lies between 7.2 and 14.4, this implies that 100% of the NodeBs deployed in that geotype use HSDPA14.4. Therefore, if NodeBs are avoided, then so are their software activations (which are technically relevant only to data services).

Moreover, our Pure BULRIC approach applies economic depreciation to the avoided costs using the avoided network element output of each asset. Since the network element output of HSPA software is only driven by HSPA traffic, the avoided network element output of HSPA software is therefore zero, so no HSPA software costs appear in the Pure BULRIC.

As a point of principle, we do not agree that HSPA software upgrades should appear in the Pure BULRIC, since they are unrelated to voice termination traffic. Our economic depreciation method reflects this fact.

Nevertheless, we have refined the calculation of HSDPA (and HSUPA) speeds so that the NodeBs in a geotype can use a mix of two different speeds of HSPA. This refinement has been included in the "Network_design" worksheet of the Mobile module. For each of the four carriers that can be modelled, we have refined the calculation to now give an interpolated mix of the two speeds that bound the average busy-hour Mbit/s per NodeB[38]. For example, an average busy-hour *downlink* Mbit/s per NodeB of:

- 7.2Mbit/s implies 100% HSDPA7.2 and 0% HSDPA14.4
- 9.0Mbit/s implies 75% HSDPA7.2 and 25% HSDPA14.4
- 10.8Mbit/s implies 50% HSDPA7.2 and 50% HSDPA14.4
- 12.6Mbit/s implies 25% HSDPA7.2 and 75% HSDPA14.4
- 14.4Mbit/s implies 0% HSDPA7.2 and 100% HSDPA14.4.

Therefore, if NodeBs are avoided, then this leads to a higher average busy-hour Mbit/s per NodeB and therefore a mix of software upgrades with a higher proportion of the faster speed. We believe that this will better reflect the situation in the absence of termination. The above are only examples: this interpolation gives a similar outcome across all possible values of busy-hour Mbit/s per NodeB. We have implemented the same refinement for the HSUPA software upgrades as well.

[38] The exception is the first option of 1.8Mbit/s, which is deployed everywhere in a geotype at the point that HSPA traffic appears in that geotype.

## 4.8 Treatment of parameter values

### 4.8.1 Comments by the operators

One operator [✂] states that it "*is concerned that the approach of AM and OPTA to dealing with uncertainty in relation to the parameter values has been to adopt the value that will generate the lowest estimated cost level. For example, this is evident in the choice of the likely number of operators, the forecast volumes as well as by the comparison of the model's results with operator data. The overall outcome is that the model is estimating a level of costs that will not be achievable by operators in practice. This is not only inefficient in itself but can be expected to have other harmful effects such as on investment over time. If Pure BULRIC were implemented, it would require operators to supply termination at a loss with every additional call minute terminated from another operator increasing the size of the loss*."

The operator [✂] believes that "*in response to uncertainty, OPTA should choose values from the upper end of the range to minimize the risk to investment associated with this uncertainty. This is consistent with the approach adopted by Ofcom in relation to the cost of capital but Ofcom's reasoning is generally applicable:*

> *"Traditionally, Ofcom has considered that the downside risk associated with taking too low a value for the ERP (discouraging discretionary investment) is more detrimental to the interests of consumers than taking too high a value (leading to higher prices to customers) and has tended to the higher end of the possible range. Having reviewed its approach in this area, Ofcom remains of this view".*[39]"

### 4.8.2 Analysys Mason/OPTA response

We do not agree with the claim that the model should be set up with *all* inputs being conservative in order to guarantee cost recovery. The BULRIC models are set up to model *efficient* operators, and conservative inputs are only used for those inputs where there is more uncertainty as to their actual value (for example, the demand forecasts).

[39] *Ofcom's approach to risk in the assessment of the cost of capital, 26 January 2005*

# 5 Process

This section records a number of comments made by the operators that are not directly related to the model development; they are included here for completeness.

The issue of spectrum payments is now considered in Annexes A/B.

