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Model documentation for the Norwegian Communications Authority

Mobile cost model version 9 (v9R)

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Contents

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1 Introduction

The Norwegian Communication Authority (Nkom) has determined prices for wholesale mobile voice termination in Norway by means of a long-run incremental cost (LRIC) method since 2007.

- In 2006, a bottom-up LRIC model (v4) was constructed and finalised for Nkom (NPT at the time) by Analysys Mason Limited (Analysys Mason), with the aim of calculating the cost of voice termination for 2G mobile operations in Norway
- In 2009, Analysys Mason upgraded this model to include 3G technologies and a 'Pure LRIC' calculation, and the final version (v7.1) was issued in September 2010
- In late 2012, Analysys Mason updated this model again, and the final version (v8.1) was issued in June 2014. This version has formed the basis of wholesale mobile termination price regulation for mobile operators in Norway since 2015.

In November 2016, Nkom consulted industry parties regarding an update to the v8.1 model, proposing four options for the extent to which the model should be revisited.[1] These options were:

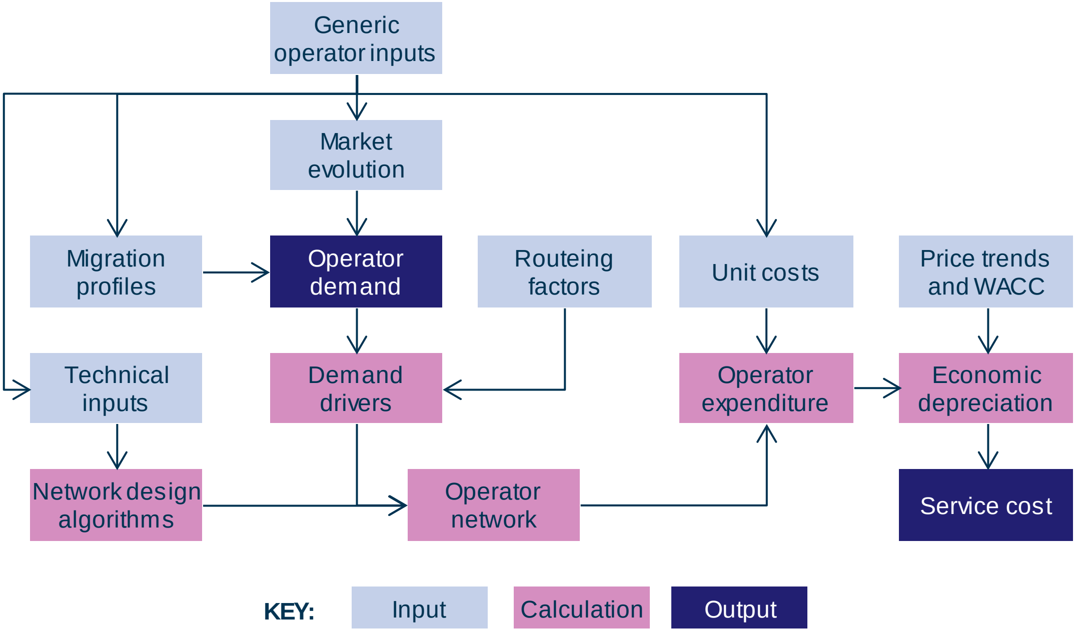
1. Using the current model without further changes
2. Using the current model after updating traffic
3. Using the current model after comprehensive input updates (e.g. costs, lifetimes, inflation, population forecasts, etc.)
4. Implementing new technology calculations (including LTE) as well as comprehensive input updates to the LRIC model.

Telenor and Telia both provided responses (which were published on Nkom's website), suggesting the second and first options respectively. Nkom decided to undertake only a limited update, consistent with the second option. In 2017, Nkom contracted Analysys Mason to undertake this update of the v8.1 model. This report documents the mobile LRIC model (the v9R model) which will be issued for industry consultation during 2017.

A schematic of the v9R model is shown below in Figure 1.1. In the v8.1 model, the operator-specific inputs for Telenor, Telia and Mobile Norway were used to calculate the inputs for a generic operator, as discussed in detail in Sections 4.1 and 4.2. The v9R model still uses the inputs for the generic operator from the v8.1 model, but the operator-specific inputs/worksheets have been removed from the working model. The model uses these generic operator demand and network design inputs in the calculation of expenditures, which are then depreciated and allocated using routeing factors to give the unit costs by service for the modelled generic operator.

1 See http://www.nkom.no/marked/markedsregulering-smp/kostnadsmodeller/lric-mobilnett/_attachment/26350?download=true&ts=15915ee6582

Figure 1.1: Model schematic [Source: Analysys Mason, 2017]



The remainder of this document is laid out as follows:

- Section 2 restates the conceptual approach developed for the v7.1 model that have then been applied in both the v8.1 and v9R models
- Section 3 describes the demand forecasting undertaken in the v9R model
- Section 4 describes the calculations included to reflect the EC/ESA Recommendations
- Section 5 describes additional changes made to the network design in the v8.1 model that are retained in the v9R model.

The report includes a number of annexes containing supplementary material:

- Annex A provides excerpts from the v7.1 model documentation describing aspects of the network design that have subsequently been revised
- Annex B provides an overview of the key changes made to the v8.1 model to produce the v9R mode
- Annex C provides an expansion of the acronyms used in this document.

2 Conceptual approach for the v9R model

The document *Conceptual approach for the upgraded incremental cost model for wholesale mobile voice call termination, 1 December 2009*[2] ('the 2009 concept paper') was developed as part of a previous LRIC modelling process for Nkom, and contained the recommendations on which the v7.1 model was based. These recommendations covered both the bottom-up calculations and any subsequent top-down reconciliation.

This section describes some revisions which were made to these recommendations for the v8.1 model, and which have been retained for the v9R model. The conceptual issues considered in the 2009 concept paper are classified in terms of four modelling dimensions: operator, technology, service and implementation.

The remainder of this section is set out as follows:

- Section 2.1 restates the conceptual recommendations from the v7.1 model and identifies those that require additional consideration
- Section 2.2 deals with conceptual issues related to the definition of the operator to be modelled
- Section 2.3 discusses conceptual issues related to the technologies employed
- Section 2.4 examines conceptual issues related to the service definitions
- Section 2.5 explores conceptual issues related to the implementation of the model.

2.1 Summary of conceptual recommendations from the v7.1 model

The 2009 concept paper was developed as part of the LRIC modelling process in 2009–2010, and established the principles for the v7.1 model. The paper included 17 recommendations that formed the basis of the v7.1 model and were reconsidered during development of the v8.1 model due to developments in the Norwegian market between 2009 and 2012. Figure 2.1 summarises the recommendations that required either minor rewording or significant revision during development of the v8.1 model. All other recommendations remained unchanged.

Figure 2.1: Conceptual decisions for the v7.1 model [Source: Analysys Mason, 2017]

Conceptual issue	Recommendation from the v7.1 model	Reconsidered?
[1] Structural implementation	Bottom-up, reconciled against top-down information	Yes (reworded)
[2] Type of operator	Actual operators with a hypothetical third network operator	Yes (reworded)
[3] Size of operator	Actual size of operators with a hypothetical third network operator	Yes (reworded)
[4] Radio technology standards	2G and 3G, as needed to reflect actual operators	Yes (revised)

2 See https://www.nkom.no/marked/markedsregulering-smp/kostnadsmodeller/lric-mobilnett/_attachment/1803?_ts=1390fd7ef91

Conceptual issue	Recommendation from the v7.1 model	Reconsidered?
[5] Treatment of technology generations	Included within the model explicitly	Yes (revised)
[6] Extension and quality of coverage	Reflect historical and expected future coverage	Yes (reworded)
[7] Transmission network	Actual transmission networks as far as possible	Yes (reworded)
[8] Network nodes	Apply scorched node, optimised for efficiency	Yes (reworded)
[9] Input costs	Mixed approach based on actual/average costs	Yes (reworded)
[10] Spectrum situation	Include capability to capture actual or hypothetical allocations, as well as licence fees	Yes (revised)
[11] Service set	Both voice services and non-voice services	Yes (revised)
[12] Wholesale or retail	Apply a 75:25 split of overhead costs	No
[13] WACC	Apply Nkom's mobile operator WACC	No
[14] Depreciation method	Economic depreciation	No
[15] Increments	Calculate LRIC, Pure LRIC and LRIC+++ costs	Yes (reworded)
[16] Years of results	All relevant past and future years (i.e. from 1992)	No
[17] Mark-up mechanism	Use equi-proportionate mark-up (EPMU)	No

During the development of the v9R model, we have only revised conceptual recommendations, which has involved removing references to the modelling of the three actual operators. This is because the v9R model only contains the inputs for the generic operator (derived from the hybridised calculations of the three actual operators developed for the v8.1 model, and retained for the v9R model). These deletions are indicated by a ~~double strikethrough~~.

2.2 Operator-related conceptual issues

The conceptual issues in this section are shown in Figure 2.2.

Figure 2.2: Decisions taken on operator-related conceptual issues for the v7.1 model [Source: Analysys Mason, 2017]

Conceptual issue	Recommendation from the v7.1 model	Reconsidered?
[1] Structural implementation	Bottom-up, reconciled against top-down information	Yes (reworded)
[2] Type of operator	Actual operators with a hypothetical third network operator	Yes (reworded)
[3] Size of operator	Actual size of operators with a hypothetical third network operator	Yes (reworded)

The operator-related issues shown above were relevant to the modelling of two actual operators and a hypothetical third operator in the v7.1 model. These were reworded to apply to a generic efficient operator for the v8.1 model.

2.2.1 Structural implementation

There are two main 'directions' for modelling the costs of the mobile network operators: bottom-up or top-down modelling. There is also a third option: a combined approach (usually called a hybrid model) can be adopted in which the bottom-up model usually 'leads' the calculation, and the top-down model supplies complementary and valuable reference data points. The modelling approach needs to be defined at the beginning of the project, prior to the collection of data, since this choice determines what will eventually be possible with the model – e.g. cross-comparison of operator data, investigation of alternative hypothetical operators.

Developing an understanding of the costs of mobile operations in the Norwegian market can be achieved by parameterising different networks and demand assumptions within a common structural form (i.e. a bottom-up model). A bottom-up model also has the benefit that it can be circulated (without any confidential operator information) to all industry parties, including non-mobile operators. This transparent circulation facilitates industry discussion of the approach taken to demand and network modelling.

Although a top-down model can produce actual costs, it lacks the ability to explore operator differences with certainty or transparency. Therefore, a hybrid model is most likely to satisfy Nkom's requirements to:

- achieve industry 'buy-in' to the approach
- provide reassurance to the operators that the model replicates not only their networks, but more importantly their overall costs
- enable accurate understanding of operator cost differences
- have a tool that can be used to explore price-setting issues.

A hybrid model requires information from market parties at both network and cost levels. However, the information requirements for a hybrid model are only marginally more extensive than those for just a bottom-up or top-down approach.

Nkom believes that bottom-up data will be relatively straightforward to source from operators' management information (e.g. demand levels, network deployments, equipment price lists), and top-down data should be available from financial accounting departments, usually with some requirement for pre-processing stages.

Nkom believes that the modelling approach that will deliver the most benefits and relevant information for its costing and price-setting activities is a hybrid model, 'led' from the bottom-up direction.

- It is not necessary to construct stand-alone, top-down models capable of full service costing and depreciation (since the bottom-up model is capable of this).
- The model and industry discussions are not hindered by opaque and confidential top-down calculations (since the bottom-up model can be discussed more freely with market parties).

The conceptual recommendation established in 2009 only needed rewording in order to capture the inclusion of a generic operator, as well as the removal of references to the "third operator" calculation.

Recommendation 1: Develop a bottom-up cost model reconciled against top-down accounting data for the three actual network operators and a generic efficient operator, resulting in a hybrid model.

2.2.2 Type of operator

The choice of operator type to be modelled feeds into Nkom's decision on pricing for suppliers of wholesale mobile voice termination. However, the choice of operator type for cost modelling purposes, as outlined here, does not preclude Nkom from adopting an alternative basis for pricing. As a result, this costing and pricing conceptual issue has been separated into its constituent costing and pricing parts. This section of the conceptual approach refers to the type(s) of operator to be costed in the model.

The main options for operator type are outlined below.

- **An actual operator:** this reflects the development and nature of an actual network operator over time, and includes a forecast evolution of the operator in order to develop long-run costs. This type of model aims to identify the actual costs of the operators being modelled, and should result in the most accurate quantification of the operators' cost differences. An operator-specific, top-down reconciliation can be carried out with this type of model. This type of model can also be used to reflect average or hypothetical operators, by adjusting various input parameters.

- **An average operator**: the cost model can combine inputs, parameters and other features of actual Norwegian network operators to form an average operator cost model. As a result, it may be harder to explore, identify and quantify the cost differences between the network operators, and reconciliation of a bottom-up model against top-down data must be carried out at an average level.

- **A hypothetical operator:** this type of model aims to generate only the cost level which would be achieved by a hypothetical operator in the market, usually a hypothetical new entrant. As such, this type of model is focused on defining the demand inputs, network design and cost levels that a hypothetical operator would experience, and therefore determines the cost base of the hypothetical operator. Because of the hypothetical nature of this model, it is more difficult to explore and quantify the differences between each actual operator's costs and the hypothetical set-up. Top-down reconciliation of a bottom-up model must also be carried out in a discontinuous manner. The "generic operator", as described by the EC/ESA Recommendations, can be seen as a type of hypothetical operator.

The choice of operator type affects two main outcomes of the modelling work:

- the level of understanding Nkom can gain on the costs of each actual network operator (and in particular differences in costs between operators)
- the ability of the model to cope robustly with alternative operator choices when it comes to determining the operator specification and network specification of cost-oriented mobile termination prices.

The conceptual recommendation established in 2009 only needed rewording in order to capture the inclusion of a generic operator, as well as the removal of references to other operator calculations.

Recommendation 2: ~~Adopt an actual operator costing for Telenor, Telia and Mobile Norway, which can accurately determine the costs of each actual network operator and robustly explore individual cost differences between these three mobile operators.~~ The model will ~~also~~ be populated to calculate the costs of a generic efficient operator in Norway. This generic operator is not intended to reflect any of the actual mobile network operators, but is intended to be generically applicable to the cost of mobile termination in Norway.

2.2.3 Size of operator

One of the major parameters that define the cost of an operator is its market share. It is therefore important to determine the evolution of the market share of the operator over time. In addition to market share measured on a subscriber basis, the model also includes the volume and profile of traffic that the modelled operator is assumed to carry.

The parameters that are chosen to model operator market share over time have a strong effect on the overall level of economic costs calculated by the model (in a mobile network, share of traffic volume is more significant than share of subscribers). These costs can change significantly if short-term economies of scale (such as network roll-out in the early years) and long-term economies of scale (such as fixed costs of spectrum fees) are fully exploited. The more quickly an operator grows, the lower the eventual unit cost will be.

The conceptual recommendation established in 2009 only needed rewording in order to capture the inclusion of a generic operator, as well as the removal of references to the “third operator” calculation.

Recommendation 3: Consistent with Recommendation 2, the ~~actual size of the three actual infrastructure operators should be modelled according to historical market development, with a forecast size for each operator. The~~ scale of the generic efficient operator will ~~also~~ be forecast. It is expected that this forecast market development will reflect both subscriber and volume equalisation ~~at some point in the future, although at a network level, if Mobile Norway is modelled with a coverage significantly lower than 99% population, then we expect to model an unequal share of traffic by network~~.

2.3 Technology-related conceptual issues

In this section, we describe the technological aspects of the model: radio technologies and generations, network coverage and transmission topology, scorched-node calibration, equipment unit costs, and the spectrum of the modelled operators. The issues discussed in this section are shown in Figure 2.3.

Figure 2.3: Decisions taken on the technology-related conceptual issues for the v7.1 model [Source: Analysys Mason, 2017]

Conceptual issue	Recommendation from the v7.1 model	Reconsidered?
[4] Radio technology standards	2G and 3G, as needed to reflect actual operators	Yes (revised)
[5] Treatment of technology generations	Included within the model explicitly	Yes (revised)
[6] Extension and quality of coverage	Reflect historical and expected future coverage	Yes (reworded)
[7] Transmission network	Actual transmission networks as far as possible	Yes (reworded)
[8] Network nodes	Apply scorched node, optimised for efficiency	Yes (reworded)
[9] Input costs	Mixed approach based on actual/average costs	Yes (reworded)
[10] Spectrum situation	Include capability to capture actual or hypothetical allocations, as well as licence fees	Yes (revised)

2.3.1 Radio technology standard

Mobile networks have been characterised by successive generations of technology, with the most significant development being the transition from analogue to digital (GSM), and the subsequent migration to UMTS. A further migration of traffic to LTE networks is also occurring in Norway.

