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Model documentation for the

Norwegian Post and

Telecommunications Authority

NPT's mobile cost model version 8 Draft (v8D)

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Contents

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1 Introduction

The Norwegian Post and Telecommunications Authority (NPT) has determined prices for mobile termination in Norway by means of the long-run incremental cost (LRIC) method since 2007.

In 2006, a bottom-up long-run incremental cost model ('v4') was constructed and finalised for NPT by Analysys Mason Limited ('Analysys Mason'), with the aim of calculating the cost of voice termination for the GSM mobile operators in Norway. In 2009, this model was upgraded to include 3G technologies and a 'Pure LRIC' calculation, and the final version (v7.1) was issued in September 2010. This version (hereinafter referred to as 'the NPT v7.1 model') currently forms the basis of wholesale mobile termination price regulation of Norwegian mobile operators.

In late 2012, NPT contracted Analysys Mason to undertake a further upgrade of the NPT v7.1 model used to set the prices for mobile termination in Norway. This report documents the draft version eight (v8D) of the mobile LRIC model (hereinafter referred to as 'the NPT v8D model') issued for consultation in March 2013. Since the NPT v7.1 model was finalised, the Norwegian mobile market has evolved in several ways, all of which have been reflected in the design of the NPT v8D model:

- Two mobile virtual network operators (MVNOs), Tele2 and Network Norway, formed a joint-venture company (Mobile Norway) in order to deploy a 2G and 3G network. Mobile Norway has deployed significant infrastructure from 2010 onwards. During the second half of 2011, Tele2's parent company (Tele 2 Sverige AB) acquired Network Norway. Therefore, these two MVNOs are now both owned by the same company.

- 3G networks and services have continued to evolve for the mobile network operators, and both Telenor and TeliaSonera (i.e. NetCom) have since launched Long Term Evolution (LTE, or 4G) networks.

- Over-the-top (OTT) services (such as mobile IP telephony and mobile VoIP, and similar services for SMS) are becoming more widespread and are therefore likely to affect the demand forecasts for circuit-switched traffic within the existing model.

- In April 2011, the European Free Trade Association (EFTA) Surveillance Authority (ESA) released a Recommendation for the costing of termination rates,[1] which is analogous to that published by the European Commission (EC) in May 2009.[2] In particular, the Recommendation requires the consideration of a 'generic' operator and 'pure' incremental costing.