*Figure 5.1: Summary of comments related to process [Source: Analysys Mason, 2012]*

| Number | Issue |
|---|---|
| 17 | Spectrum payments |
| 18 | Cost of capital |
| 19 | EC Recommendation |

## 5.1 Spectrum payments

One operator [✄] believes that *"there will be a range of issues in seeking to make inferences from the auction results*" and "*looks forward to commenting on the proposed approach in due course*."

## 5.2 Cost of capital

One operator [✄] "*refers to its views set out in its response to the first consultation. In particular, if a relatively low mobile beta estimated during the financial crisis is to be applied then a measure of the equity risk premium estimated over a consistent period should also be adopted. Further, the practical estimation of mobile betas should be adjusted to remove the impact of operators that have both mobile and fixed revenues.*"

This operator believe that the argument set out in Annex 6.C "*is confusing project-specific risks with the undiversifiable risks that are relevant to the cost of capital. In particular, beta measures the risk of one asset relative to the risk of all assets. It is not a measure of absolute risk*".

## 5.3 EC Recommendation

One operator [✄] wishes to know "*how is conformity with the European Commission's Recommendation and standard practice on Pure BULRIC guaranteed?*" It believes that "*Pure BULRIC is in conformity with the European Commission's Recommendation on FTR and MTR and standard practice across Europe, and assumes implicitly cost recovery of the non-traffic related components via the customer*". Therefore, the operator claims, "*the Pure BULRIC approach is appropriate for the Dutch market and leads to the highest economic welfare for consumers.*"

# Annex A : Supplementary consultation on spectrum assumptions

The document entitled *Supplementary note for OPTA – consultation questions for the Dutch industry parties following the multi-band spectrum auction* (reference 35097-514) was released for consultation on 20 December 2012 by OPTA. The contents of that document are shown below.

## A.1 Introduction

Onafhankelijke Post en Telecommunicatie Autoriteit ('OPTA') has commissioned Analysys Mason Limited ('Analysys Mason') to update the bottom-up long-run incremental cost (BULRIC) models of fixed and mobile networks in the Netherlands, for the purposes of pricing wholesale fixed termination and wholesale mobile termination.

On 15 October 2012, we issued our final report to OPTA, entitled *Conceptual specification for the update of the fixed and mobile BULRIC models, Final version after industry comment*. This final conceptual specification contained a number of concepts relating to the radio spectrum within the model:

**Final concept 7:** We shall model an operator with 2×11.6MHz of GSM spectrum. We shall model an operator with 2×23.2MHz of DCS spectrum.

**Final concept 8:** We shall model an operator with 2×20MHz of UMTS spectrum.

**Final concept 9**: The assumed values of EUR per MHz per pop shall be revisited once the outcome of the 2012 auction is known.

On 14 December 2012, Agentschap Telecom concluded the multi-band frequency auction in which spectrum in six bands was auctioned (800MHz, 900MHz, 1800MHz, 1900MHz, 2100MHz and 2600MHz). Most licences were packaged in 5MHz blocks, with some being for paired spectrum. The majority of the spectrum was auctioned with a 17-year licence, with the exception of the 2100MHz and 1900MHz licences, which were 4-year licences. Existing holders of spectrum are obliged to pay monthly occupancy fees for extending the use of their current spectrum until they have been able to clear and release the spectrum to the new owners, and we understand that this short-term extension is limited to 21 months.

This note for OPTA considers the outcome of the auction, and sets out the relevant questions to the industry parties in relation to concluding on the spectrum **amount** and spectrum **valuation** to be used in the final BULRIC model for mobile termination rates. OPTA intends to seek responses to these questions from the industry parties and then to conclude and release the final BULRIC model results in its draft decision on Market 7. This paper considers the amount and valuation of spectrum accordingly.