There are four main options for the radio technology standard that is explicitly included in the model:

GSM only — This approach attempts to construct cost estimates based on the mature current technology, which is then assumed to remain in operation in the long run. A GSM-only approach can be considered conservative because it may not reflect any productivity gains that might be expected from a move to next-generation technology – although suitable proxy treatments for the next generation can be applied to the GSM-only construct.

Including analogue in past years — It is possible to make allowances for higher-cost (but nevertheless valid) technologies in earlier years, by calculating technology-specific costs and producing a weighted average cost per terminated minute (reflecting the balance of minutes carried on analogue and GSM). However, analogue services are no longer offered in Norway, and so the weighted average cost will not take into account an analogue component, and efficient forward-looking costs will be unaffected by historical analogue operations.

Including UMTS The explicit inclusion of UMTS has added complexity and model detail, and produces a lower eventual cost estimate in the situation where voice termination costs are migrating to a lower-cost UMTS technology. This option makes the bottom-up model significantly more complex, and additional supporting top-down cost data is required for UMTS.

Including advanced technologies in future years Today's UMTS (third-generation) networks are characterised by active (but evolving) high-speed data services (HSDPA and HSUPA).

Two additional technologies have now been deployed in Norway:

- (third-generation) UMTS900, which uses refarmed 900MHz frequencies to provide wider area coverage than can be achieved with the current 2100MHz UMTS frequencies

- (fourth-generation) LTE deployments at 2600MHz and other frequencies, which requires deployment of a new air interface (as well as new user equipment). However, once deployed, this technology will allow both significantly increased data traffic throughput and *proper*[3] mobile voice over IP.

From the perspective of mobile termination regulation, the modern-equivalent technology should be represented in the model – that is, the proven and available technology with the lowest cost over its lifetime. 20 years ago, the modern-equivalent technology for providing mobile telephony was analogue (NMT).

At the time of the original cost modelling work in 2006, Nkom considered that GSM was primarily the efficient technology for providing voice termination. Currently, all Norwegian mobile networks provide both GSM and UMTS voice and data services, and migration of traffic from GSM to UMTS has been underway for some years. All UMTS networks in Norway offer HSDPA services as standard.

Given the current focus of the model on voice termination, Nkom continues to believe that it is not necessary to explicitly model LTE. This decision can be attributed to the uncertainty over key aspects of LTE network deployment:

- the expected long-term coverage of the networks
- their ability to deliver voice in the longer term
- the relevant spectrum allocations
- the extent of infrastructure sharing between operators.

The forecast increase in LTE coverage will have an impact on the traffic carried over 2G and 3G networks. The v9R model does not need to explicitly model the network design for LTE to consider

3 That is, LTE mobile handsets will not have a circuit-switched LTE transmission mode, and voice will be carried over the air interface as packetised IP traffic.

this, although it does need to consider the voice, SMS and data services that are carried over 2G and 3G networks. The model also implicitly considers some sharing of infrastructure costs between today's main (2G+3G) networks, and future (2G+3G)+LTE networks, for example by applying some percentage profile of LTE demand into the routeing factors used for cost allocation.

The conceptual recommendation established in 2009 was therefore set as follows:

> **Recommendation 4:** Use a model which reflects the operators' actual GSM and UMTS networks from 1993 onwards. The model should contain actual GSM traffic and subscriber volumes and reflect the prices paid for modern-equivalent GSM equipment in each year. The model should also contain existing UMTS subscribers, traffic, HSPA data and network equipment, since all Norwegian mobile operators are using UMTS network infrastructure. The rate of migration from GSM to UMTS will be projected from the latest actual status of the mobile operators. Deployment of UMTS900 is anticipated in the situation that GSM networks are shut down. LTE networks will not be explicitly modelled, however migration of voice, SMS and high-speed data services to an LTE network will be included, and some sharing of infrastructure costs to LTE demand may be included using a proportionate cost allocation to LTE.

2.3.2 Treatment of technology generations

Modelling a single-technology network in a long-run cost model provides a simplification of the multi-technology reality. Mobile network generations are only expected to remain valid for a finite number of years, but a long-run cost model effectively makes predictions of parameters in perpetuity. Therefore, just as operators manage the migration of demand and subscribers from one generation to the next, a LRIC model can make corresponding parametric assumptions.

Three particular areas appear most significant in the context of mobile voice termination costing:

Migration of traffic — The migration of traffic from one network to another affects the output profile produced by the network assets of each technological generation. This changes the level of unit costs over time for each generation, irrespective of depreciation method.[4] The long-run cost from a single technology that can be operated in perpetuity will be lower than the long-run cost of a technology with a finite lifetime (provided there are assets which have a higher lifetime output[5]). However, a single-technology model will not necessarily capture any productivity gains from moving to the next technology, such as higher system capacity or greater service demand. Therefore, a single-technology, long-run cost may be higher than the blended average cost from successive generations of mobile cellular technology with improved efficiency.

4 Although, of course, the choice of depreciation method determines *when and how* unit costs change as a result of migration.

5 Which is likely to be the case, if there are long-lived assets which are technology specific (e.g. a licence fee).

What is important from a cost modelling perspective is to understand the implications of modelling a single-technology network and single-technology demand for the level and timing of cost recovery when contrasted with the multi-technology situation faced by real mobile operators.

Proxies for change Proxies for factors that change from one generation to the next may be applied in a cost model to mimic the effects of successive technology generations. As introduced under 'Migration of traffic' above, successive generations of cellular technology can be expected to have measurable output rises.[6] Also, the cost per unit of capacity is likely to reflect continued technological improvement.[7] The key issue for a LRIC model is consistency: modelling continued demand growth without technological evolution (and vice versa) would appear to be inappropriate.

Economies of scope A number of network and non-network costs will in effect be shared by successive generations of technology – in these instances it will be possible to extract the same (or greater) utilisation from an asset irrespective of the rate or existence of migration. Certain network assets fall into this category: for example, base-station sites may continue to be rented from one generation to the next, backhaul transmission may be transparent to 2G and 3G traffic, business overhead functions will support both technology generations, etc. Given these economies of scope between technology generations, service costing for certain assets should be independent of migration.

As discussed in Section 2.3.1 above, LTE will only be modelled implicitly in the v9R model, which affects the treatment of technology generations. The conceptual recommendation established in 2009 was reworded as follows:

Recommendation 5: Consistent with Recommendation 4, adopt a consistent set of long-run forecast parameters: in particular, GSM volumes and GSM equipment prices, and UMTS volumes and UMTS equipment prices. An increasing proportion of voice traffic is being carried on UMTS networks in Norway, and migration of data users from GPRS to UMTS/HSPA networks also results in a (significantly) greater proportion of data traffic being carried on the next-generation technology. Next-generation technologies should also enable higher total volumes of voice and data traffic to be carried. According to the current rate of migration to UMTS, it appears that operators are migrating more slowly than forecast in the original model. This suggests that the original expectation of GSM shut-down in 2015 is unlikely to be achieved. Therefore, GSM shut-down is projected for at least 2020. While the model considers 3G technology in perpetuity, migration from UMTS to LTE has been added into the demand calculations.

6 This has been observed for analogue to GSM, and is expected for GSM to UMTS.

7 For example, analogue to digital, TDMA to W-CDMA.

2.3.3 Extension and quality of coverage

Coverage is a central aspect of network deployment, and of the radio network in particular. Appropriate coverage assumptions to apply to the modelled operator can be determined through the following questions:

- How should historical coverage be reflected?
- How far should geographical coverage extend in the long run?
- How fast should the long-run coverage level be attained?
- What quality of coverage[8] should be provided, at each point in time?

The definitions of coverage parameters have two key implications for the cost calculation:

Level of unit costs due to present value (PV) of expenditures — The rate, extent and quality of coverage achieved over time determine the present value (PV) of associated network investments and operating costs. The degree to which these costs are incurred before demand materialises represents the size of the 'cost overhang'. The larger this overhang, the higher the eventual unit costs of traffic will be.

Identification of network elements and common costs that are driven by traffic — In a situation where coverage parameters are relatively large, fewer network elements are likely to be dependent on traffic. This reduces the sensitivity of the results to assumed traffic algorithms.

Furthermore, common costs are generally incurred when costs remain fixed in the long run. With larger coverage parameters specified for an operator, increasing proportions of network costs are invariant with demand and hence likely to be common costs.

For the operator-relevant conceptual issues discussed in Section 2.2, the conceptual recommendation established in 2009 was reworded to take into account the move to a generic efficient operator in the v8.1 model.

Recommendation 6: Consistent with Recommendation 2, actual historical levels of geographical coverage and coverage quality for the three actual network operators should be reflected in the model. A forecast for future geographical coverage should be applied in the model, consistent with operators' planned coverage expansions. Planned improvements in coverage quality should also be reflected in parts of the network that are not driven by traffic. A national coverage profile will be applied to the generic efficient network operator. The GSM and UMTS coverage profiles of the mobile networks should be modelled separately, taking into account UMTS900 which is being used for eventual full national coverage by 3G.

8 By quality of coverage we are specifically referring to the density of radio signal – within buildings, in hard-to-reach places, in special locations (e.g. airports, subways, etc.).

2.3.4 Transmission network

A number of factors affect the choice of transmission network used by an operator. These include:

- historical demand and network evolution
- forecast demand and network evolution
- its preference for build or buy
- availability of new generations of transmission technology from alternative providers
- range and price of wholesale transmission services.

The conceptual recommendation established in 2009 only required rewording to capture the fact that the generic operator can then use the transmission methods as modelled for the actual operators in earlier versions of the model.

Recommendation 7: Consistent with Recommendation 2, each ~~operator's actual~~ transmission network should be modelled~~, identifying material differences in the choice, technology or cost of transmission elements but~~ aiming to adopt an efficient, modern and standardised modelling approach where possible. This standardised approach will ~~then~~ be applied to the generic operator.

2.3.5 Network nodes

A mobile network can be considered as a series of nodes (with different functions) and links between them. Of these node types, the most important are sites for base stations, sites for BSCs/RNCs and sites for switching equipment. In developing algorithms for these nodes, it is necessary to consider whether the algorithm should and does accurately reflect the actual *number* of nodes deployed. In situations where an operator's network is not viewed as efficient or modern in design, or where network rationalisation is planned, the model may be allowed to deviate from an operator's actual number of nodes. This aspect may be particularly relevant when looking at GSM and UMTS networks – since later equipment tends to have a higher capacity and is therefore more likely to be located in fewer, larger switching sites.

Specification of the degree of network efficiency is a crucial regulatory costing issue, and one which is sometimes addressed through the application of a 'scorched-node' principle. This ensures that the number of nodes modelled is the same (exactly or effectively, as required) as in reality, albeit with modern-equivalent equipment deployed at those nodes. This is coupled with the commonly held view that mobile networks are generally deployed and operated efficiently, due to infrastructure competition. The main alternative is to apply the 'scorched-earth' principle, which allows the number and nature of nodes modelled to be based on a hypothetical efficient network, even if it deviates from operational reality.

Adopting a scorched-node principle requires an appropriate calibration of the model, to ensure that node counts correspond with reality. This ensures that the level of assets in the model is not underestimated due to factors that are not explicitly modelled. The application of network node adjustments indicates the network efficiency standards which will define the level of cost recovery allowed through regulated charges.

The conceptual recommendation established in 2009 required some clarification with regard to the treatment of the generic efficient operator.

For the generic operator, the aim is to reasonably reflect the network nodes of the actual operators in Norway and, as such, we are not using a scorched-earth approach. Instead, we have defined particular generic operator inputs using the values of the actual operators. As these actual operator values have been derived using the scorched-node principle, the generic operator will implicitly reflect the scorched-node principle.

Examples of the generic operator inputs derived in this manner include cell radii for coverage sites, cell radii for in-fill sites and the number of switching locations.

Recommendation 8: Consistent with Recommendation 2, adopt actual network designs in terms of numbers of network nodes. The starting point for this will be submitted data on the number and nature of nodes in operators' actual networks, which we shall validate for high-level efficiency with our expert view. ~~In the radio network, we suggest applying a scorched-node calibration to ensure that the model can replicate operators' actual deployed site counts: this effectively ensures that radio network design parameters which are not modelled explicitly are implicitly captured in the model.~~ The efficient nodes for the generic efficient operator are defined using the values of the actual operators. As these actual operator values have been derived using a scorched-node principle, the generic operator will implicitly reflect the scorched-node principle.

2.3.6 Input costs

To calculate the costs of a mobile network using a bottom-up incremental cost model, the unit costs of different types of network equipment are a required input. There are four general approaches that could be taken to define input costs:

Actual cost — This method allows the identification of the unit costs applicable to each operator in order to develop two complete sets of equipment cost data. Whilst comprehensive, this method can result in difficulties when trying to understand reasons for overall cost differences between operators, since there may be no cross-references between unit costs when populating the two models.

Lowest cost — The mobile operators in Norway have strong incentives to purchase and operate their network equipment at the lowest possible cost. Therefore, it is reasonable to assume that the price paid by any operator for a given unit of equipment will be the lowest possible price that the operator could pay, and using any lower value will result in the operator being unable to recover its full costs. However, using the lowest unit costs carries a risk of underestimation of costs, since:

- one operator might have access to lower unit costs that cannot be replicated by another operator
- a lower unit cost in one category might be balanced by a higher unit cost in another
- the efficient unit cost might not necessarily be the lowest, as there are other considerations involved in a real purchasing decision (e.g. ties to maintenance contracts, vendor selection, etc.).

Highest cost Using the highest unit costs has the same potential problems as using the lowest unit costs, but leading to a risk of overestimating costs.

Average cost Given the staggered nature of network deployment, the price paid for any given unit of equipment by each operator at any given time will naturally vary. However, the discipline of competition in the retail market should mean that all operators aim to minimise their costs over the long term. Therefore, using averaged unit costs should produce an efficient overall network cost.

A further advantage of using average costs is that it avoids adhering dogmatically to a particular principle (e.g. lowest or highest cost), which can be unreasonable under certain circumstances, and instead provides a reasonable, practicable alternative.

The conceptual recommendation established in 2009 was reworded for the v8.1 model to apply to the generic operator.

Recommendation 9: Given the practical and regulatory difficulties of accurately and unambiguously defining the lowest cost base for an operator, we recommend a mixed approach based on actual and average costs. Our starting point for assessing the level of input costs will be the actual costs incurred by the operators – informed by data submitted by the operators. Where it can be shown that unit costs equate closely to the same functional network elements (e.g. a BSC of the same capacity), we shall endeavour to use average costs applicable to all operators. ~~Where it can be shown that each operator has a materially different unit cost base (e.g. in the price of a suite of equipment from a particular vendor), then operator-specific actual costs will be adopted.~~ Efficient unit costs will need to be estimated for the generic operator model, without revealing confidential operator data.

2.3.7 Spectrum situation

Actual mobile operators' spectrum allocations – in terms of amount,[9] band[10] and any fees[11] paid – and use of their allocated spectrum, are likely to differ. Some of these differences may be assessed to be outside of the operators' control – e.g. restrictions on the availability and packaging of spectrum over time.

Any cost differences arising from these spectrum allocations or their use should be understood and estimated, and if appropriate (and significant) they could be taken into account in the cost basis of regulated prices. This involves understanding how the differences in operators' spectrum result in different network deployments, how these are best captured and parameterised in the model, and ultimately what the resulting cost differences are. The benefit of being able to model the actual spectrum of the operators is that it makes it much more straightforward to manage the scorched-node calibration of a bottom-up network design with actual data, and to reconcile calculated costs with actual costs.

Alternatively, some hypothetical amount of spectrum could be defined, which would require a clear understanding of the cost differences between this hypothetical allocation and the actual operator allocations. It would be possible to attempt to construct a purely hypothetical spectrum model without clear reference to actual operator factors. This hypothetical approach could, for example, be defined assuming that the generic operator has an "average" allocation of spectrum in the Norwegian market.

The conceptual recommendation established in 2009 was revised in order to specify the methodology used for the allocation of spectrum to the generic efficient operator in the v8.1 model. Additional text was included to explicitly consider the principle of future licence renewals. In the v7.1 model, all licences were renewed periodically, with renewal fees assumed to increase with inflation.

> **Recommendation 10:** ~~Develop a model capable of capturing the network and cost differences due to the actual operators' spectrum allocations, through modification of a small number of key parameters.~~ Generic spectrum allocations will be developed/defined for the generic operator. Our principled position with regard to future licence auctions/renewals is not to pre-empt any future expected value or allocation and therefore to retain the current modelling approach of regularly renewing the existing spectrum allocations and applying inflation-increasing payments.