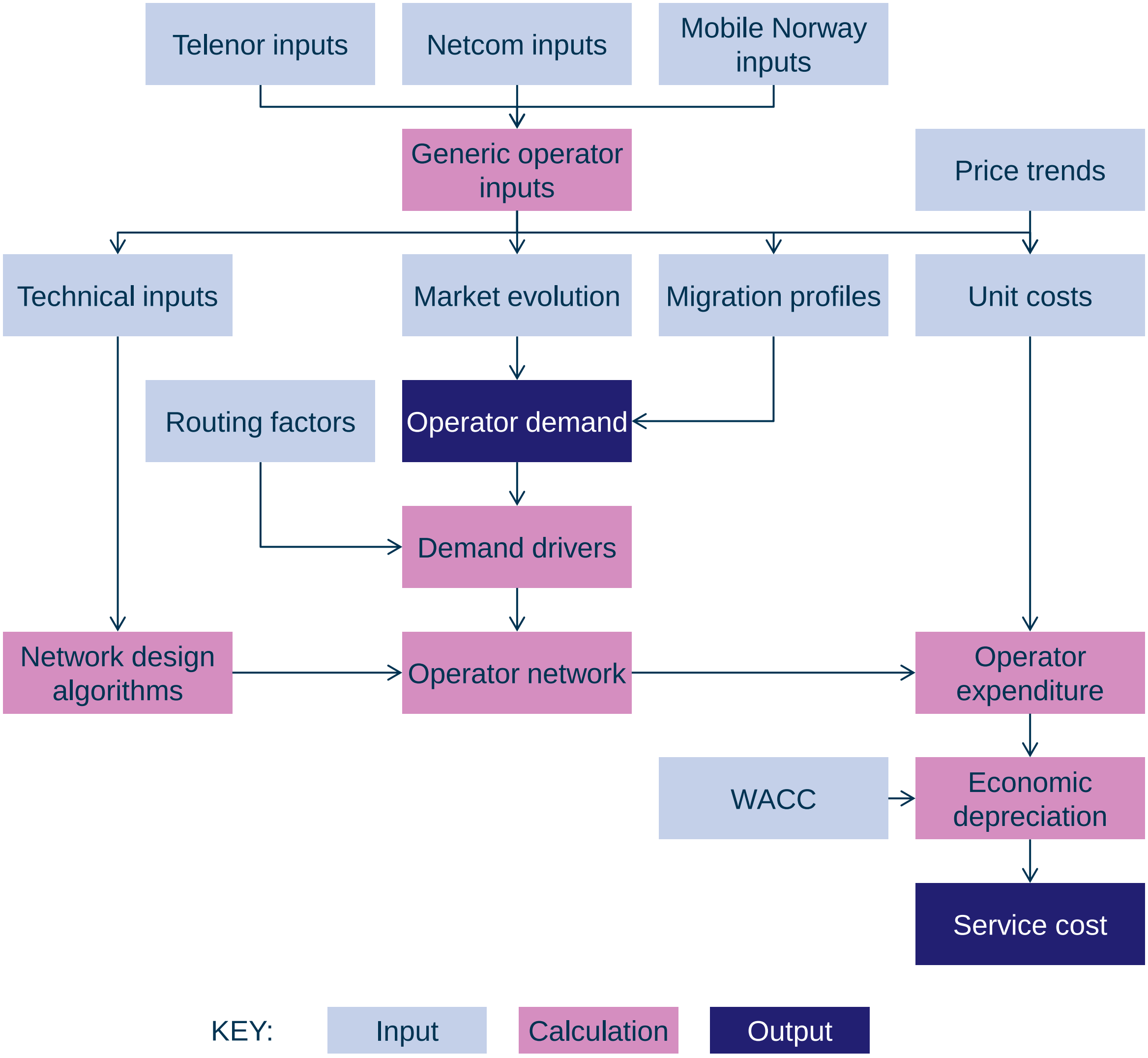
1 See http://www.eftasurv.int/media/internal-market/ESAs-Recommendation-on-termination-rates.pdf

2 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

Once finalised from version 8 draft (v8D) to version 8 final (v8F), NPT intends for the v8F model to inform its future decisions on wholesale termination regulation. This document describes the v8D model for industry consultation.

A schematic of the NPT v8D model is shown below in Figure 1.1. The operator-specific inputs are used to calculate the inputs for a generic operator as discussed in detail in Sections 4.1 and 4.2. The model uses these demand and network design inputs in the calculation of operator expenditure, which is then depreciated and allocated using routeing factors to give the unit costs by service for the three actual mobile network operators and the modelled generic operator.

Figure 1.1: Model schematic [Source: Analysys Mason, 2013]



The remainder of this document is laid out as follows:

- Section 2 describes our reconsideration of the conceptual approach from the NPT v7.1 model to give the concepts used in the NPT v8D model
- Section 3 describes the changes made to the demand forecasting in the NPT v8D model

- Section 4 describes the calculations included to reflect the EC/ESA Recommendations
- Section 5 describes additional changes made to the modelled network design.

The report includes a number of annexes containing supplementary material:

- Annex A provides excerpts from the v7.1 model documentation that describe aspects of the network design that have since been revised
- Annex B provides an overview of the key changes made to the NPT v8D model
- Annex C provides an expansion of the acronyms used within this document.