## A.2 Amount of spectrum (2G)

We observe the following facts on the situation before the auction:

- KPN had approximately 50% of the mobile market and 64.8MHz of GSM spectrum
- Vodafone had approximately 25% of the mobile market and 33.2MHz of GSM spectrum
- T-Mobile had approximately 25% of the mobile market and 83.6MHz of GSM spectrum (it should be noted that T-Mobile acquired Orange's spectrum allocation in 2007/2008).

In undertaking finalisation activities with the industry group, the mobile BULRIC model reflects:

- a constant forecast for mobile voice traffic
- a conservative forecast for mobile data growth, reflecting the forecast for traffic carried on GSM/UMTS (above that, more data will be carried over LTE, but this is not modelled).

Following the auction, it is now clear that:

- T-Mobile has more GSM spectrum than its market share indicates and we are not forecasting any significant growth in GSM traffic in the coming years
- a constant forecast mobile voice market should not require additional amounts of spectrum to support its delivery
- more spectrum in the 900MHz and 1800MHz bands (an additional 28MHz) is now licensed to the mobile market
- the existing incumbent operators are the only players holding 900MHz and 1800MHz frequencies.

On the basis of this information, there are at least three possible ways of defining the amount of spectrum to be included in the cost model based on an efficient generic operator (with 33.3% market share):

*Amount 1* **Assume that all 900MHz and 1800MHz spectrum in the market can be used to deliver the forecast GSM voice and GSM data traffic.**

This leads to <u>2×11.6MHz of 900MHz and 2×23.2 of 1800MHz</u> spectrum for the generic operator (210MHz for the total GSM market).

*Amount 2* **Estimate the amount of spectrum in the market which is likely to be used for LTE1800 and (after some re-organisation) exclude this from the GSM part of the BULRIC model.**

In this approach, we observe that:

- KPN has not acquired more spectrum and so may not currently have spare spectrum for LTE1800

- Vodafone has gained 26.8MHz of spectrum in the combined GSM bands
- T-Mobile has gained 6.4MHz of spectrum in the combined GSM bands.

This gained spectrum (33.2MHz or 2×16.6MHz) could, after some re-organisation, be available to support LTE1800 in excess of the current GSM network situation. As LTE operates in 5MHz carriers, this can be rounded to 2×15MHz available for LTE1800 in excess of current GSM usage.

Therefore, excluding this 2×15MHz of gained spectrum, there is 2×11.6MHz of 900MHz and 2×18.2MHz of 1800MHz spectrum for the generic operator (178MHz for the total GSM market).

*Amount 3* **Use the BULRIC model to calculate the amount of spectrum which delivers the most efficient (lowest) cost per minute for voice traffic, taking into account that this approach intrinsically relies upon a given spectrum value in order that the trade-off between sites and spectrum costs can be computed.**

The model suggests that for a 33.3% share operator, a range of approximately 2×5MHz to 2×15MHz of 1800MHz spectrum (in addition to 2×11.6 of 900MHz spectrum) would be cost-efficient at the old valuation of EUR0.30 per MHz per pop, and that a minimum around 2×9MHz of spectrum is likely. Adopting this approach results in 2×11.6MHz of 900MHz and 2×9MHz of 1800MHz spectrum for the generic operator (123.6MHz for the total GSM market).