2.4 Service-related conceptual issues

The conceptual issues discussed in this section are shown in Figure 2.4.

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9 Amount of paired MHz, less guard bands.

10 PGSM, EGSM or DCS.

11 One-time or recurring fees, including duration of any licence payment.

Figure 2.4: Decisions taken on the service-related conceptual issues for the v7.1 model [Source: Analysys Mason, 2017]

Conceptual issue	Recommendation from the v7.1 model	Reconsidered?
[11] Service set	Both voice services and non-voice services	Yes (revised)
[12] Wholesale or retail	Apply a 75:25 split of overhead costs	No

2.4.1 Service set

The treatment of economies of scope achieved by the actual voice and data operators depends on whether the modelled operator offers non-voice SMS, GPRS, EDGE and HSPA services to its subscribers. Economies of scope arising from the provision of these services across a shared infrastructure should result in a lower unit cost for voice services where total traffic volumes are higher than if they were carried on separate networks. The standalone network costs (e.g. hardware and software) incurred by the operators – and therefore likely to be reflected in the model – implicitly include the support for non-voice services.

Assessing both voice and data services in the model increases the complexity of the calculation and the supporting data required, but should result in a lower unit cost for voice services due to economies of scope. Conversely, it can also be complex to exclude costs relevant to non-voice GSM services (and develop a standalone voice cost). In Norway, some non-voice services (e.g. SMS and GPRS) are reasonably proven services, rather than emerging services. In the case of HSPA, traffic volumes have grown rapidly – therefore a conservative approach to forecasting future data traffic may be appropriate if suggested economies of scope are significant (subsequently strongly reducing the economic cost of voice on the basis of an uncertain data traffic forecast).

Recommendation 11 as established in 2009 refers only to conventional GSM and UMTS services. It therefore required revision to indicate that the v8.1 model includes forecasts for additional services, namely:

- LTE data megabytes
- over-the-top (OTT) variants of voice services
- OTT variants of SMS services.

Recommendation 11: The modelled operator should provide data services (SMS, GPRS, EDGE, HSPA and LTE) alongside voice services. The modelled operator will additionally provide OTT variants of voice and SMS services that will be carried over the network as high-speed data (HSPA and LTE). The associated economies of scope will be shared across all services, although care will be taken where uncertain growth forecasts significantly influence the economic cost of voice. The approach to allocating costs between voice and UMTS data services (particularly HSPA) will be carefully examined during the implementation of Recommendation 15 (choice of increment) since there is likely to be a much larger proportion of traffic from data services in today's networks.

2.4.2 Wholesale or retail

In a **vertically separated** model, network services (such as traffic) are costed separately from retail activities (such as handset subsidy or brand marketing). Business overheads are then marked up between network and retail activities, and the wholesale cost of supplying mobile termination is only concerned with the costs of the network plus a share of business overheads.

In a **vertically integrated** model, retail costs are considered integral to network services and included in service costs through a mark-up, along with business overheads.

To date, Nkom has identified its market analysis as relating to the wholesale call termination market. As such, Nkom intends to consider only those costs that are relevant to the provision of the wholesale network termination service in a vertically separated business. However, costs that are common to network and retail activities will be recovered from wholesale network services and retail services. This will be treated as a mark-up on the LRIC (though excluded by definition from the Pure LRIC).

A vertically separated approach results in the exclusion of many non-network costs from the cost of termination. However, it brings with it the need to assess the relative size of the economic costs of retail activities in order to determine the magnitude of the business overheads to be added to the incremental network costs.

The conceptual recommendation as established in 2009 was left unchanged.

Recommendation 12: Consistent with the original model, we propose to maintain the indirect cost treatment of business overhead expenditure. This allocation results in an approximately 75:25 split between network and retail activities respectively. In the upgraded model, retail costs will not be remodelled; instead the 75:25 split of overhead costs will be applied as an exogenously defined cost allocation.

2.5 Implementation-related conceptual issues

The conceptual issues discussed in this section are shown in Figure 2.5.

Figure 2.5: Decisions taken on the implementation-related conceptual issues for the v7.1 model [Source: Analysys Mason, 2017]

Conceptual issue	Recommendation from the v7.1 model	Reconsidered?
[13] WACC	Apply Nkom's mobile operator WACC	No
[14] Depreciation method	Economic depreciation	No
[15] Increments	Calculate LRIC, Pure LRIC and LRIC+++ costs	Yes (reworded)
[16] Years of results	All relevant past and future years (i.e. from 1992)	No
[17] Mark-up mechanism	Equi-proportionate mark-up (EPMU)	No

2.5.1 WACC

The appropriate level of return to be allowed on regulated services is a standard aspect of regulatory cost modelling. The level of WACC has a direct, material effect on the calculated cost of termination, but it does not need to be applied in the model until the final costing stages. The conceptual recommendation as established in 2009 did not need to be changed.

Recommendation 13: Update Nkom's mobile operator WACC calculation.

2.5.2 Depreciation method

The model for mobile network services produces a schedule of capital and operating expenditures. These expenditures must be recovered over time, ensuring the operator can also earn a return on investment. There are four main potential depreciation methods:

- historical cost accounting (HCA) depreciation
- current cost accounting (CCA) depreciation
- tilted annuity
- economic depreciation.

Economic depreciation is the recommended approach for regulatory costing. Figure 2.6 below shows that only economic depreciation considers all potentially relevant depreciation factors.

Figure 2.6: Factors considered by each depreciation method [Source: Analysys Mason, 2017]

	HCA	CCA	Tilted annuity	Economic
Modern-equivalent asset (MEA) cost today		✓	✓	✓
Forecast MEA cost			✓	✓
Output of network over time				✓
Financial asset lifetime	✓	✓	✓	✓[12]

In a mobile network cost model where demand varies over time (e.g. for an actual operator), results produced using tilted annuity will differ significantly from those produced using economic depreciation. The difference between HCA and CCA depreciation is the inclusion of modern-equivalent asset prices – which is applied in the calculation as *supplementary depreciation* and *holding gains/losses*. The difference between HCA and CCA is generally uninteresting, in the light of more significant differences between HCA and economic depreciation.

Economic depreciation is a method for determining a cost recovery that is economically rational, and therefore should:

- reflect the underlying costs of production: i.e. modern-equivalent asset (MEA) price trends

12 Economic depreciation can use financial asset lifetimes, although strictly it should use economic lifetimes (which may be shorter, longer or equal to financial lifetimes).

- reflect the output of network elements over the long run.

The first factor relates the cost recovery to that of a new entrant to the market (if that market were competitive), which would be able to offer the services based on the current costs of production.

The second factor relates the cost recovery to the 'lifetime' of a mobile business, in that investments and other expenditures are in reality made throughout the life of the business (especially large, up-front investments), on the basis that it will be possible to recover them from all demand occurring in the lifetime of the business. All operators in the market are required to make these large up-front investments and recover costs over time. These two factors are not reflected in HCA depreciation, which simply considers when an asset was bought, and over what period the investment costs of the asset should be depreciated.

The implementation of economic depreciation in the model is based on the principle that *all (efficiently) incurred costs should be fully recovered, in an economically rational way*. Full recovery of all (efficiently) incurred costs is ensured by checking that the PV of actual expenditures incurred is equal to the PV of economic costs recovered. An allowance for a return on capital employed, specified by the WACC, is also included in the resulting costs.

The conceptual recommendation established in 2009 remained unchanged for the v9R model.

Recommendation 14: Nkom intends to retain the original model's economic depreciation calculation to recover incurred network expenditure over time, with a cost recovery in accordance with MEA price trends, network output over the long run, and the discount rate. In addition, for comparative purposes only, a straight-line accounting depreciation calculation will also be applied in the model. ~~Further details of economic depreciation are supplied in the Annex, but operators have the opportunity to comment on the implementation of economic depreciation in the draft model released to industry during this consultation process.~~

2.5.3 Increments

Increments in a cost model take the form of a service, or set of services, to which costs are allocated, either directly (for incremental costs) or via a mark-up mechanism (if common costs are to be included). Specifically, the model constructed is used to gain an understanding of how costs vary, or are fixed, in response to different services. This enables costs to be identified as either common or incremental. In the final stages of the costing calculations, common costs may be marked up onto the relevant increments.

The size and number of adopted increments affects the complexity[13] of results and the magnitude[14] of the marked-up incremental costs.

13 More increments = more calculations required of the model and more common costs (or a larger aggregate common cost) to deal with in the mark-up.

14 Through the mark-up mechanism.

Incremental costs should in practice be determined by calculating the difference in costs *with* and *without* the increment present. Subsequently, calculating the difference in costs with and without *combined increments* would determine the precise structure of costs that are *common* to the various sets of increments. An incremental costing approach that runs through this complete set of small increment permutations can give rise to very complex results, which must be resolved carefully to ultimately identify marked-up incremental costs. However, calculating the incremental cost of *only a single increment* simply requires the model to calculate the network and associated expenditures *with* and *without* the defined increment.

Where increments include more than one service, rules need to be specified to allocate the incremental costs to the various component services. These allocation rules could be on the basis of average loading, peak loading or some other method. Increments which combine distinguishable services such as voice traffic, SMS traffic and GPRS traffic will need carefully assessed routeing factors for allocating costs to the services – since in this combined increment approach non-voice service incremental costs are identified through routeing factors, rather than network algorithms.

Most of the costs associated with a mobile network are driven by traffic (i.e. it is the marginal increase in traffic that drives the marginal increase in cost). However, this is not the case for a subset of network costs that are driven by the number of subscribers. These costs typically include the visitor location register (VLR) and home location register (HLR), which principally function as databases of subscribers and their locations, plus the switching costs associated with the service of periodically updating the location of all active subscribers.

Whilst the network cost of updating the HLR and reporting the location of handsets is dependent on subscriber numbers, there is a precedent in Europe for recovering these costs through received calls (which should therefore include on-net voice and also SMS delivery). This is because location updates and interrogating the VLR/HLR for subscriber location are only required for terminating traffic – and can be considered a common cost for all terminated traffic.

The magnitude of incremental costs, and costs common to increments, depends on the interaction of the number and nature of increments with the cost functions of network elements. More complex increments will require network design algorithms that are cognisant of relevant volume components.

Applying a combined traffic increment implies focus on the routeing factors which share out traffic costs – particularly the degree to which SMS and data traffic load the network (or are accommodated by it in other ways, such as channel reservations).

Applying small increments implies a focus on the network design algorithm at the margin, and the degree to which capacity-carrying elements vary in the long run with the variance of different traffic types. The v7.1 model can calculate the incremental costs of wholesale mobile voice termination (which we have referred to as the “Pure LRIC”) by either:

- including or excluding technical network design adjustments

- applying economic depreciation to the avoided cost of termination traffic, or calculating the difference in the economic depreciation when including or excluding termination traffic.

Any combination of these two effects can currently be calculated. However, the v9R model is intended to focus on the Pure LRIC calculation that includes network adjustments and calculates economic depreciation of the avoided costs.

The conceptual recommendation established in 2009 was reworded to emphasise this approach.

Recommendation 15: In order to supply Nkom with the range of potential costs which it may apply to wholesale termination regulation, the model should calculate both LRIC+++ and LRIC results. Accordingly, the original model LRIC+++ method will be updated to include the relevant UMTS aspects, whilst the ESA Recommendation will be used to define an avoidable cost calculation ('Pure LRIC') approach to the wholesale mobile termination service. In the Pure LRIC case, we shall explore the sensitivity of the result to the technical assumptions that are applied in the model to estimate the difference in costs without mobile termination volumes. Specifically, it will be possible to include appropriate network design adjustments. Economic depreciation will be applied to the avoided expenditures of terminated voice.

2.5.4 Years of results

There are three options for the timeframe of the calculation:

One year only (e.g. 2009)	This approach can simply compare costs today with prices today.
Forward-looking only (e.g. 2009 onwards)	A forward-looking calculation is capable of answering questions about the future, but is difficult to reconcile with the past (and therefore, potentially, the present).
All years (e.g. 1992 onwards)	Having a calculation for all years will make it easier to use full time-series data and consider all costs over time. It provides the greatest clarity within the model regarding the implications of adopting economic depreciation (compared to other forms of depreciation).

The calculation of mobile termination costs in particular years provides a range of information:

- current-year costs can be compared to current-year prices
- forecast costs can be used to define RPI-X price caps
- a full time series of costs can be used to estimate windfall losses/gains due to a change from historical to accounting cost paths and provides greater clarity on the recovery of all costs incurred from services over time.

Analysys Mason's experience of bottom-up LRIC models, and their use in conjunction with top-down information, indicates that a full time-series model provides:

- the greatest clarity and confidence in results, particularly when it comes to reconciliation against historical top-down accounting data
- the widest range of information with which to understand how the costs of the operators vary over time and in response to changes in demand/network evolution
- the opportunity to include additional forms of depreciation (such as accounting depreciation) with minimal effort.

The conceptual recommendation established in 2009 was reworded to capture the current approach used.

Recommendation 16: Nkom proposes to adopt a full time-series model that calculates the costs of ~~all three actual~~ operators from ~~their GSM launches in~~ 1993 ~~and 2009~~ (and capturing the first GSM expenditure in 1991 and 1992 where relevant), following on to UMTS deployments in 2001 and beyond. The model will therefore be able to calculate operators' costs in current and future years, giving Nkom the greatest understanding of cost evolution and flexibility in exploring pricing options. The generic operator will be modelled according to a recent entry date, in a full time-series approach that considers all years of operation after launch.

2.5.5 Mark-up mechanism

The specification of a LRIC+++ model will result in certain cost components being classified not as incremental, but as common costs. Common costs are those costs required to support one or more services, in two or more increments, in circumstances in which it is not possible to identify which specific increment causes the cost. Such costs do occur in mobile networks (and more extensively in mobile business overheads). However, depending on the maturity of the network, they may not be as significant as in a fixed network. These common costs need to be recovered from services in some way, generally by using a mark-up on incremental costs in a LRIC+++ situation.

Two main methods for mark-up mechanism have been put forward and debated in the context of mobile termination costing:

Equal proportionate mark-up (EPMU) — In this method, costs are marked up pro-rata to incremental costs. It is simple to apply, and does not rely on developing additional supporting information to control the mark-up calculation. EPMU has been applied by Ofcom and PTS in their previous mobile cost calculations.

Ramsey pricing, and its variants — Ramsey pricing is a targeted common-cost mark-up mechanism which loads the burden of common-cost recovery on those services with low price elasticity (thus causing the least distortion of consumer consumption and welfare away from the optimal). There are variants of Ramsey pricing methods which take into account operator profit (as opposed to welfare) maximising incentives, or additional effects such as network externalities. Supplementary information is required by these approaches to control the mark-up algorithms.

The choice of mark-up mechanism affects the resulting marked-up unit costs, particularly where non-equal mark-ups are applied, and especially if common costs are large. This choice therefore directly influences the cost-oriented price for mobile termination.

The conceptual recommendation established in 2009 was not changed.

Recommendation 17: Nkom proposes to apply an equi-proportionate mark-up (EPMU) for network common costs and the network share of business overheads in the LRIC+++ calculation.

3 Demand forecasting

Since the v7.1 model was developed, certain new trends and technologies have emerged in the mobile market, requiring a reassessment of how the demand forecasts are modelled. The most significant of these changes have been:

- the global development of fourth-generation (LTE) mobile networks and devices
- the increasing adoption of OTT services such as mobile IP telephony and mobile VoIP (and similar services for SMS) by mobile users, as an alternative to traditional voice and SMS messaging.

This section discusses how the demand forecasts have been adapted to encompass these changes:

- Section 3.1 discusses the implicit modelling of LTE traffic and services in the model
- Section 3.2 discusses the inclusion and modelling of OTT traffic.

In addition, data from Nkom, operators and publicly available datasets has been used to update demand parameters in the v9R model:

- Section 3.3 details the updates made to historical demand parameters
- Section 3.4 discusses the changes made to forecast demand parameters.

3.1 LTE demand forecasting

Following development of the v7.1 model in 2010, both Telenor and Telia have begun deploying LTE networks across Norway.

In the Swedish mobile LRIC model, PTS modelled an urban LTE network to consider the impact of aspects such as the sharing of network costs of sites or backhaul transmission between 2G/3G and LTE networks. The version of the model issued in July 2011[15] indicated that, for a 2G/3G network operator:

- including an urban LTE network covering 30% of the population reduced the LRIC+++ of mobile termination by approximately 5% in the long run
- including an urban LTE network covering 30% of the population had almost no impact (<0.5%) on the Pure LRIC of mobile termination.