2 Conceptual approach for the NPT v8D model

The document *Conceptual approach for the upgraded incremental cost model for wholesale mobile voice call termination, 1 August 2009*[3] ('the 2009 concept paper') was developed as part of the previous LRIC process and contained the recommendations on which the NPT v7.1 model was based, covering both the bottom-up calculations and the subsequent top-down reconciliation. This section describes some revisions to these recommendations, which we believe are required.

The conceptual issues previously considered 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 reaffirms the conceptual issues associated with the NPT v7.1 model and distinguishes 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 recommendations from the NPT v7.1 model

The 2009 concept paper was developed as part of the previous LRIC process and established the principles for the NPT v7.1 model. The paper included 17 recommendations that will form the basis of the NPT v8D model, but are being reconsidered due to recent developments in the Norwegian market. Figure 2.1 summarises the recommendations that will require either minor rewording or significant revision in the NPT v8D model. All other recommendations remain unchanged.

Figure 2.1: Conceptual decisions for the NPT v7.1 model [Source: Analysys Mason, 2013]

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

3 See http://www.npt.no/marked/markedsregulering-smp/kostnadsmodeller/lric-mobilnett/_attachment/1803?_ts=1390fd7ef91

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

In the subsequent sections, modifications to recommendations are highlighted in red.

2.2 Operator-related conceptual issues

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

Figure 2.2: Decisions on the operator-related conceptual issues taken for the NPT v7.1 model [Source: Analysys Mason, 2013]

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

The operator-related recommendations are relevant to the modelling of two actual operators and a hypothetical third operator in the NPT v7.1 model. These have been reworded for the NPT v8D model to apply to the three actual operators and a generic efficient operator.

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 alternative: 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 complimentary and valuable reference data points. It is necessary to define the modelling approach 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 the different mobile operators in the Norwegian market can be achieved by being able to model, and parameterise, operators' networks and demand differences 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. In addition, operator-specific models can be discussed bilaterally with each mobile party.

In order to make appropriate decisions regarding price regulation for the Norwegian market, NPT will need to understand the actual costs that each operator faces. 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 NPT'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 demands information from market parties on both network and cost levels. However, the information demands for a hybrid model is only marginally more extensive than would be needed for just a bottom-up or top-down approach.

NPT 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.

NPT believes that the modelling approach that will deliver the most benefits and relevant information for its costing and price-setting activities will be a hybrid model, 'led' from the bottom-up direction. This bottom-up led hybrid model essentially means that the top-down part of the hybrid model is less onerous for all parties, and refined for the purpose of being used as inputs to a bottom-up model:

- 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 top-down 'model' can be condensed to simply a presentation of suitably categorised top-down accounting data, against which the bottom-up model can be reconciled.

The recommendation established in 2009 only needs rewording in order to capture the inclusion of a Mobile Norway-specific calculation and a generic operator, as well as the removal of references to the "third operator" calculation.

> **Recommendation 1, reworded**: 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 NPT's decision on pricing for suppliers in Market 7. However, the choice of operator type for cost modelling purposes, as outlined here, does not preclude NPT 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 will aim 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**: by adopting an average operator approach, the cost model will merge 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 the 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 is described by the EC/ESA Recommendation, 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 NPT 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 recommendation established in 2009 only needs rewording in order to capture the inclusion of a Mobile Norway-specific calculation and a generic operator, as well as the removal of references to the "third operator" calculation.

Recommendation 2, reworded: Adopt an actual operator costing for Telenor, TeliaSonera[4] 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 ~~should be applicable to Mobile Norway as the third infrastructure operator. Actual MVNOs will also be included~~.

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, we also include the volume and profile of traffic that the operator is carrying within the scope of operator size.

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 the operator grows, the lower the eventual unit cost will be.

The recommendation established in 2009 only needs rewording in order to capture the inclusion of a Mobile Norway-specific calculation and a generic operator, as well as the removal of references to the "third operator" calculation.