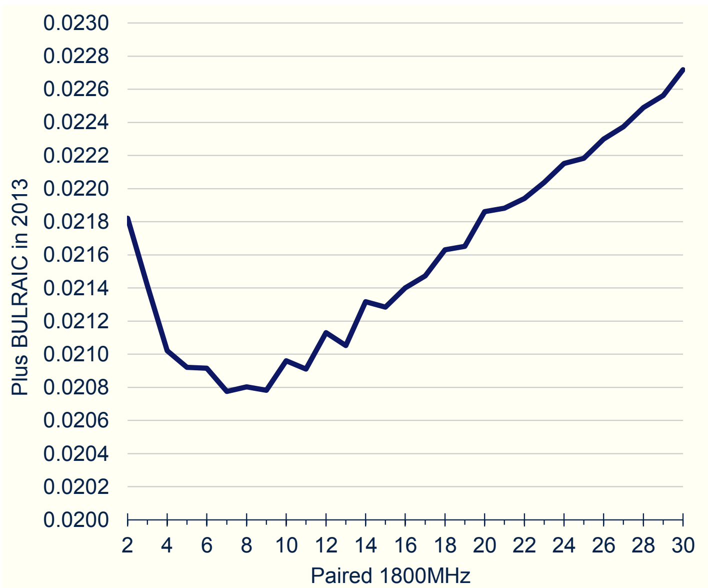



*Figure A.1: Calculation of Plus BULRAIC for different allocations of 1800MHz spectrum to an operator with 33% market share [Source: Analysys Mason, 2012]*

*Option A* **Round all spectrum amounts to 2×5MHz carriers**

In addition to the amounts set out above, there is an option to round the allocations into 2×5MHz blocks (consistent with the new licence structure).

**Question 1 for industry parties**: Please explain your view on the allocation of GSM spectrum (Amount 1, Amount 2 or Amount 3, as well as Option A) that you think is reasonable and efficient to include in the final BULRIC model.

## A.3 Amount of spectrum (3G)

Final concept 8 defined that the modelled operator should hold 2×20MHz of 3G spectrum. As the first carrier of this spectrum is allocated to voice and data traffic in the BULRIC model, and the subsequent carriers of spectrum are allocated only to data traffic, we do not consider that it is necessary to revise the amount of 3G spectrum used in the model for the purposes of calculating the cost of mobile termination. Industry parties are not requested to comment on this aspect.

## A.4 Valuation of spectrum

The draft (v4) BULRIC model retained the valuation of spectrum concluded upon during the 2010 mobile termination costing study. This valuation was set at EUR0.70, EUR0.30 and EUR0.45 per MHz per pop in the 900MHz, 1800MHz and 2100MHz bands respectively (in 2009 Euro terms). Final concept 9 indicated that these values would be updated once the outcome of the auction was known. There are a number of different spectrum valuation options that need to be resolved in order to obtain updated unit valuations for spectrum:

*GSM valuation 1 ("top-down")*

In order to calculate 900MHz and 1800MHz licence extension fees, SEO is required to derive **top-down** band valuations for the GSM frequencies using the auction outcome *split down* using some underlying auction bid data. These SEO valuations will be published in due course.

These band valuations, converted into a price per MHz per pop (adjusted for the 15-year licence duration and 2009 Euro currency in the model) could be used as the required model inputs.

*GSM valuation 2 ("bottom-up")*

A **bottom-up** approach to deriving the spectrum valuation relies upon deciding 'fundamental underlying spectrum values' for the purposes for which the spectrum could be used (e.g. GSM900, UMTS900, GSM1800, LTE1800, etc.) and then adding up and multiplying these values by the overall amount of each type of spectrum available.

This method must be 'reconciled' with the actual outcome of the auction in order to confirm whether the bottom-up valuation is consistent with the observed outcome, and/or to explain any discrepancy in reconciliation (e.g. scarce or excess spectrum, lot restrictions, tactical bidding).

This bottom-up method would rely on the existing spectrum valuation as follows (all values are expressed in EUR per MHz per pop, 2009 Euros, 15-

year licence duration) and the following bottom-up assumptions:

- low frequency coverage spectrum for voice = EUR0.70
- high frequency capacity spectrum for voice = EUR0.30
- mobile broadband capability = EUR0.15
- new spectrum (not currently occupied by mobile traffic, so is additive to the total spectrum available and can be deployed without clearance or migration issues) = +50%
- scarce spectrum (e.g. not enough lots for existing players, so the scarcity results in a higher price/value) = +50%
- not scarce spectrum (e.g. the margin value of specific spectrum reduces if operators already hold significant spectrum in that band) = -50%.