From these results, we have concluded that the considerable additional complexity of implementing an LTE network design, in addition to the existing 2G/3G network designs, is not proportionate to the impact of LTE networks. Therefore, we do not explicitly model the network design for LTE, though we do consider its share of voice, SMS and data services. We also assume a percentage of LTE demand to be passed into the routeing factor table for shared infrastructure assets supporting

15 See http://www.pts.se/upload/Remisser/2011/Telefoni/10-8320-pts-mobil-lric-final-model.zip

the 2G+3G and LTE network layers (primarily radio sites). This estimates the effects of cost sharing between services.

The migration of voice, SMS and high-speed data services to an LTE network was added into the demand calculations in the v8D model and has been retained for the v9R model. The changes made and calculations used for deriving the services carried over the LTE network are found on the *M9R* worksheet and are discussed in more detail below.

3.1.1 Voice and SMS demand forecast updates

The voice and SMS forecasts in the v7.1 model were derived on a total-volume, technology-neutral basis. To account for the proportion of voice and SMS that will be moved across onto the LTE network in the future, a similar methodology has been used as for the migration of services from 2G to 3G networks.

The traffic demand calculations were updated for the v8.1 model by adding 3G-to-LTE voice and 3G-to-LTE SMS migration profiles to the market calculations. These migration profiles were designed such that voice and SMS traffic on the 3G network remains largely stable throughout the forecasting period. A start date of 2015 has been used for the beginning of migration of voice and SMS services to LTE, given the likely timescale for voice over LTE (VoLTE) and IMS deployment by operators.

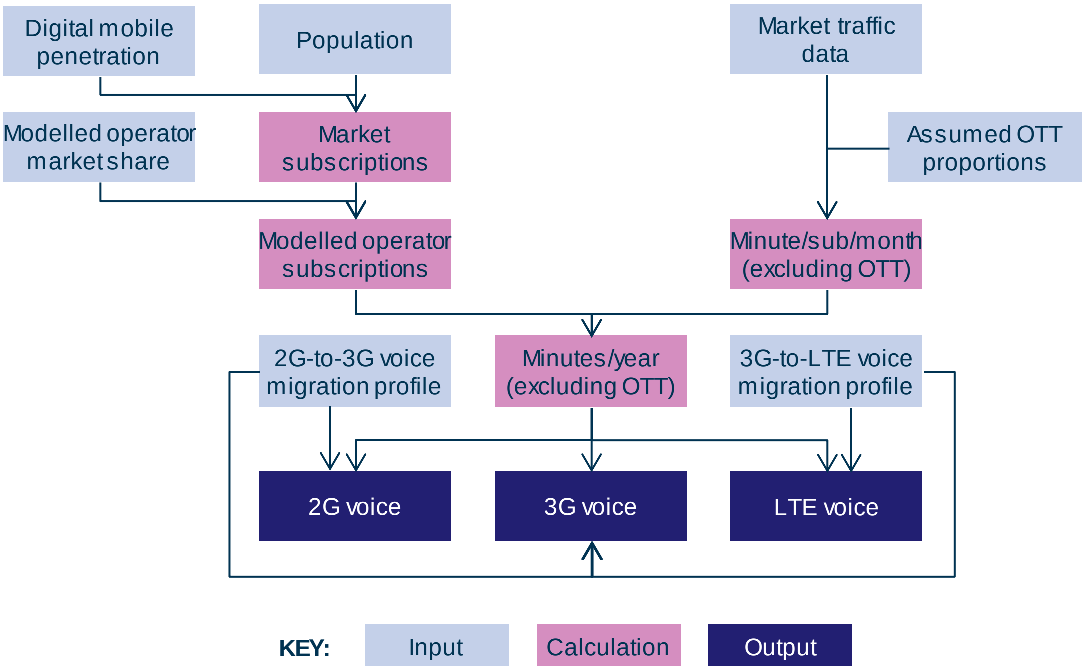
These new traffic migration profiles feed into the calculations of 3G and LTE voice demand forecasts, as shown in Figure 3.1 below. The specific calculations are as follows:

$$3G\ voice\ traffic = Market\ voice\ traffic \times (1 - \%\ traffic\ carried\ over\ 2G - \%\ traffic\ carried\ over\ LTE)$$

$$LTE\ voice\ traffic = Market\ voice\ traffic \times \%\ traffic\ carried\ over\ LTE$$

This structure is replicated for the calculation of SMS traffic across the modelled technology generations.

Figure 3.1: Illustration of the voice traffic calculations in the v9R model [Source: Analysys Mason, 2017]



3.1.2 Cost sharing with LTE

The model is capable of including a proportion of LTE megabytes in the routeing factors of network assets which are likely to support 2G, 3G and LTE radio infrastructure (effectively radio sites). This has the effect of reflecting (in a lower LRIC and LRIC+++ result) the greater economies of scope which can be anticipated from the use of a combined 2G+3G+LTE network infrastructure.

As the LTE network is not explicitly modelled, the pure LRIC of the wholesale voice termination increment in a 2G+3G+LTE network model is not calculated (this result is effectively only calculated in the 2G+3G case present in the network design algorithms).

3.1.3 Updates to demand forecasts for high-speed data

While the v7.1 model contained forecasts for total market voice minutes and SMS, the forecast of high-speed data traffic considered only megabytes carried over 3G (specifically, the HSPA) networks.[16]

Inputs for the total high-speed data traffic (across all technologies) were added to the v8.1 model, using figures derived from historical operator data on the proportion of total mobile broadband traffic carried over LTE and year-on-year growth in data usage per connection derived from Nkom market data. Our modelled migration of data traffic to the LTE network begins in 2009, reflecting the launch of LTE networks in Norway.

16 Low-speed data is assumed to be those megabytes carried over the GPRS/EDGE and UMTS R99 networks.

The LTE high-speed data traffic is therefore calculated as the difference between this total v9R model forecast and the existing v7.1 model HSPA forecast, which has been forecast to remain stable from 2016 onwards, as illustrated in Figure 3.14. The details of this calculation methodology can be seen in Figure 3.2 below.

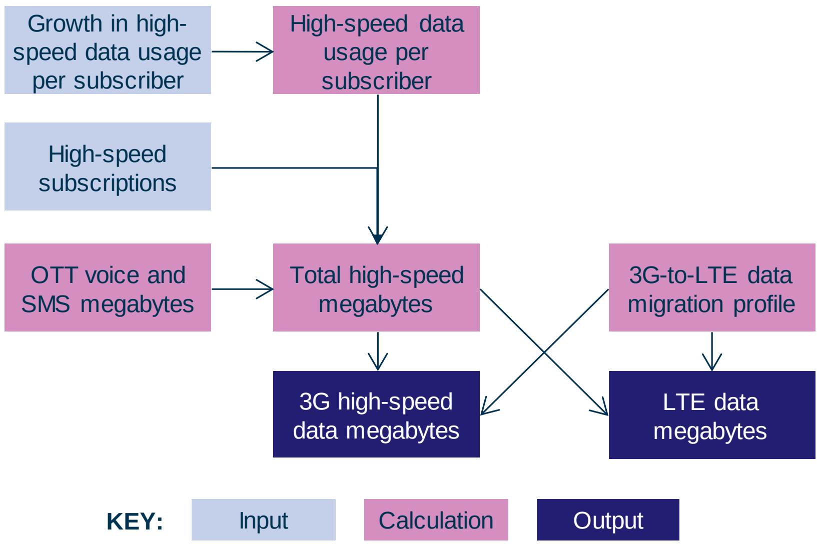


Figure 3.2: Illustration of the high-speed data traffic demand calculations in the v9R model [Source: Analysys Mason, 2017]

3.2 OTT traffic

OTT services are carried by third-party clients using data bearers. This traffic is not interconnected via voice gateways, since it is carried as data bits. Therefore, operators do not necessarily know the minutes/messages carried as OTT. OTT services are expected to become more widespread in Norway and so are likely to affect the demand forecasts of circuit-switched traffic within the model.

In the future, substitution may occur for conventional mobile voice and, similarly, usage of data messaging could increase at the expense of conventional SMS usage. This means that more voice/messages are likely to be carried as data bits in the network.

When considering OTT voice and SMS traffic for the v8.1 model, we continued to forecast *total* voice usage by service, and *total* SMS by service. We then separated the OTT voice and SMS traffic out from the total, technology-neutral, traffic projections in the v8.1 model using a modelled proportion of this traffic that is carried by OTT in each year. This proportion was derived from operator data, as well as information from Nkom's "*The population's use of electronic communications in 2011*" survey.[17]

Figure 3.3 below indicates that at the time the v8.1 model was developed few users surveyed made regular use of OTT services. This suggested very low levels of take-up for OTT services in Norway, and this conclusion is supported by operator data. Use of OTT services was expected to increase rapidly, however, with the proliferation of smartphones and development of various OTT services such as iMessage, GoogleTalk, FaceBook messaging, mobile Skype, etc.

[17] See http://data.norge.no/data/befolkningens-bruk-av-elektroniske-kommunikasjonstjenester-2011

Frequency of OTT service use	Voice services	Messaging services
Daily	0.40%	2.96%
Weekly	2.67%	2.54%
Other usage	4.95%	9.07%
No usage	91.98%	82.52%

Figure 3.3: Results of Nkom's "The population's use of electronic communications in 2011" survey [Source: Nkom, 2011]

Therefore, we used a conservative forecast for OTT take-up in the v8.1 model, with a slow increase in the proportion of voice/SMS traffic carried as OTT to 15% in the long term. We have not revised this forecast for the v9R model.

The OTT traffic is then converted to high-speed megabytes and included in the modelled service demand as HSPA and LTE traffic. The conversion rate used for the OTT voice traffic (average of 30kbit/s and 100kbit/s) is derived from the Skype figures for both the minimum and recommended download and upload speeds for calling, as reported on its website.[18] Meanwhile, the conversion factor for OTT SMS traffic uses the bytes per SMS factor from the v7.1 model.

The calculated megabytes of data traffic are then included in the high-speed data traffic forecasts. However, the relationship between OTT voice traffic and high-speed data traffic is not one-to-one, with an on-net call requiring both an upload and a download of the call data for each party. Similarly, both incoming and outgoing calls require the network to upload and download the call data. The resulting data traffic flows can be seen in Figure 3.4 below.

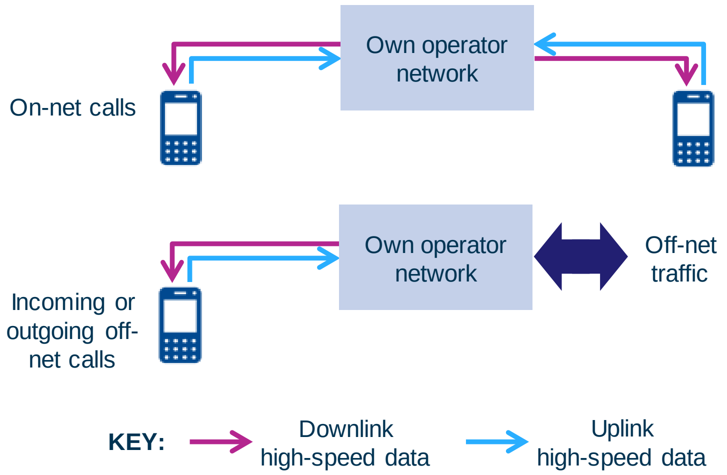


Figure 3.4: Data traffic generated by OTT voice calls [Source: Analysys Mason, 2017]

As a result of the difference in treatment of data traffic to voice traffic, the OTT voice traffic is included in the high-speed data forecasts as follows:

$$Upload\ data\ OTT\ voice\ megabytes = 2 \times on{-}net\ OTT\ minutes + incoming\ OTT\ minutes + outgoing\ OTT\ minutes$$

18 See https://support.skype.com/en/faq/FA1417/how-much-bandwidth-does-skype-need

$$Download\ data\ OTT\ voice\ megabytes = 2 \times on{-}net\ OTT\ minutes + incoming\ OTT\ minutes + outgoing\ OTT\ minutes$$

SMS traffic, conversely, behaves in a similar manner to data traffic, and an on-net OTT SMS is both downloaded and uploaded once, while an incoming OTT SMS is downloaded once and an outgoing OTT SMS uploaded once. These traffic flows are shown in Figure 3.5 below.

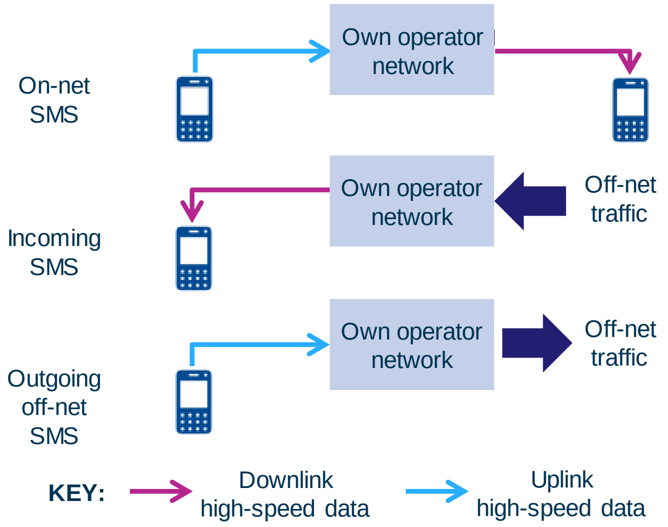


Figure 3.5: Data traffic generated by OTT messages [Source: Analysys Mason, 2017]

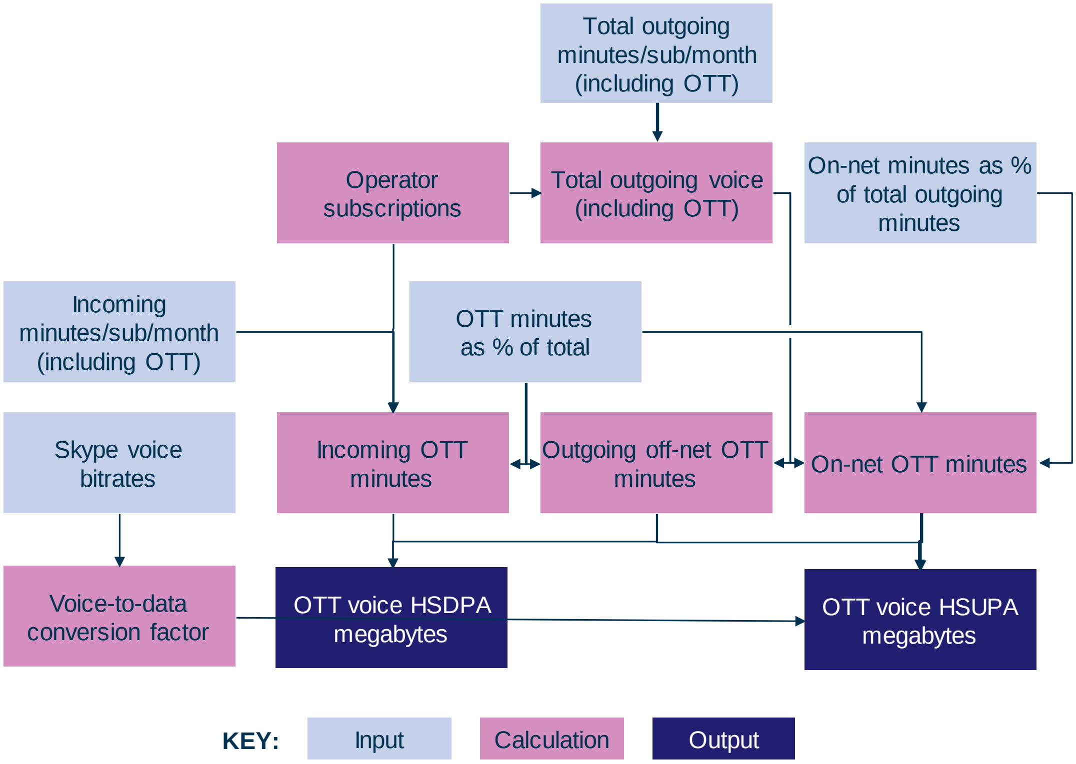
The treatment of OTT SMS traffic means that we use the following formulae in our mapping of OTT SMS traffic onto the modelled high-speed demand forecasts:

$$Upload\ data\ OTT\ SMS\ megabytes = on{-}net\ OTT\ minutes + outgoing\ OTT\ minutes$$

$$Download\ data\ OTT\ SMS\ megabytes = on{-}net\ OTT\ minutes + incoming\ OTT\ minutes$$

The changes made and calculations used for deriving the OTT traffic and megabytes are found on the *M9R* worksheet, and illustrated for voice traffic in Figure 3.6 below. The structure of the equivalent calculations for OTT SMS traffic is identical.