4 This operator will continue to be referred to as NetCom in the v8D model.

Recommendation 3, reworded: Consistent with Recommendation 2, the actual size of the three actual ~~incumbent~~ 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. ~~NPT will also consider the likelihood of a fourth UMTS infrastructure player entering the market in the near future, and whether any demand scenarios are relevant for exploration in this respect~~. ~~The actual scale of MVNOs will also be modelled.~~

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 revisited in this section are shown in Figure 2.3.

Figure 2.3: Decisions on the technology-related conceptual issues taken for the NPT v7.1 model [Source: Analysys Mason, 2013]

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

2.3.1 Radio technology standard

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

There are 4 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 proxy treatments for the next generation can be suitably 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 – such an allowance would involve 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 would not take into account an analogue component, and efficient forward-looking costs will be unaffected by historical analogue operations.

Including UMTS

Including UMTS explicitly 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. The bottom-up model is significantly more complex as a result of including UMTS and requires additional supporting top-down cost data 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).

In the coming years, two additional technologies will continue to be deployed in Norway:

- (third-generation) UMTS900, which utilises re-farmed 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 – this technology requires a new air interface to be deployed (as well as new user equipment). However, once deployed, this technology will allow both significantly increased data traffic throughput and *proper*[5] mobile voice over IP.

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

[5] 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.

At the time of the original cost modelling work in 2006, NPT 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 is proceeding in some way. All UMTS networks in Norway offer HSDPA services as standard.

At the current point in time (2013), and given the current focus of the model on voice termination, NPT continue to believe that it is not necessary to explicitly model LTE in principle. This decision can be attributed to the uncertainty over key aspects of LTE network deployment:

- the long-term coverage expected for the networks
- the relevant spectrum allocations
- the extent of infrastructure sharing between operators.

The forecast increase of LTE services will have an impact on the traffic carried over the 2G and 3G networks. However, the NPT v8D model does not need to explicitly model the network design for LTE to consider this, although it does need to consider the voice, SMS and data services that are carried over 2G/3G networks. It may also need to implicitly consider some sharing of infrastructure costs between (2G+3G) today's main 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.

It should also be noted that both the EC and ESA Recommendation indicate that a "model for mobile networks should be based on a combination of 2G and 3G employed in the access part of the network", which supports the approach proposed above.

The recommendation established in 2009 will therefore be revised as follows:

Recommendation 4, revised: 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 ~~traffic and~~ 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 – a long-run cost model effectively makes predictions of parameters in perpetuity. Therefore, as operators manage the migration of demand and subscribers from one generation to the next, so too can a LRIC model make corresponding parametric assumptions.

Three particular areas appear most significant in the context of mobile 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[6]. 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[7]). 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 improving generations of a mobile cellular technology. 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[8]. Also, the cost per unit of capacity is likely to reflect continued technological improvement[9]. The key issue for a LRIC model is consistency: modelling continual levels of 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 effectively be shared by successive generations of technology – in these instances it will be possible to extract the same (or greater) utilisation from an

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

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

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

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

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, it is proposed to model LTE implicitly in the NPT v8D model, which affects the treatment of technology generations. The recommendation established in 2009 will therefore be reworded as follows:

Recommendation 5, reworded: 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.

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[10] of coverage 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 The rate, extent and quality of coverage achieved over time determine the present value (PV) of associated network investments

10 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.).

value (PV) of expenditures	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 recommendation established in 2009 requires rewording to take into account the move from two actual operators and a hypothetical third operator in the NPT v7.1 model to three actual operators and a generic efficient operator in the NPT v8D model.

> **Recommendation 6, reworded**: 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.

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
- build or buy preference of individual mobile operators
- availability of new generations of transmission technology from alternative providers
- range and price of wholesale transmission services.

During the upgrade of the model, it will be necessary to analyse differences in network transmission to carry traffic from the base stations, and to connect switching sites with backbone capacity.