It is then necessary to adjust for 2012 currency and licence duration (4 or 17 years) to reconcile the overall bottom-up estimates with the top-down auction outcome.[40]

*2100MHz spectrum valuation*

SEO is not required to calculate a band valuation for 2100MHz spectrum, and the only spectrum auctioned in December 2012 was four-year licences for two 2×5MHz lots (operators already holding 2×50MHz of this spectrum). As a result, we do not think that the recent multi-band auction can realistically be used to set a new value for all 2100MHz spectrum used by the existing operators for voice and data services, and propose the v4 model valuation should apply.

*Extension value*

Extension payments for existing spectrum are to be charged per month until the spectrum is cleared and released. These payments are optional for the incumbent operators, subject to the time it takes them to clear the spectrum. The payments can also be seen as an incentive for the incumbents to release spectrum for potential new entry.

In relation to the BULRIC model, there are at least two options:

- exclude the extension payments from the model as they are short-term option payments associated with re-organising the spectrum for new

40 This bottom-up valuation results in the following for the Dutch multi-band auction, prior to the 4 or 17 year licence duration and Euro currency adjustments:

- 800MHz = new, scarce, LTE = (0.70+0.15) × 200% = EUR1.70
- 900MHz = GSM and capable of supporting UMTS900 = EUR0.85
- 1800MHz = capable of supporting LTE1800 = EUR0.45
- 2100MHz = not scarce, voice and HSPA = 0.45 × 50% = EUR0.23
- 2600MHz = not scarce, mobile broadband = (0.15) × 50% = EUR0.08

After the duration adjustments (×1.05 for 17 years, ×0.24 for 4 years), and Euro currency adjustments (x1.06), these underlying spectrum valuations result in a reconciled total auction value of EUR3.7 billion for KPN, Vodafone and T-Mobile, which is close to their actual total payment of EUR3.64 billion.

entry, and they are not efficient long-run costs of three-player market operations

- include the extension payments in some way (e.g. by modelling a licence duration of 21 months plus 17 years, incorporating both the extension and the auction fees).

*Extension period*

We understand that the extension period is under the control of the existing users of spectrum – extension fees are charged monthly per MHz of unreleased spectrum (up to a maximum of 21 months). However, it is not clear at this stage how long the incumbents may choose to incur the extension fees prior to releasing the spectrum.

**Question 2 for industry parties**: Please explain your view on how the GSM spectrum (900MHz and 1800MHz) should be valued for the efficient generic operator BULRIC model (e.g. 'top-down', 'bottom-up' or other), and whether any adjusted 2100MHz spectrum value should be developed.

**Question 3 for industry parties**: Please explain what you think the efficient treatment of extension fees should be for the BULRIC model, and provide any expectations or plans you currently have on the duration of the extension period prior to spectrum release.

# Annex B : Responses to the supplementary consultation on spectrum assumptions

Six responses were received to the supplementary consultation note on the allocation and assumed valuation of the modelled spectrum (see Annex A). These responses were from BCPA, UPC, Tele2, KPN, Vodafone and T-Mobile. Below, we describe the resulting conclusions with regard to:

- 3G spectrum valuation and allocation
- spectrum extension fees
- 2G spectrum valuation
- 2G spectrum allocation.

## B.1 3G spectrum valuation and allocation

Respondents made no comments on the 3G (2100MHz) spectrum allocation, so the assumption of 2×20MHz in the BULRIC model will be retained.

On the issue of 2100MHz valuation, two respondents [✂] made no comments, whilst two other respondents [✂] were agreeable to the bottom-up approach. A fifth respondent [✂] suggested using the v4 model value, and the sixth respondent [✂] stated that the bottom-up approach could be acceptable since such a small proportion of the band was auctioned in 2012. Both the bottom-up approach and the v4 model assume a value of EUR0.45 per MHz per pop, which we therefore believe is appropriate to use in the final model.

## B.2 Spectrum extension fees

Given the covenant signed on 16 January 2013,[41] we conclude that licence extension fees are not relevant to the BULRIC model. The three mobile operators were agreeable with this approach provided the covenant was signed.