Figure 3.6: Illustration of the OTT voice calculations in the v9R model [Source: Analysys Mason, 2017]



3.3 Updates of historical demand parameters

Historical demand updates for the years 2013–16 were provided both in the Nkom market data and by operators in response to data requests made to Telenor, Telia and ICE. In particular, the Nkom statistics were taken from the database published on Nkom's Ekomstatistikken website.[19] These were used in the update of historical demand parameters undertaken for the v9R model.

A new demand data worksheet (*M9R*) was included in the v9R model and updated in order to align demand inputs with Nkom market data.

Details of the demand parameters that have been updated for the total mobile market since the v8.1 model are shown in Figure 3.7 below.

19 See http://www.nkom.no/files/ekomportal/alle.csv

Service	Source used for data update
Digital mobile penetration	Nkom market data
Market share of high-speed subscriptions	Nkom market data
Mobile broadband penetration	Nkom market data
Outgoing voice minutes per subscriber per month	Nkom market data
Voice migration profiles	Operator data
Incoming voice minutes per subscriber per month	Operator data
Low-speed data megabytes per subscriber per month	Operator data
Mobile broadband megabytes per high-speed subscription per month	Operator data

Figure 3.7: Historical demand parameters in the v9R model updated for the years 2013–16 [Source: Analysys Mason, 2017]

3.4 Updates of forecast parameters

The population year-end historical data and forecasts have also been updated for the years 2014–41 using data from Statistisk Sentralbyrå (SSB).[20]

These changes made to the 2013–16 parameters in the v9R model (as discussed in Section 3.3) have resulted in revisions being made to some of the long-term demand forecasts. These are shown in Figure 3.8 below.

Service	v8.1 forecast	v9R forecast
Digital mobile penetration	115.0%	113.0%
Mobile broadband penetration	20.0%	15.5%
Originated voice	190 min/sub/month	197 min/sub/month
Incoming voice	110 min/sub/month	120 min/sub/month
Low-speed data usage	100MB/sub/month	8MB/sub/month
High-speed data usage per subscriber (digital plus mobile broadband)	2490MB/sub/month	20900MB/sub/month

Figure 3.8: Modelled long-term forecast endpoints in the v8.1 and v9R models [Source: Analysys Mason, 2017]

The most significant of the updated forecasts since the v8.1 model are described in more detail below, namely:

- the modelled population forecasts (Section 3.4.1)
- the modelled penetration forecasts (Section 3.4.2)
- the modelled data traffic forecasts (Section 3.4.3).

20 See http://www.ssb.no/befolkning, Table 11167, MMMM forecast.

3.4.1 Population

The v9R model projects that the population will continue to grow, reaching 6.406 million in 2041. The new forecast is approximately 1% lower than that assumed in the v8.1 model.

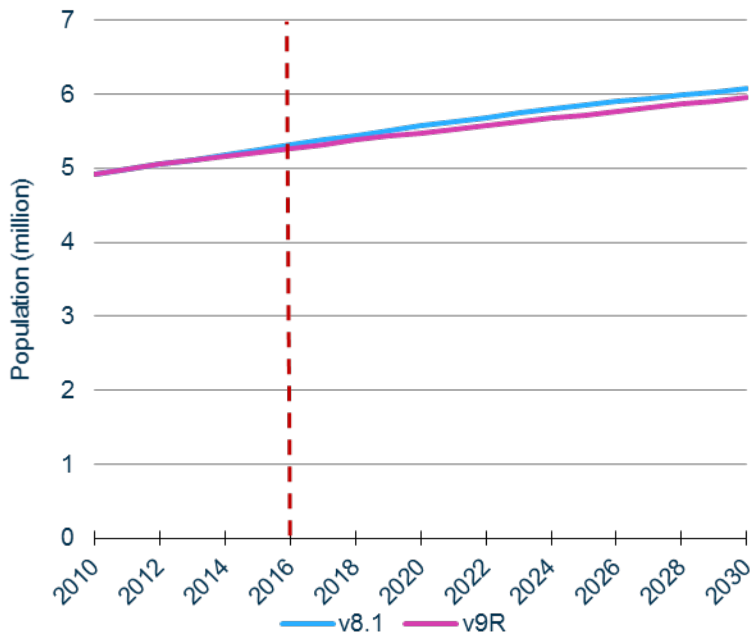


Figure 3.9: Population forecasts in the v8.1 and v9R models [Source: Analysys Mason, 2017]

Although the population is forecast to grow across all Fylker, growth is more rapid in Fylker such as Oslo and Akershus, as can be seen in Figure 3.10 below.

Forecast compound annual growth rate (CAGR) to 2026	Fylker
1.01% to 1.50%	Akershus, Aust-Agder, Buskerud, Hordaland, Oslo, Rogaland, Vest-Agder
0.51% to 1.00%	Hedmark, Møre og Romsdal, Nord-Trøndelag, Østfold, Sør-Trøndelag, Troms, Vestfold
0.01% to 0.50%	Finnmark, Nordland, Oppland, Sogn og Fjordane, Telemark

Figure 3.10: Compound annual growth rate of population forecasts by Fylke for the years 2016–2026 [Source: Statistisk Sentralbyrå (SSB), 2017]

3.4.2 Penetration

The long-term forecast for digital mobile penetration has been reduced from 115% in the v8.1 model to 113% in the v9R model. The penetration in the v9R model has been calibrated to fit with updated data points for the years 2013–2016. A comparison of these forecasts is shown in Figure 3.11.

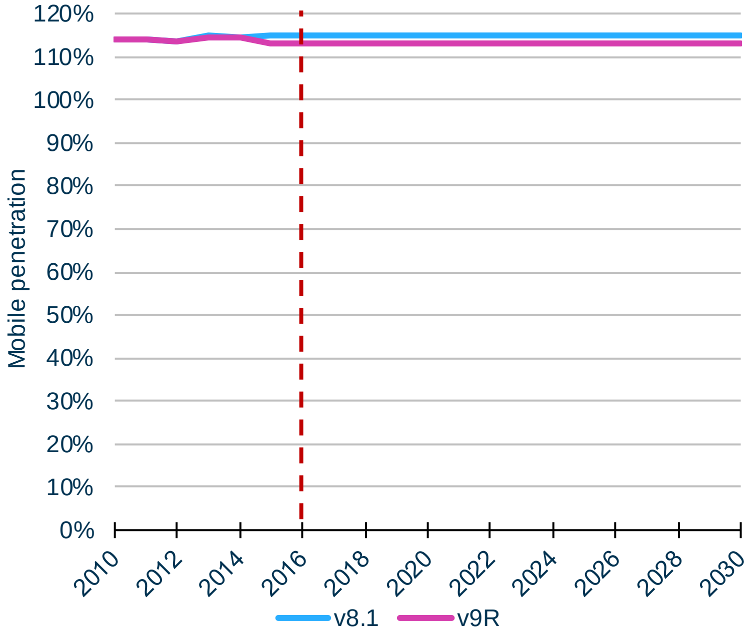


Figure 3.11: Mobile penetration in the v8.1 and v9R models [Source: Analysys Mason, 2017]

The long-term forecast for mobile broadband penetration has also been reduced, from 20% in the v8.1 model to 15.5% in the v9R model. The penetration in the v9R model has been calibrated to fit with the updated data points for the years 2013–2016. The mobile broadband penetration forecasts are shown in Figure 3.12.

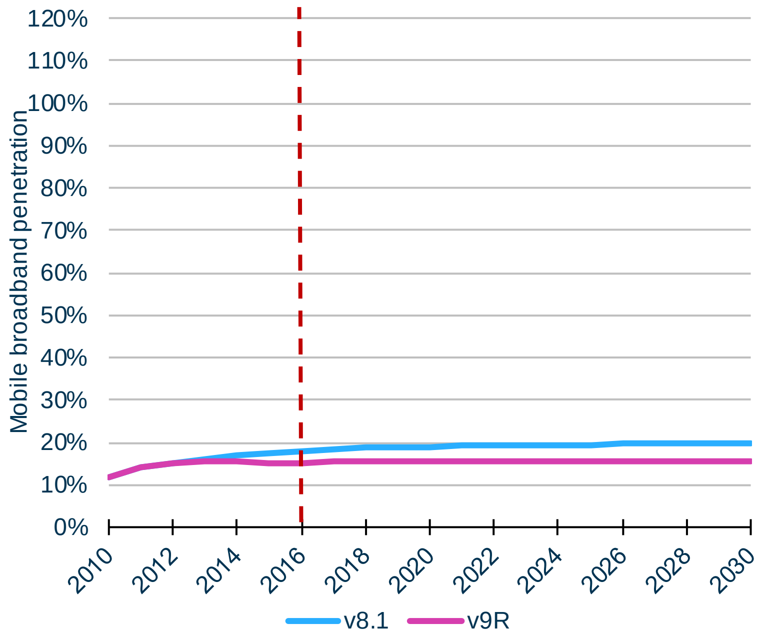


Figure 3.12: Mobile broadband market penetration in the v8.1 and v9R models [Source: Analysys Mason, 2017]

3.4.3 Data traffic

The growth forecasts for total mobile broadband data traffic discussed in Section 3.1.2 result in a rapid increase in modelled data traffic, even compared to the growth assumed in the v8.1 model, as shown in Figure 3.13 below.

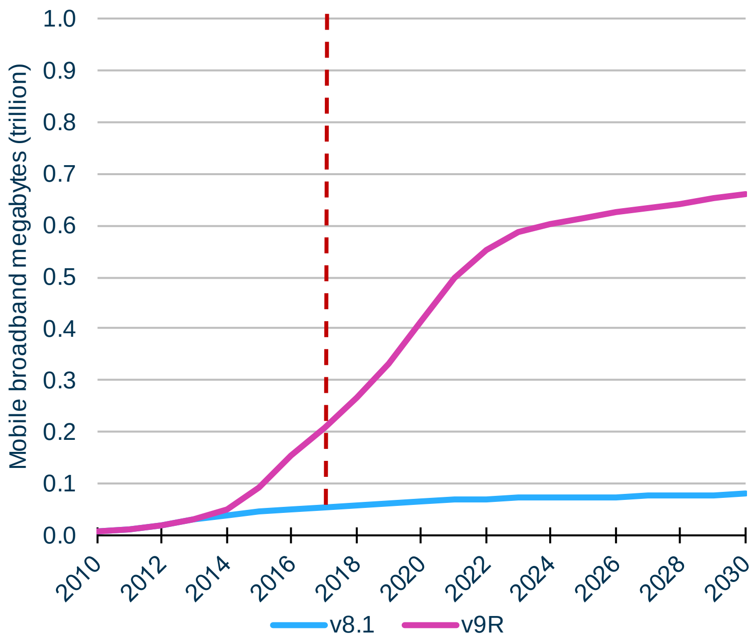


Figure 3.13: Comparison of total mobile broadband data consumption in the v8.1 and v9R models [Source: Analysys Mason, 2017]

While the proportion of this data traffic carried by LTE networks increases during the modelled time period, as shown in Figure 3.14 below, the long-term demand forecasts for 3G services in the v9R model are set such that 3G data volumes remain stable at approximately 30 billion megabytes from 2014 onwards. This is similar to the assumption in the v8.1 model, and we consider this to be an efficient use of the modelled 3G network.

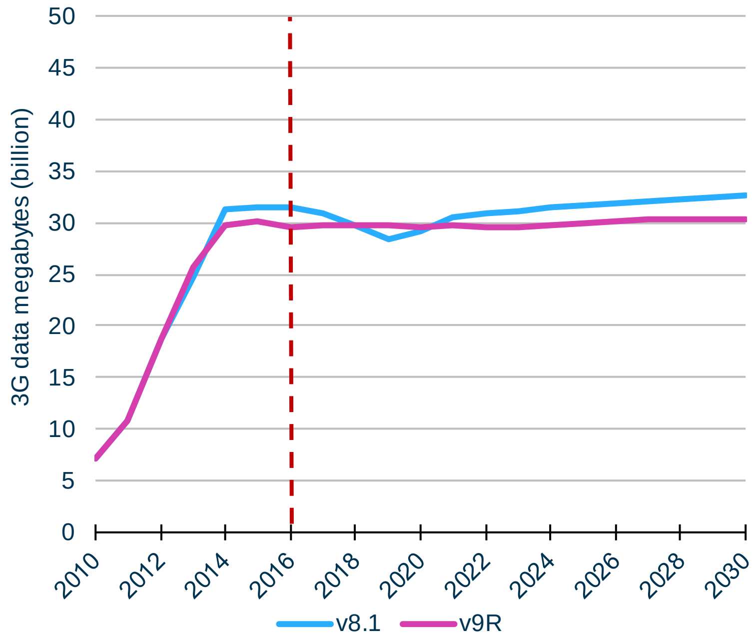


Figure 3.14: Comparison of 3G data volumes in the v8.1 and v9R models [Source: Analysys Mason, 2017]

4 Calculations related to the EC/ESA Recommendations

Both the EC[21] and the ESA[22] released recommendations regarding the costing calculations for mobile termination rates. A number of adjustments were made to the v8.1 model to consider these recommendations, which have been retained in the v9R model:

- Section 4.1 outlines the structure for the addition of a generic operator
- Section 4.2 discusses the definition of the inputs for this generic operator
- Section 4.3 describes the 'Pure LRIC' calculation included in the v9R model
- Section 4.4 sets out the existing LRIC and LRIC+++ calculations in Nkom's model.

4.1 Structure of the generic operator calculation

The v9R model represents a generic Norwegian operator.

The modelling of a generic operator is outlined in the ESA's recommendation on the costing of termination rates, which recommends modelling an efficient-scale operator (by implication, not an actual operator). This is very similar to the EC's Recommendation of May 2009.[23]

To create a generic operator calculation in the v8.1 model, the inputs were determined as a function of the inputs from the actual MNOs at the time (Telenor, Telia and Mobile Norway). These actual operator inputs had been calibrated and reconciled to available operator data (up to 2011 or 2012) during development of the v8.1 model and were related to:

- demand (e.g. subscribers, traffic)
- network design (e.g. cell radii, mix of backhaul topologies)
- costs (e.g. unit capex, cost trends, lifetimes, etc.).

The generic operator can be calculated by choosing 'Generic_operator' on the *Ctrl* worksheet. The inputs are then selected on the *M*, *NtwDesSlct*, *UtilIn*, and *CostBase* worksheets. The generic-operator inputs are pasted values in the Excel worksheets of the v9R model. This is because the worksheets containing confidential operator-specific data (where the generic operator input calculations are undertaken) were redacted from the published v8.1 model, which provided the starting point for the latest modelling process. However, we left a note of formulae used to generate the generic-operator inputs beside each selected input cell, so that it can be inspected by industry parties.

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21 See http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:124:0067:0074:EN:PDF

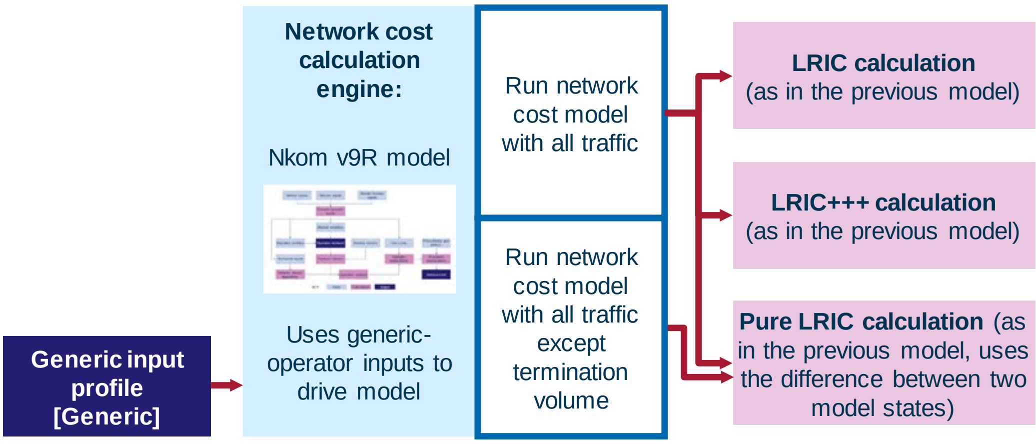
22 See http://www.eftasurv.int/media/internal-market/ESAs-Recommendation-on-termination-rates.pdf

23 COMMISSION RECOMMENDATION of 7 May 2009 on the Regulatory Treatment of Fixed and Mobile Termination Rates in the EU (2009/396/EC); available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:124:0067:0074:EN:PDF

As the generic operator's inputs do not exactly reflect any specific MNO (but rather rounded average or standardised inputs) and all operator confidential data is redacted, the model is suitable for distribution to all industry parties.