All differences between the modelled operators' actual networks will have associated cost implications. Therefore, it will be necessary to identify material transmission differences and explore the method and rationale for selecting the chosen network transmission.

The recommendation established in 2009 only requires a rewording to capture the fact that the generic operator can then use the transmission methods as modelled for the actual operators.

Recommendation 7, reworded: 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 the operators' network is not viewed as efficient or modern in design, or where network rationalisation is planned, the model may be allowed to deviate from the operators' actual number of nodes. This aspect may be highlighted 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 encompassed by 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 efficiently deployed and operated due to infrastructure competition. The main alternative is 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 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.

While the recommendation established in 2009 remains fully applicable regarding the three actual network operators, it requires some clarification with regard to the treatment of the generic efficient operator.

For the generic operator, we wish 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, revised: 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, discussed below, that could be taken in defining 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. This method, whilst comprehensive, 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. Using the lowest unit costs carries the risk of underestimation of costs, since:

- one operator might have access to lower unit costs that cannot be replicated by the other 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 cost.

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 recommendation established in 2009 has been reworded for the NPT v8D model to apply to the generic operator rather than the third operator.

Recommendation 9, reworded: 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[11], band[12] and any fees[13] paid – and use of their allocated spectrum, are likely to differ. Some of these differences may be assessed

11 Amount of paired MHz, less guard bands.

12 PGSM, EGSM or DCS.

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

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 use should be understood and estimated, and could be taken into account in the cost basis of regulated prices if appropriate (and significant). 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 greatly assists manageable scorched-node calibration of a bottom-up network design with actual data, and reconciliation of calculated costs with actual costs.

Alternatively, some hypothetical amount of spectrum could be defined –this 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 recommendation established in 2009 has been revised in order to specify the methodology used for the allocation of spectrum to the generic efficient operator in the NPT v8D model. Additional text has been 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, revised**: 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. ~~It is expected that spectrum differences are negligible for Telenor and TeliaSonera.~~ 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 repeating the existing spectrum allocations and applying inflation-increasing payments.

2.4 Service-related conceptual issues

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

Figure 2.4: Decisions on the service-related conceptual issues taken for the NPT v7.1 model [Source: Analysys Mason, 2013]

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

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. 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, and should result in a lower unit cost for voice services due to economies of scope. Conversely, however, excluding costs relevant to non-voice GSM services (and developing a standalone voice cost) can also be complex. 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 requires revision to indicate that the NPT v8D model now includes forecasts for additional services, namely:

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

Recommendation 11, revised: The modelled operator should provide data services (SMS, GPRS, EDGE, HSPA and LTE) alongside voice services. The modelled operator will additionally provide over-the-top (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 ~~(compared to four years ago when data accounted for less than 5% of network traffic)~~.

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, NPT has identified its market analysis as that relating to the wholesale call termination market. As such, NPT 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 Recommendation as established in 2009 has been left unchanged.

Recommendation 12, unchanged: 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 revisited in this section are shown in Figure 2.5.

Figure 2.5: Decisions on the implementation-related conceptual issues taken for the NPT v7.1 model [Source: Analysys Mason, 2013]

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

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 Recommendation as established in 2009 does not need to be changed.

Recommendation 13, unchanged: Update NPT's mobile operator WACC calculation.

2.5.2 Depreciation method

The model for mobile network services will produce 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. The table below shows that only economic depreciation considers all potentially relevant depreciation factors.

Figure 2.6: Factors considered by each depreciation method [Source: Analysys Mason, 2013]

	HCA	CCA	Tilted annuity	Economic
Modern-equivalent asset (MEA) cost today		✓	✓	✓
Forecast MEA cost			✓	✓
Output of network over time				✓
Financial asset lifetime	✓	✓	✓	✓[14]

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 economic depreciation. The difference between HCA and CCA depreciation is 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
- reflect the output of network elements over the long run.