## B.3 2G spectrum valuation

Four respondents [✂] support the bottom-up methodology proposed. A fifth respondent [✂] wants to see further justification for this methodology, whilst the sixth [✂] respondent finds it arbitrary and instead supports the top-down methodology.

First of all, we believe there should be less focus on the SEO valuations[42], since as a result of the covenant they are no longer going to be used within the industry (and the bottom-up approach was

41 See http://www.agentschaptelecom.nl/actueel/nieuws/2012/convenant-vergunninghouders

42 To derive these valuations for the 900MHz/1800MHz spectrum bands, we use the average price per MHz derived for these bands by the SEO using the auction results, adjusted by a factor 1.06 for inflation and a factor of 1.05 to account for the licence duration being 17 years rather than the modelled 15 years.

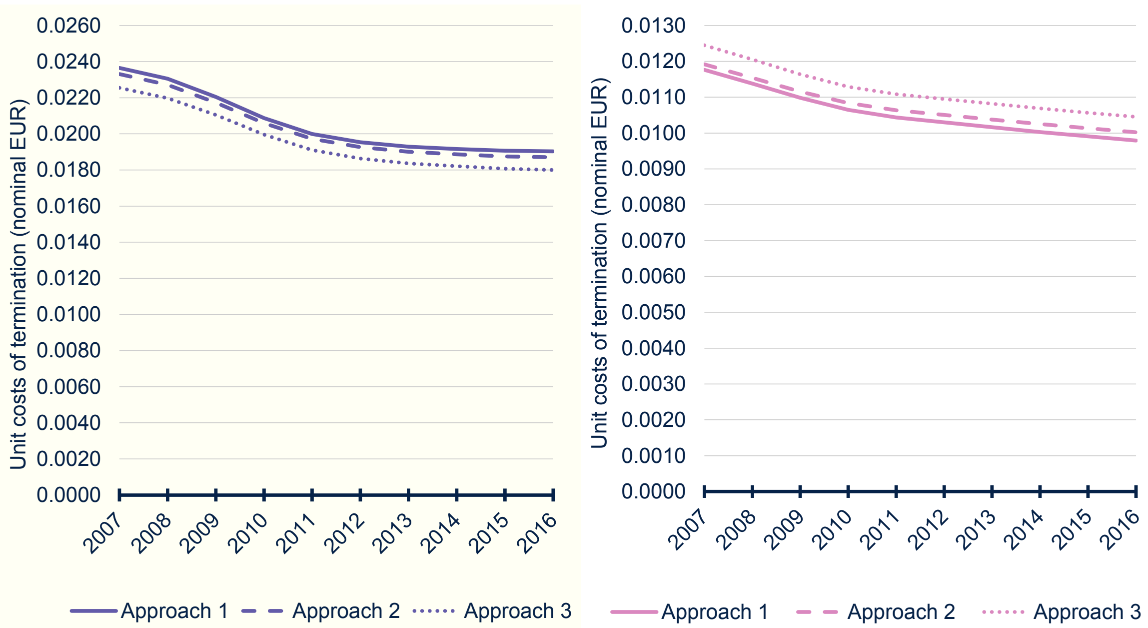
not materially different from the SEO valuations for 900MHz and 1800MHz, on average). We believe the bottom-up methodology has sufficient support from respondents to be considered for the final model. Furthermore, it is ultimately reconciled back to the actual amounts paid, meaning that the spectrum valuations in the v3/v4 model are retained (as these are the starting point for the bottom-up approach).

## B.4 2G spectrum allocation

The consultation note asked for feedback on three approaches that assumed 2×23.2MHz, 2×18.2MHz and 2×9MHz of 1800MHz spectrum respectively should be included in the cost model based on an efficient generic operator. Three respondents [✂] were in favour of Approach 3 and the remaining three respondents [✂] were in favour of Approach 1 (and against Approach 3).