Figure 4.1 below shows the structure of the v9R model, which has been published by Nkom.

Figure 4.1: Structure of the redacted v9R model as published by Nkom [Source: Analysys Mason, 2017]



4.2 Generic operator input derivations

As in the case of the third network operator modelled in the v7.1 model, certain inputs for the generic operator need to be chosen in principle (in particular, certain inputs cannot always be defined as a function of those of the actual operators). Our definition of these inputs for the v8.1 model is described in Figure 4.2 below: these inputs have been retained for the v9R model. The derivation of the generic-operator inputs for coverage and subscriber market share is described in more detail in Sections 4.2.1 and 4.2.2 respectively.

Figure 4.2: Key input values for the generic operator [Source: Analysys Mason, 2017]

Input	Value	Comments
Radio technologies	2G, 3G and LTE networks – although the LTE network is not explicitly modelled	All three MNOs in Norway currently use both 2G and 3G technologies, and all three have spectrum available (permanently or temporarily) for LTE technologies
Operator network deployment	2012 asset purchase for a 2013 network launch with immediate scale	Reflects the cost constraints that would exist in a fully contestable market (where costs are set by an operator that can reach the immediate scale of an existing operator)
Subscriber market share	Average value based on number of networks (35% for voice, 33% for data); achieved immediately	Defined as 1/N, where N = the number of comparable mobile coverage networks in Norway, representing an efficient operator's market share
Coverage profile	Almost ubiquitous GSM and UMTS population coverage (almost 100%)	Reflects coverage of other national network operators
2G/3G network shutdowns	2G shutting down in 2020 and 3G in perpetuity	Reflects assumptions established in the v7.1 model
Core network technologies	All-IP core from launch	Modern-equivalent asset for core networks
Transmission technologies	Backhaul topologies currently used by operators	Reflects actual 2G technologies used by Norwegian operators. 3G backhaul is assumed to be Ethernet from launch
Service set	Full range of 2G (respectively 3G) voice, SMS and data services offered from launch of the 2G (respectively 3G) network	Reflects service set currently offered by actual Norwegian operators. LTE service volumes are forecast, though not costed. It is also possible to include LTE volumes in the LRIC and LRIC+++ cost allocation

The specific approach used to derive other input values for the generic operator is documented in Figure 4.3 below.

Figure 4.3: Other input values for the generic operator [Source: Analysys Mason, 2017]

Input derivation	Name of input
Average of MNOs (rounded)	• Low-speed data user proportion • Voice, SMS and low-speed data migration profiles for 2G to 3G/3G to LTE • Spectrum allocations and payments • Coverage and in-fill cell radii • Air interface and network blocking probabilities • Unit capital/operating expenditure per network element • Call attempts per successful call and average call duration • Proportion of weekday traffic in a year • 2G voice, 3G voice and HSPA traffic demand per geotype • Voice, SMS, low-speed data and high-speed data busy-hour proportions • Type of site proportions across owned tower, third-party tower and third-party roof site • Proportion of 2G sites available for 3G NodeB upgrade • BTS capacity • Proportion of NodeBs with HSDPA 7.2 and HSUPA activated • 2G and 3G repeater requirements • Proportion of sites that use microwave backhaul • BSC/RNC capacity (TRXs) • MSC coverage, CPU parts and port parts inputs • MGW/MSS/MSC parameters • BSC, RNC and core network locations • Traffic routeing across national backbone transmission links • HLR parameters • SMSC/MMSC/GSN parameters • Network layer shutdowns (2G radio, 3G radio, layered core)
Common operator inputs	• Asset lifetimes and planning periods • Capital and operating cost trends
Sum of operator 2G, 3G and LTE values, multiplied by generic-operator market share and relevant 2G-to-3G and 3G-to-LTE migration paths	• Digital subscriptions – year end • High-speed data subscriptions – year end • 2G/3G/LTE incoming, on-net and outgoing off-net voice • 2G/3G/LTE incoming, on-net and outgoing off-net SMS • MMS • 2G/3G low-speed data traffic (GPRS/R99) • 3G/LTE high-speed data traffic (HSPA/LTE)
Assumed to be inactive	• Transit switching centre locations • % national minutes which are also transited across transit layer (if present) • Backhaul 64kbit/s link channel threshold • Access nodes per cluster node • Legacy core network layer shutdown • Year in which GSM operator stops overlaying additional sites
Set to launch year of the network, 2012	• Network layer activations • Launch of 3G coverage network • Year that MSCs are made 3G-compatible

4.2.1 Generic operator coverage

The generic operator is assumed to have both a GSM and UMTS coverage network. The v9R model assumes almost ubiquitous GSM population coverage for the generic operator using 900MHz spectrum. This is made up of both wide-area and in-fill coverage, with 80% of coverage being wide area, and the remaining 20% being in-fill coverage.

The generic operator is assumed to deploy UMTS coverage using both 2100MHz and 900MHz spectrum. This coverage is assumed to be for 99.99% of the population, with the corresponding area coverage shown by Fylke in Figure 4.4 below.

Fylker	UMTS area coverage
Oslo, Østfold, Vestfold	90–100%
Akershus, Hedmark, Møre og Romsdal, Nord-Trøndelag, Sogn og Fjordane	80–90%
Rogaland, Telemark, Vest-Agder	70–80%
Aust-Agder, Buskerud, Nordland, Sør-Trøndelag, Troms	60–70%
Finnmark, Hordaland, Oppland, Svalbard	50–60%

Figure 4.4: Comparison of total UMTS area coverage by Fylke [Source: Analysys Mason, 2017]

4.2.2 Generic operator subscriber market share

As stated in Figure 4.2, the assumed generic-operator market shares are derived as the average value based on the number of coverage networks in Norway.

For the market share of voice, it is assumed that Norway is covered by 2.85 networks, with two operators (Telenor/Telia) attaining almost 100% coverage and a third operator assumed to attain 85% population coverage in the long run. This value is in line with the efficient coverage level derived as part of the June 2012 recommendation published by Nkom.[24] These assumptions give a generic-operator voice-market share of 100%/285%= 35.1%.

We note that although the Mobile Norway network exited the market in 2014, ICE has been increasing its market presence and network coverage since that time. Therefore, we assume that the long-run coverage of 2.85 networks in Norway remains the case. It is for this reason that we assume the proportion of voice that is on-net remains the same as in the v8.1 model (since the v9R model must consider a market with 2.85 coverage networks going forward, rather than reflecting the reduction to two coverage networks that occurred in 2014).

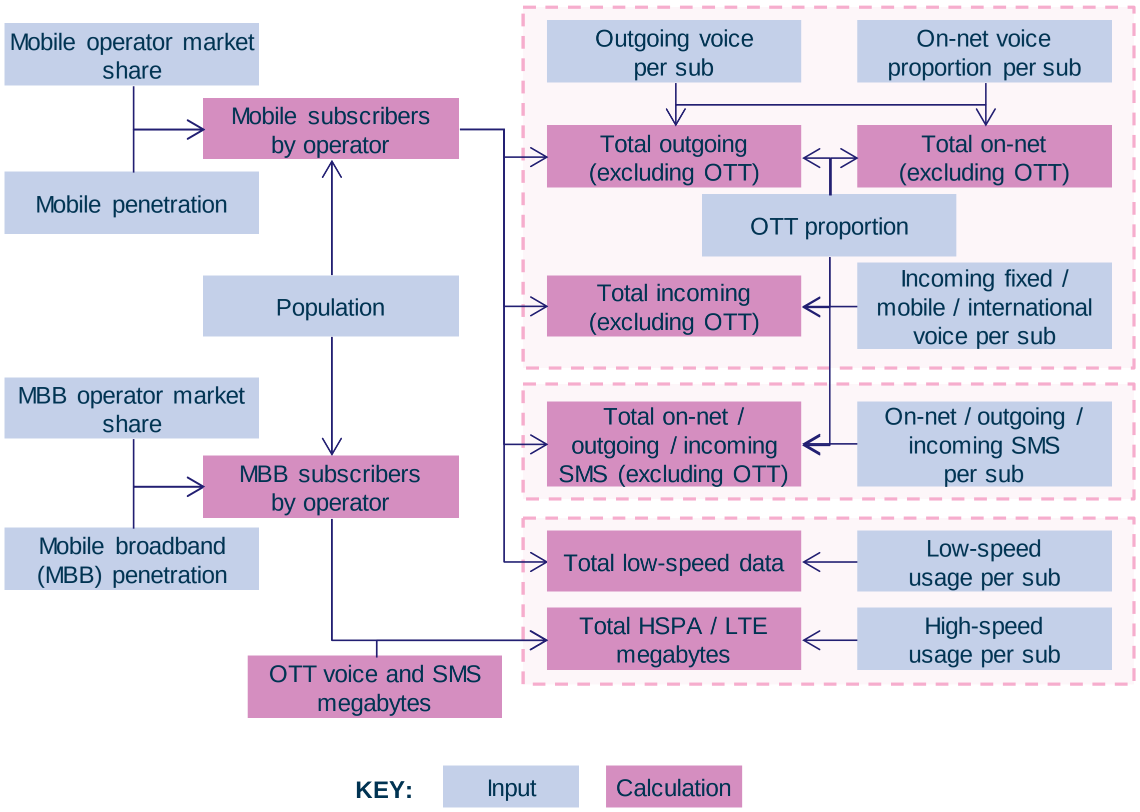
For the market share of data, we assume a generic-operator data-market share of 33.3%.

24 See http://www.nkom.no/marked/markedsregulering-smp/marked/marked-7/_attachment/2346?_ts=139b9c2a05b

4.2.3 Generic operator subscriber demand calculations

In the v9R model, we have maintained consistency between historical and forecast input definitions. For example, while an actual operator's input may have previously been defined using actual data for historical periods and an extrapolation to an endpoint for future periods, the generic operator's input is defined as a function of the actual operators' data consistently across both historical and future periods.

Figure 4.5: Calculation flow of actual operators which is replicated for the generic operator [Source: Analysys Mason, 2017]



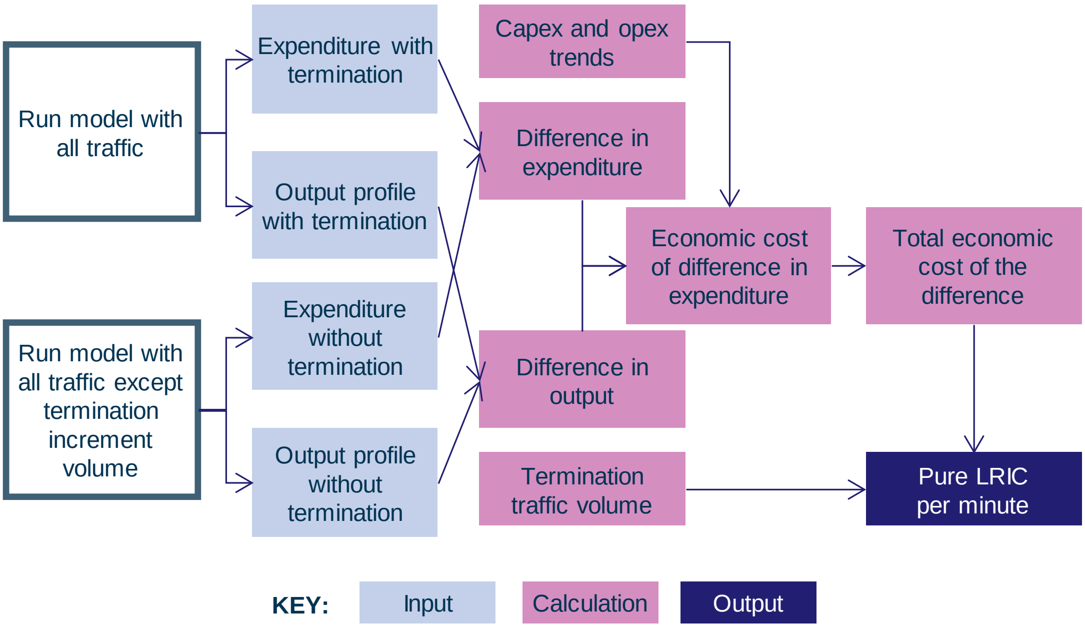
4.3 The Pure LRIC calculation

The v7.1 model was developed in early 2009, when a draft version of the EC Recommendation was available. The Pure LRIC implemented at the time is set out in Section 7.2 of the v7.1 model documentation.[25] In April 2011, the ESA subsequently released its own Recommendation.

Both Recommendations specify that only the costs ‘avoided when not offering voice termination’ are allocated to the voice termination service, with wholesale termination to be treated as the ‘last’ service in the network. In addition, it is specified that non-traffic-related costs (such as subscriber costs), network common costs and business overhead costs are not to be allocated to the end result.

To calculate the Pure LRIC in the v9R model requires that the model is run twice: once with wholesale mobile terminated voice and once without. Clicking on the “Run Pure” macro button on the *Ctrl* worksheet will result in the model calculating twice, with the necessary information from both runs stored as values on the *PureLRIC* worksheet. The Pure LRIC of termination is then calculated as shown in Figure 4.6.

Figure 4.6: Calculation of Pure LRIC [Source: Analysys Mason, 2017]



The difference in both capex and opex (the *avoidable* expenditures) is determined from the two model calculations, and economic depreciation is then applied to this difference. This is run separately for capex and opex, in order to apply their respective cost trends. The Pure LRIC of termination in each year is then calculated as the ratio of total economic cost in that year divided by total (avoided) terminated minutes.

In calculating the Pure LRIC, the modelled network design assumptions reflect some of the consequences of the modelled network carrying a lower traffic loading over its lifetime when

[25] See http://www.nkom.no/marked/markedsregulering-smp/kostnadsmodeller/lric-mobilnett/_attachment/1804?_ts=1390fd85d55

termination is excluded. The Pure LRIC calculation has been further refined in the modelling in terms of two technical adjustments (detailed in Sections 4.3.1 and 4.3.2 below). This is because a pure LRIC calculation is based on the technicalities of the cost model at the margin (in response to a small increment of traffic). These refinements and their settings have been retained for the v9R model.

These technical adjustments can be de-activated in the model calculation, giving an alternative "purest" LRIC calculation, as was similarly described in Section 7.2 of the v7.1 model documentation.

4.3.1 Technical adjustments to the network design to increase traffic sensitivity

The Pure LRIC calculation has been adjusted to include specific traffic sensitivity in parts of the network design where assets are not avoided (i.e. not avoided in the network model calculations), but where it can be expected that assets would be avoided in the case of a real network dimensioned for no termination traffic.

These adjustments in the network calculation alter how asset counts are calculated when excluding voice termination, and as such increase the modelled avoidable cost and thus the Pure LRIC.

The adjustments in the v9R model are:

- a smaller-scale deployment of GSM and UMTS in-fill sites
- a slight increase in the 3G cell radii for the six most urban Fylker.[26] This accounts for the "cell breathing" effect in UMTS, where a lower assumed traffic loading in the long term (such as the entire removal of wholesale terminated voice) can allow for a larger planned coverage cell radius.

4.3.2 Technical adjustments to the costing calculation to include non-traffic-sensitive costs

The Pure LRIC calculation has also been adjusted to include costs from certain assets that are not dimensioned to be traffic-sensitive, but where it can be expected that costs would be avoided in the case of a network dimensioned for no termination traffic. For example, this includes wholesale-related costs from assets such as the network billing system, intelligent network (IN) platform and the network management system (NMS).

The v9R model provides the functionality to include part or all of the calculated LRIC per unit of output (i.e. excluding all mark-ups) for the selected assets as an additional contribution to the Pure LRIC. The methodology for this is shown in Figure 4.7. The routeing factors by asset for the 2G and 3G voice termination services are used to calculate the LRIC contribution per minute for a 2G terminating minute and 3G terminating minute respectively. The voice migration profile is then used to derive a blended contribution per minute, which is added to the calculated Pure LRIC.