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

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 of being able 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 to be used 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 Recommendation established in 2009 will remain unchanged.

> **Recommendation 14, unchanged**: NPT 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 final costing stages, common costs may be marked up onto the relevant increments.

The size and number of adopted increments affects the complexity[15] of results and the magnitude[16] of the marked-up incremental costs.

15 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.

16 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 *with* and *without* the defined increment.

Where increments include more than one service, rules will 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 it is through routeing factors, rather than network algorithms, that non-voice service incremental costs are identified.

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 NPT v7.1 model is capable of calculating the incremental costs of wholesale 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 of the economic depreciation when including or excluding termination traffic.

Any combination of these two effects can currently be calculated. However, the NPT v8D model is intended to focus on the Pure LRIC calculation that **includes network adjustments** and **calculates economic depreciation of the avoided costs**.

The Recommendation established in 2009 has been reworded to emphasise this approach.

> **Recommendation 15, reworded**: In order to supply NPT 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 costs of terminated voice.

2.5.4 Years of results

There are three options for timeframes for 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 as to 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 as to 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 Recommendation established in 2009 will not be changed.

Recommendation 16, unchanged: NPT proposes to adopt a full time-series model that calculates the costs of operators from their GSM launch in 1993 (and capturing the first GSM expenditure in 1991 and 1992), 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 NPT the greatest understanding of cost evolution and flexibility in exploring pricing options. The third operator will be modelled according to a recent entry date, in a full time-series approach that considers its current and future years of operation.

2.5.5 Mark-up mechanism

The specification of an 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 are 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 least distorting consumer consumption and welfare away from the optimal). Variants exist on 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 Recommendation established in 2009 will not be changed.

Recommendation 17, unchanged: NPT 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 development of the NPT v7.1 model, certain new trends and technologies have emerged in the mobile market, which have required a reassessment of the modelling of the demand forecasts. The most significant of these changes have been:

- the global development of fourth generation (4G, or LTE) mobile networks and devices
- an increase in adoption of over-the-top (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.

The details of our adaptations of the demand forecasts to encompass these changes are discussed below:

- Section 3.1 discusses the implicit modelling of LTE traffic and services in the NPT v8D model
- Section 3.2 discusses the inclusion and modelling of OTT traffic.

In addition, data received from NPT, operators and from publicly available data sets has been used to update demand parameters in the NPT v8D 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 the development of the NPT v7.1 model in 2010, both Telenor and TeliaSonera have begun deploying LTE networks, rolling out in a number of the main cities in Norway.[17]

The ESA Recommendation[18] explicitly states that "*the bottom-up model for mobile networks should be based on a combination of 2G and 3G employed in the access part of the network*". Therefore, the NPT v8D model does not directly model the costs of LTE services.

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 final version of the model issued in July 2011[19] indicated that, for a 2G/3G network operator:

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17 Based on Telenor's website, LTE coverage is currently limited to parts of Oslo, Stavanger, Trondheim, Bergen, Kristiansand and near Frederikstad. Based on TeliaSonera's website, coverage appears to be more extensive and includes much of the coast of south-east Norway and other areas in central Norway.

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

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

- 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 the possibility of a percentage of LTE demand to be passed into the routeing factor table for shared infrastructure supporting 2G+3G and LTE network layers (effectively, radio sites). This estimate the effects of cost sharing between services, but is not active in the basecase of the draft model.

The migration of voice, SMS and high-speed data services to an LTE network has been added into the demand calculations in the NPT v8D model. The changes made and calculations used for deriving the services carried over the LTE network are found on the *D3_M8* worksheet and are discussed in more detail below.

3.1.1 Voice and SMS demand forecast updates

The previous NPT v7.1 model's voice and SMS forecasts 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 is used as for the migration of services from 2G to 3G networks. As a result, the total voice/SMS traffic across all technology generations remains largely the same as in the NPT v7.1 model, with only the proportion of this traffic for each generation updated in the NPT v8D model.