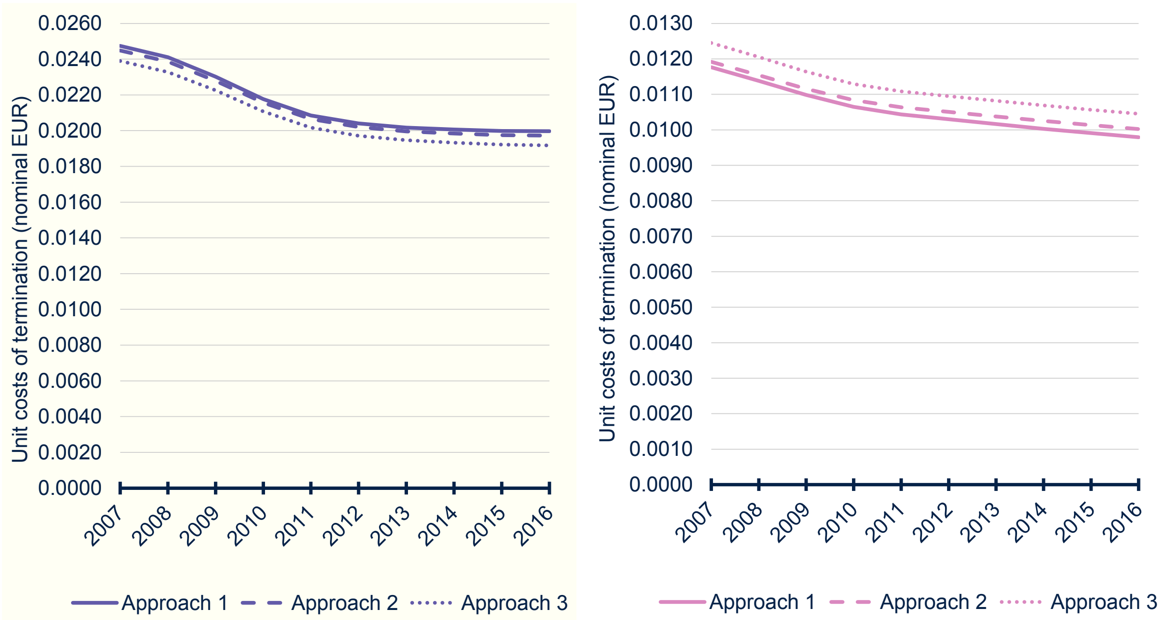
Figure B.1 below compares the final model results using the three approaches, assuming that the spectrum valuations from the v3/v4 model are retained. As can be seen, Approach 1 leads to a higher Plus BULRAIC, while Approach 3 gives a figure that is EUR0.1 cent lower. Conversely, Approach 1 leads to a lower Pure BULRIC, while Approach 3 leads to a figure nearly EUR0.1 cent higher.

*Figure B.1: Comparison of the Plus BULRAIC (left) and Pure BULRIC (right) for approaches 1, 2 and 3 using the existing spectrum valuations [Source: v5 model, 2013]*




If we use the SEO valuations for the 900MHz/1800MHz spectrum bands, then the model produces very similar curves to those above, as shown below in Figure B.2.