26 These include Akershus, Hordaland, Oslo, Østfold, Rogaland and Vestfold.

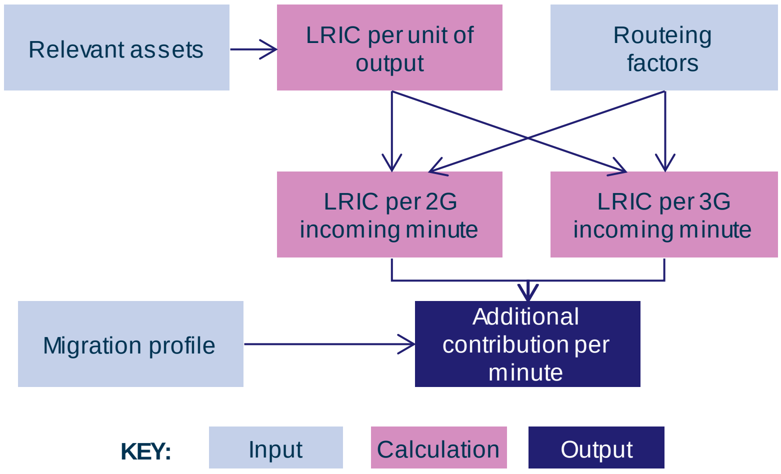


Figure 4.7: Calculation of an additional contribution to the Pure LRIC to capture non-traffic-sensitive costs [Source: Analysys Mason, 2017]

4.4 The LRIC and LRIC+++

The LRIC and LRIC+++ are calculated in the same way as for the v7.1 model, consistent with the approaches previously used across Europe for fixed and mobile termination costing.

For the LRIC, as detailed in Section 7.1 of the v7.1 model documentation,[27] the average incremental costs of traffic are defined in aggregate, then allocated to various traffic services using routeing factors.

The LRIC+++ is then derived using three equi-proportionate cost-based mark-ups:

- network common costs (including the mobile coverage layer)
- location update (LU) costs
- network share of administrative overheads.

These three non-incremental costs are shown in Figure 4.8 below as the blue, white and purple boxes, respectively.

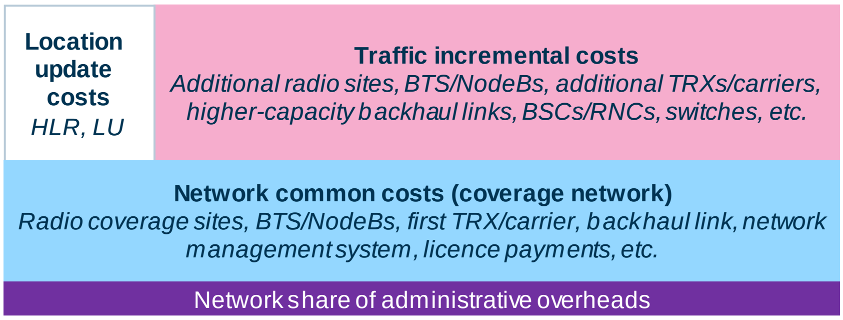


Figure 4.8: Illustration of the costs relevant to the LRIC+++ [Source: Analysys Mason, 2017]

[27] See http://www.nkom.no/marked/markedsregulering-smp/kostnadsmodeller/lric-mobilnett/_attachment/1804?_ts=1390fd85d55

5 Mobile network design

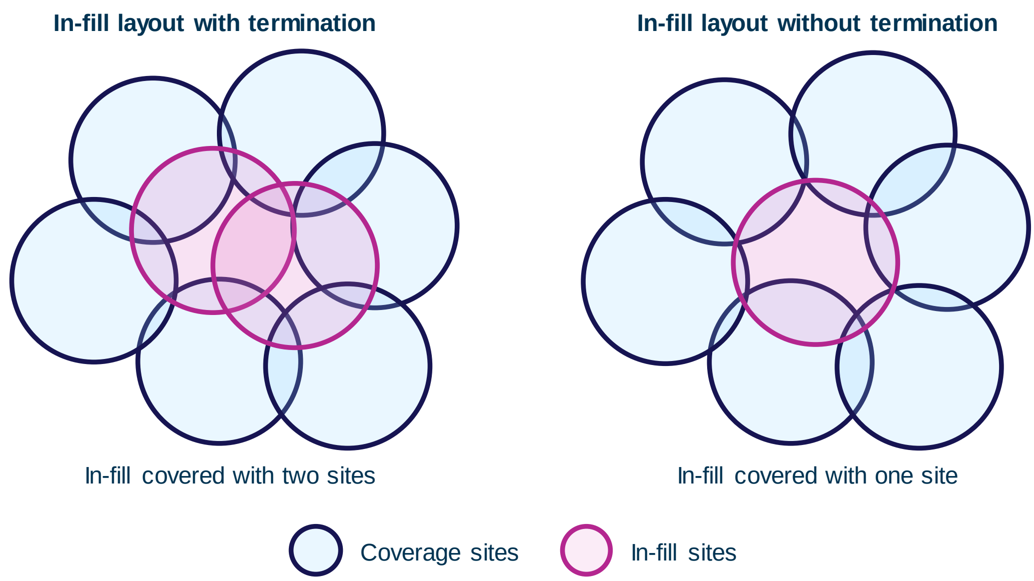
For full details of the network design in the v7.1 model, please refer to Section 4 and Annex A of the v7.1 model documentation.[28] The majority of the mobile network design remains unchanged in the v9R model. The small numbers of changes that were made during the development of the v8.1 model (and left unchanged in the v9R model) are described below.

5.1 Pure LRIC in-fill adjustments

For full details of the original cost model coverage and in-fill design, please refer to Section 4.1.2, Annex A.1.1 (for 2G) and Annex A.2.1 (for 3G) of the v7.1 model documentation.

In-fill sites are used to fill the gaps in 2G and 3G wide-area coverage and improve the contiguousness of the network. They consequently have a smaller cell radius, reflecting the smaller uncovered areas which these cells satisfy – with in-fill also acting partially to provide capacity in areas of overlap with the initial coverage layer. In the absence of termination traffic, in-fill sites would likely be rearranged to reduce their capacity function and increase the coverage function, as shown in Figure 5.1 below.

Figure 5.1: Wide-area 2G coverage and in-fill [Source: Analysys Mason, 2017]



For this reason, the model conceptually assumes that if x% of traffic is removed from the 2G network by excluding termination, then x% of in-fill sites can be removed from the 2G network. This is captured in the model by assuming a larger cell radius for the in-fill sites under the model's 'no

28 See http://www.nkom.no/marked/markedsregulering-smp/kostnadsmodeller/lric-mobilnett/_attachment/1804?_ts=1390fd85d55

termination traffic' case. This is calculated using the equation below, where x is the proportion of traffic excluded and k is the cell radius multiplier:

$$k = \sqrt{\frac{1}{(1-x)}}$$

The model includes a 2G multiplier for the in-fill radius pre-2006 and post-2008, reflecting the changing proportion of terminating traffic in the 2G network with the launch of 3G and LTE radio networks.

A 3G in-fill multiplier is also included in the model, but this is assumed to remain constant, given that the traffic-reduction effect from removing termination observed in the 3G network is smaller than on the 2G network. This is because the 3G network must also support mobile broadband (HSPA) traffic, and so proportionally much less 3G traffic is avoided when termination traffic is excluded from the network than is the case with the 2G network.

The model has no cell-breathing effect from 3G in-fill sites. This is for two reasons: because in-fill sites by definition fill in gaps, there is a significant overlap with the other (wide-area) coverage sites; secondly, by reducing the number of in-fill sites in response to the reduced load, the average load on the in-fill sites would remain the same (i.e. they would not 'relax'). For the avoidance of doubt, the effect of cell breathing is retained for the wide-area coverage sites, deployed in "Stage 1" and "Stage 3" 3G coverage in the model.

5.2 HSPA upgrades

For full details of the HSPA network design, please refer to Annex A.2.3 of the v7.1 model documentation.[29] In addition to the four grades of HSPA deployed in the v7.1 model, three further HSPA software upgrades were included in the v8.1 model. The grades that are now modelled are shown in Figure 5.2 below.

HSDPA grades	HSUPA grades
3.6Mbit/s	1.46Mbit/s
7.2Mbit/s	5.76Mbit/s
14.4Mbit/s	
21Mbit/s	
42Mbit/s	

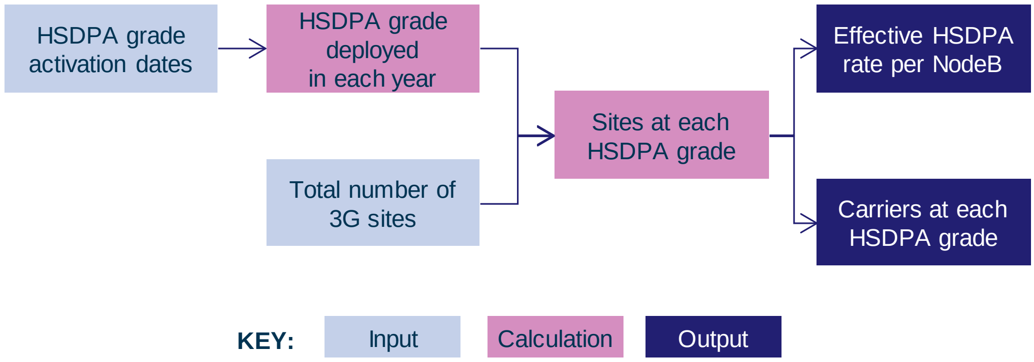
Figure 5.2: Grades of HSPA modelled [Source: Analysys Mason, 2017]

In the v7.1 model, all 2100MHz and 900MHz UMTS sites were deployed with a minimum grade of HSDPA3.6 using a single shared carrier. In addition, a proportion of sites could then be assumed to be upgraded to HSDPA7.2 (and then subsequently to HSDPA14.4). In the model, all Fylker are

29 See http://www.nkom.no/marked/markedsregulering-smp/kostnadsmodeller/lric-mobilnett/_attachment/1804?_ts=1390fd85d55

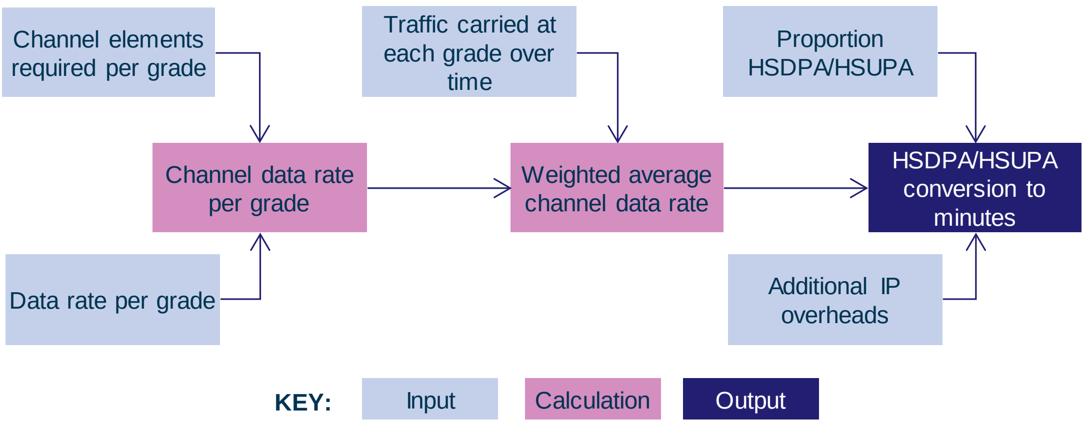
upgraded to an HSDPA grade in a specified year of activation as shown in Figure 5.3 below. An equivalent approach is used for HSUPA deployments.

Figure 5.3: Deployment of HSDPA elements [Source: Analysys Mason, 2017]



The conversion factor for converting HSPA data megabytes to voice-equivalent minutes is used in the routeing factor table to allocate costs between voice and data services. This factor was updated in the v8.1 model to reflect the new modelled grades of HSPA and is calculated based on the "weighted-average channel data rate". This is defined by the total amount of traffic carried at each HSDPA and HSUPA grade over the modelling period, as described in Figure 5.4.

Figure 5.4: Modelling flow of HSDPA and HSUPA conversion factors [Source: Analysys Mason, 2017]



5.3 UMTS Ethernet backhaul deployment

For full details of the original cost model backhaul network design, please refer to Annex A.1.4 (for 2G) and Annex A.2.4 (for 3G) of the v7.1 model documentation.

As with the v7.1 model, 3G backhaul was assumed to be logically and physically separate from 2G backhaul in the v8.1 model. The model provides the option to deploy Ethernet backhaul links for 3G backhaul. The network design for 2G backhaul and non-Ethernet 3G backhaul is unchanged from the previous v7.1 model.

The model splits the 3G backhaul requirements into microwave and leased-line backhaul. The proportion of each of these categories that are Ethernet is then calculated using a migration profile (specified by Fylke and over time for each operator). Tunnel sites are treated separately and are assumed to migrate to Ethernet backhaul using their own profile.

The Ethernet links can vary in speed depending on the amount of traffic (including voice, R99 and HSDPA traffic) per site by Fylke. The Ethernet backhaul is dimensioned as either 20Mbit/s or 50Mbit/s links, based on the average busy-hour traffic throughput per site in each Fylke. The number of site links is then aggregated across geotypes by speed.

The required number of Ethernet ports is also dimensioned for the 3G network both for voice and wireless Ethernet links, in terms of 10Mbit/s ports.

The different configurations for 3G backhaul, and their corresponding port requirements, are shown in Figure 5.5 below.

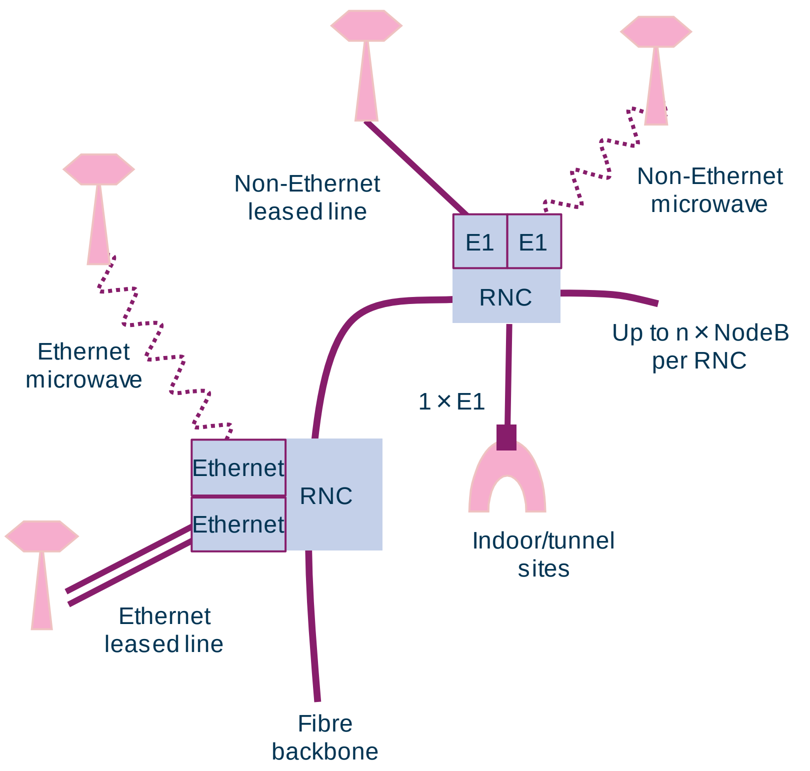


Figure 5.5: 3G backhaul physical configuration [Source: Analysys Mason, 2017]

5.4 Spectrum licences

The spectrum allocations and spectrum fees for the 2100MHz spectrum licences have been set in line with the results of the auction in November 2012,[30] with a renewal period of 20 years.

Nkom does not intend to take a position on future spectrum auctions and their outcomes. Therefore, the 900MHz/1800MHz licences are modelled as being renewed every 12 years, with costs increasing in line with inflation forecasts.

30 See http://www.nkom.no/aktuelt/nyheter/2-ghz-auksjonen-avsluttet

Annex A Excerpts from the v7.1 model documentation

For full details of the network design in the v7.1 model, please refer to Section 4 and Annex A of the v7.1 model documentation.[31] During development of the v8.1 model, revisions were made to the network design concerning in-fill coverage and 3G channel kit requirements. These revisions have been retained in the v9R model.

For reference, the relevant sections of the v7.1 model documentation are provided below.

A.1 Coverage

Coverage was determined on the basis of the radio database of each of the operator’s networks, as submitted to Nkom as part of the data request issued for the development of the v7.1 model. From this database, the area covered at a signal strength of –94dBm was calculated: this strength represents approximate outdoor coverage. Coverage calculations were made for the following sets of frequencies:

- GSM900
- GSM1800
- GSM900+GSM1800 (i.e. GSM)
- UMTS.

Indoor coverage, in terms of area and population, reflected by a higher signal strength, is commensurately lower, though not used to drive network deployment in the model.