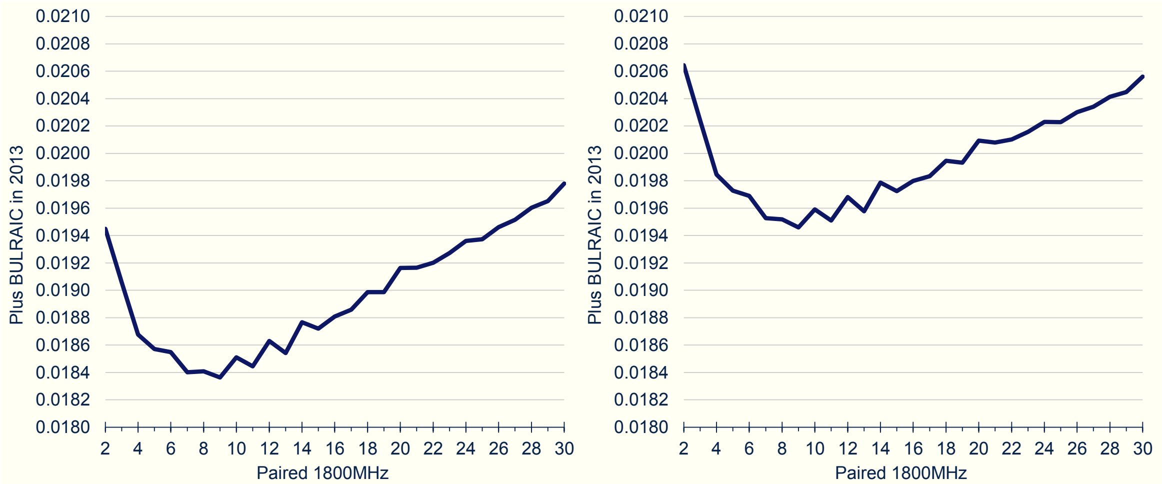
*Figure B.2: Comparison of the Plus BULRAIC (left) and Pure BULRIC (right) for approaches 1, 2 and 3, using the SEO spectrum valuations [Source: v5 model, 2013]*




We do not believe that any convincing arguments were presented as to why Approach 1 must now apply. The actual MNOs purchased more spectrum in the auction than their current holdings, but this must be for other purposes than those implied within our cost model since, for example, we assume constant voice traffic and little data traffic growth.

We recognise there are drawbacks for Approach 3, particularly in the broad range of approximately 2×5MHz to 2×15MHz, where the calculated cost curve is relatively flat. This is true whether we use the existing valuations or the SEO valuations, as shown below in Figure B.3. We show in the chart that the unit costs of traffic keep going up as spectrum increases from 2×15MHz to 2×30MHz. However, the optimum 1800MHz allocation is almost identical in both cases.

*Figure B.3: Plus BULRAIC for different allocations of 1800MHz spectrum to an operator with 33% market share, using the existing (left) and SEO (right) 900MHz/1800MHz spectrum valuations [Source: v5 model, 2013]*




Our starting position in the v4 model consultation stages of using "all spectrum/3" was at least predicated on the expectation of further traffic growth (or on new GSM entry following the auction, meaning "all spectrum/4"). There is now almost no voice traffic growth expected in the forecast, so more spectrum is not needed for voice traffic. Therefore, Approach 1 appears to be an unreasonable assumption to make. Furthermore, the charts generated by Approach 3 indicate that allocating as much 1800MHz spectrum as is assumed in Approach 1 is inefficient in the context of our modelled demand.

We believe that Approach 2 is a sensible compromise, since it:

- is close to the current situation
- sits at the conservative top end of Approach 3
- still reflects the fact that assuming "all spectrum/3" is inefficient given the expectation of the future evolution of mobile voice
- balances the higher/lower costs across the Pure BULRIC and Plus BULRAIC cases.

The results for 2013 are as follows for the various options:

| Nominal EUR | Plus BULRAIC, rounded 2dp | Pure BULRIC, rounded 2dp | Plus BULRAIC, rounded 1dp | Pure BULRIC, rounded 1dp |
|---|---|---|---|---|
| **Using existing spectrum valuations** | | | | |
| Approach 1 | 1.93 | 1.02 | 1.90 | 1.00 |
| Approach 2 | 1.90 | 1.04 | 1.90 | 1.00 |
| Approach 3 | 1.84 | 1.08 | 1.80 | 1.10 |
| **Using SEO valuations** | | | | |
| Approach 1 | 2.02 | 1.02 | 2.00 | 1.00 |
| Approach 2 | 2.00 | 1.04 | 2.00 | 1.00 |
| Approach 3 | 1.95 | 1.08 | 1.90 | 1.10 |

*Figure B.4: Comparison of 2013 cost results at different levels of decimal rounding [Source: v5 model, 2013]*