In the initial network roll-out years, additional sites are assumed to be rolled out to maximise the area covered, with little or no overlap between cells. In the later years, sites are deployed for in-fill purposes. These sites fill the gaps in wide-area coverage and improve the contiguousness of the network. They consequently have a lower cell radius, reflecting the smaller uncovered areas which these cells satisfy. This concept is shown in Figure A.1 for the operators’ GSM networks:

31 See http://www.npt.no/marked/markedsregulering-smp/kostnadsmodeller/lric-mobilnett/_attachment/1804?_ts=1390fd85d55

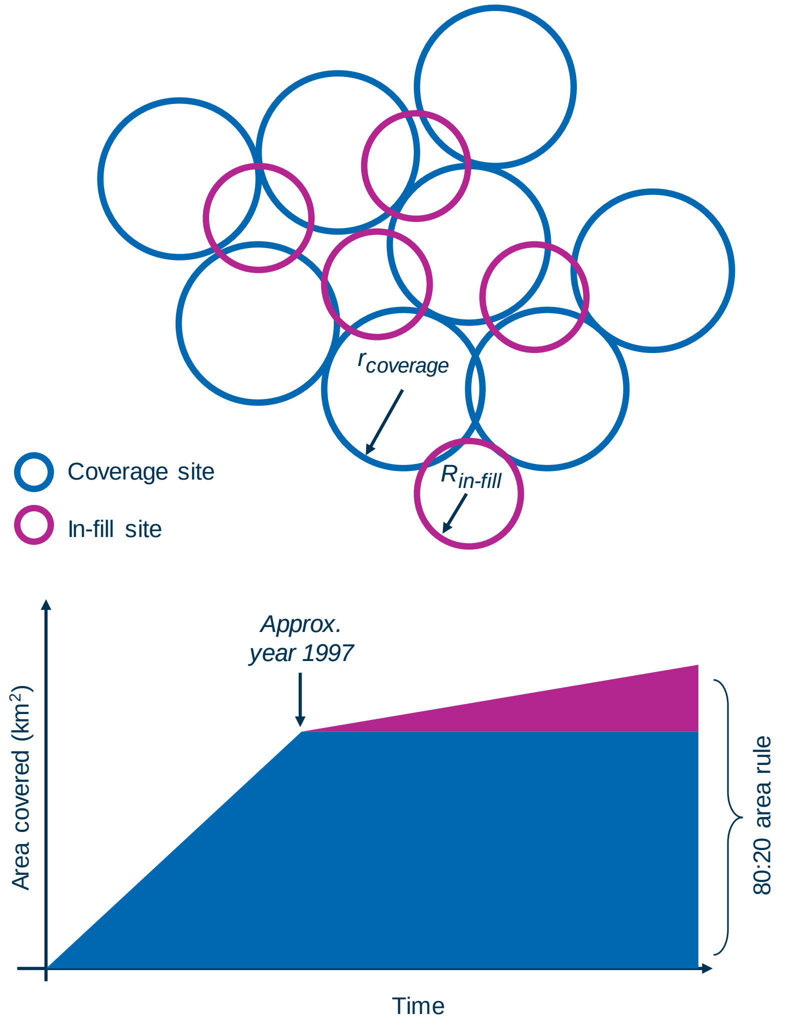


Figure A.1: Wide-area GSM coverage and in-fill [Source: Analysys Mason, 2017]

The coverage profile of the GSM network is defined on the basis of 900MHz frequencies, using the inputs from the original (v4) model, updated for the period 2005–2008 using outputs of the GSM coverage recalculation performed by Nkom in 2009.

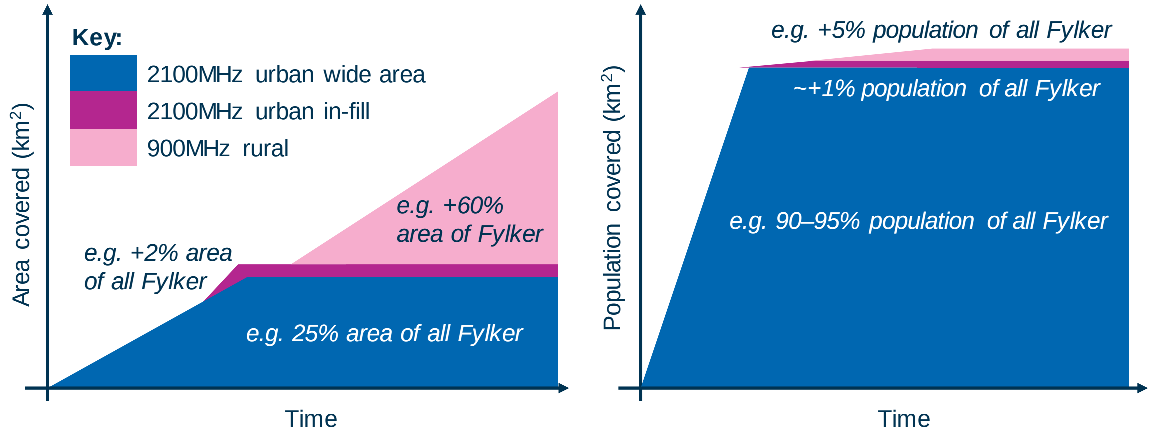
For the modelled UMTS networks, the approach to wide-area and in-fill coverage has been modified slightly. The UMTS model assumes the following roll-out process:

- "wide-area" coverage of the **urban** areas in each Fylke is deployed using 2100MHz spectrum
- "in-fill" coverage of the **urban** areas in each Fylke is deployed using 2100MHz spectrum
- **rural** coverage in each Fylke is deployed using UMTS900 equipment, on the assumption that as GSM frequencies become unloaded, they can be refarmed for a 900MHz UMTS deployment.

Therefore, the first two parts of this coverage roll-out are similar to the GSM network algorithm, albeit with alternative parameters reflecting the proportion of population (and hence area) and cell radius used for the deployment. The third part of UMTS coverage aims to replicate GSM coverage in order that the GSM network may be shut down.

This concept is shown in Figure A.2 below for the operators' UMTS networks. Although the roll-out using 2100MHz spectrum only covers approximately 25% of the Norwegian land area, it reaches more than 90% of the population. UMTS900 is then used to increase the UMTS coverage to equal to GSM coverage, but only covers the remaining 5–10% of population across a large area of the country.

Figure A.2: UMTS coverage and in-fill [Source: Analysys Mason, 2017]



The parameters determining these calculations can be found in the *NtwDesBase* and *NtwDesSlct* worksheets.

A.2 Channel element (CE), channel kit (CK) and carrier requirements

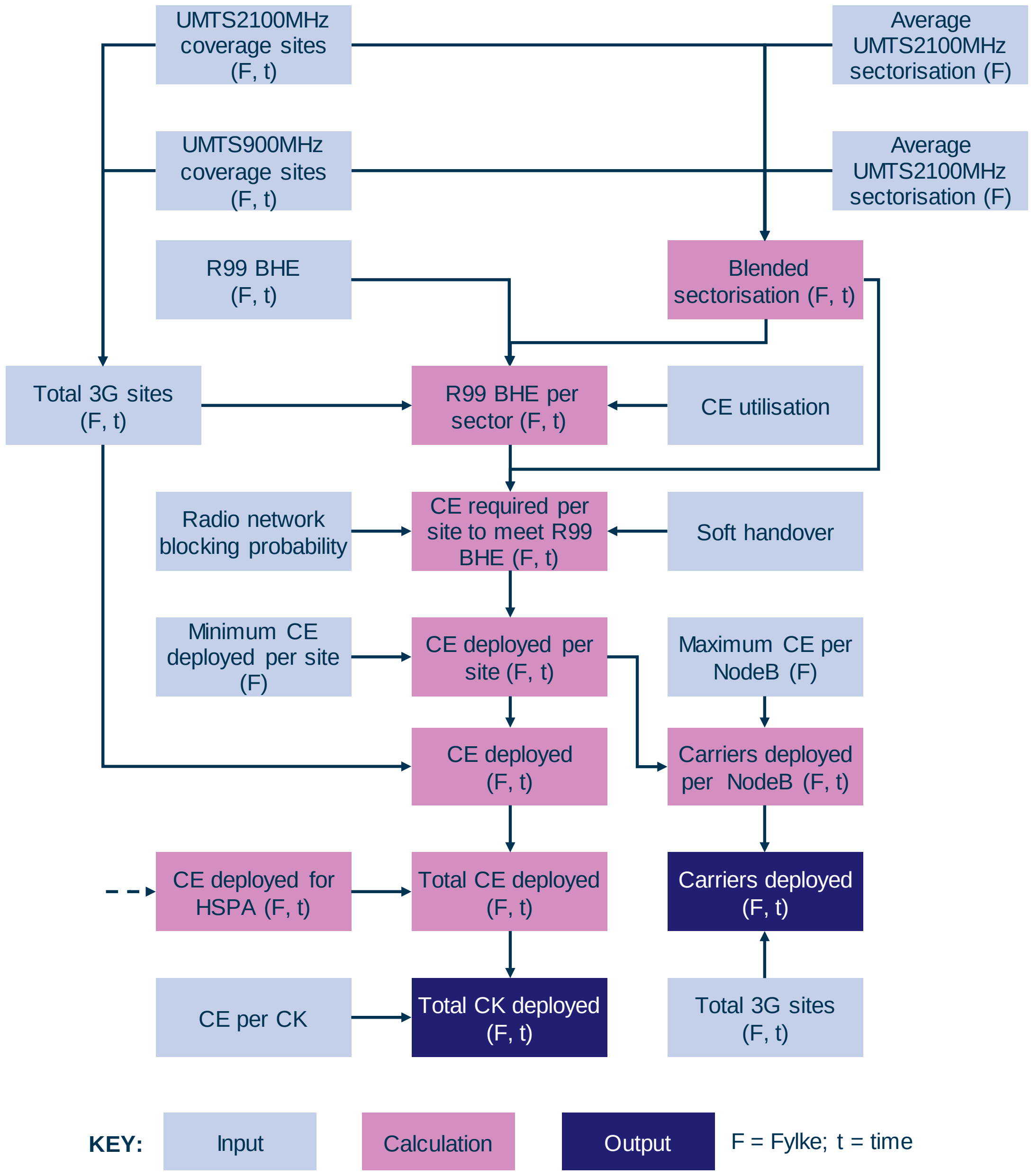
Channel kit requirements are calculated separately for voice/R99 and HSPA, by first calculating the channel element requirements.

To calculate CE requirements for voice and R99 data, the inputs required are:

- total voice and R99 busy-hour Erlangs traffic by Fylke
- total NodeB sectors and sites by Fylke
- channel element utilisation.

Figure A.3 shows a flow diagram describing the calculation of CE/CK required. Having calculated the number of CEs deployed at each site, the number of carriers required can then be calculated directly.

Figure A.3: Channel kit deployment [Source: Analysys Mason, 2017]



The blended site sectorisation across the whole 3G network, by Fylke, is calculated as a first step. The Erlang demand per NodeB sector is then derived and converted into a CE requirement per sector using the Erlang B table. This calculation accounts for both CE utilisation and soft handover. The CE requirement per site is then calculated using the blended sectorisation and assuming that a minimum number of 64 CEs are activated on every NodeB. The number of CEs required is obtained by multiplying the number of sites and the CE requirement per site.

The number of carriers required, first per site and then in total, can then be calculated according to a maximum number of CEs deployed per NodeB (128).

The model also includes a cross-check to ensure that the deployed HSDPA capability (in terms of average HSDPA rate per NodeB) can support the offered throughput (in terms of average HSDPA busy-hour throughput per NodeB) in all Fylker in all years.

The cross-check assumes underutilisation of HSDPA channel elements that is greater than R99 channel elements. This is because of the greater difference between the cell loading at its maximum and the loading of the average busy hour for HSDPA compared with that for voice and R99 data. As a result, an average-to-peak busy-hour Erlangs loading of 200% is used in deriving HSDPA channel element utilisation.

This cross-check is linked into the *Ctrl* worksheet and is highlighted in red if the check fails.

Annex B Model adjustments from v8.1 to v9R

In this section, we describe the adjustments made to the calculations and input values of the v8.1 model when deriving the v9R model.

B.1 New calculations

DataForChanges worksheet — A new worksheet has been added to centralise the inputs updated as part of this model update. Each input update can be turned on or off individually using a TRUE/FALSE button on this worksheet.

B.2 Revised input parameters

Updated market subscriber information — Based on Nkom market data, the market shares of 'registered and hosted subscribers (excluding telemetry)' and 'high-speed data subscriptions by operator' have been updated for the period 2013–2016.

Update of demand data for 2013–2016 — Operator data and Nkom market data for the period 2013–2016 have been used to update the assumed market demand in these years. These parameters can be found in a new market calculation worksheet in the v9R model (*M9R*). More detail on these demand-related updates can be found in Section 3.3.

Update of demand forecasts — The updated historical data received from the operators and Nkom for the period 2013–2016 has resulted in some forecast volumes diverging from those in the v8.1 model. As a result, we have updated the forecasts to give a more realistic projection of demand. The specific forecasts updated are discussed in more detail in Section 3.4.

Update of the modelled WACC — The WACC in the v8.1 model has been adjusted to the value that has been calculated in parallel to the cost model update by Professor Thore Johnsen.

Updated inflation — The inflation values assumed for 2014–2016 have been updated using the regular reports produced by Norges Bank. The forecast to 2020 has been updated using the most recent published report.[32] A comparison of the inflation forecasts in the v8.1 model and v9R model is shown in Figure B.1 below.

The values beyond 2020 only affect the outputs of the model after 2020 (as inflation is only applied as a final step). The values have been updated to be

32 See Pengepolitisk report 1/17, http://static.norges-bank.no/contentassets/e6f32a816e5340c280de3f91eb907227/ppr_1_17.pdf?v=03/28/2017090205&ft=.pdf

2.5% after 2020, which is consistent with the long-term inflation assumed in the derivation of the WACC.

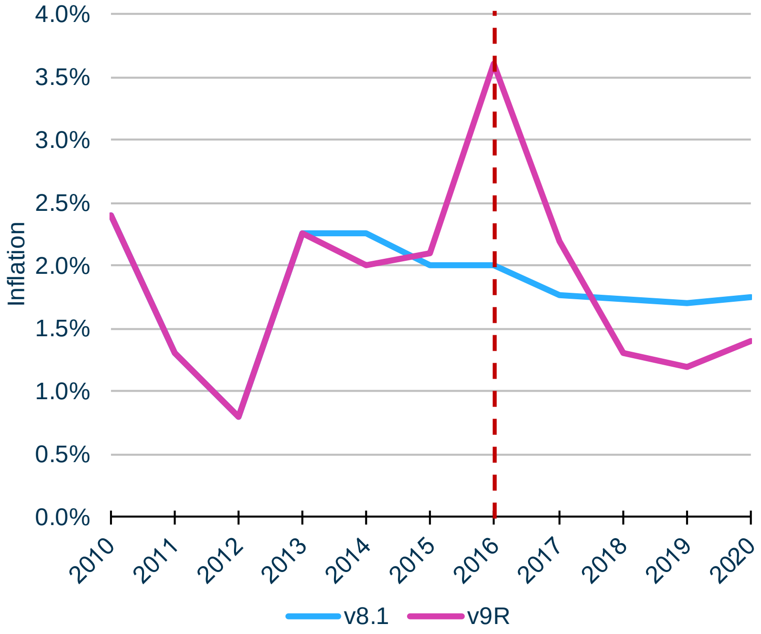


Figure B.1: Comparison of the inflation forecast in the v8.1 and v9R models [Source: Analysys Mason, 2017]

Annex C Expansion of acronyms

2G	Second generation of mobile telephony
3G	Third generation of mobile telephony
BSC	Base station controller
BTS	Base (transmitter) station
EC	European Commission
EDGE	Enhanced data for global evolution
EPMU	Equi-proportionate mark-up
ESA	EFTA Surveillance Authority
GPRS	General packet radio system
GSM	Global system for mobile communications
GSN	GPRS serving node
HLR	Home location register
HS(D)(U)PA	High-speed (downlink) (uplink) packet access
IMS	IP Multimedia Subsystem
IN	Intelligent network
IP	Internet Protocol
LMA	Last mile access
LRIC	Long-run incremental cost
LRIC+++	Long-run average incremental costs, including mark-ups for network common costs, location updates and business overheads
LTE	Long-term evolution
LU	Location update
Mbit/s	Megabits per second
MGW	Media gateway
MHz	Megahertz
MMSC	Multimedia message service centre
MNO	Mobile network operator
MSC	Mobile switching centre
MSS	MSC server
MVNO	Mobile virtual network operator
Nkom	Norwegian Communications Authority
NMS	Network management system
NodeB	Denotes the 3G equivalent of a BTS
OTT	Over-the-top
PTS	Swedish Post and Telecom Authority
R99	Release-99
RNC	Radio network controller
SMS	Short message service
SMSC	SMS centre
TRX	Transceiver
UMTS	Universal mobile telecommunications systems
WACC	Weighted average cost of capital