The traffic demand calculations are updated by introducing 3G to LTE voice and SMS migration profiles to the *D3_M8* worksheet of the model. These migration profiles are derived 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 VoLTE and IMS deployment by operators.

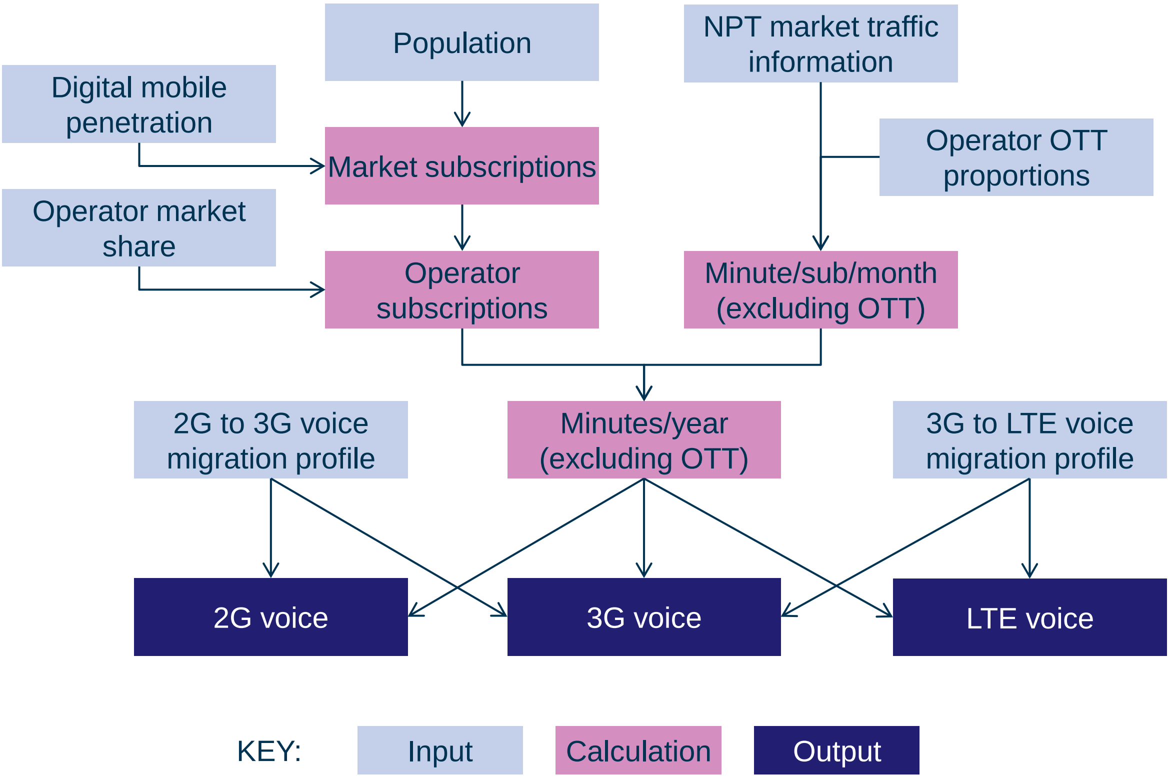
These new traffic migration profiles feed into the calculations of 3G and LTE voice demand forecasts as can be seen in Figure 3.1 below, with the specific calculations as follows:

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

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

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

Figure 3.1: Illustration of the voice traffic calculations in the NPT v8D model [Source: Analysys Mason, 2013]



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) greater economies of scope which can be anticipated by 2G+3G+LTE combined 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 High-speed data demand forecast updates

While the NPT v7.1 model contained forecasts for total market voice minutes and SMS, the forecast high-speed data traffic considered only megabytes carried over 3G (specifically, the HSPA) networks[20].

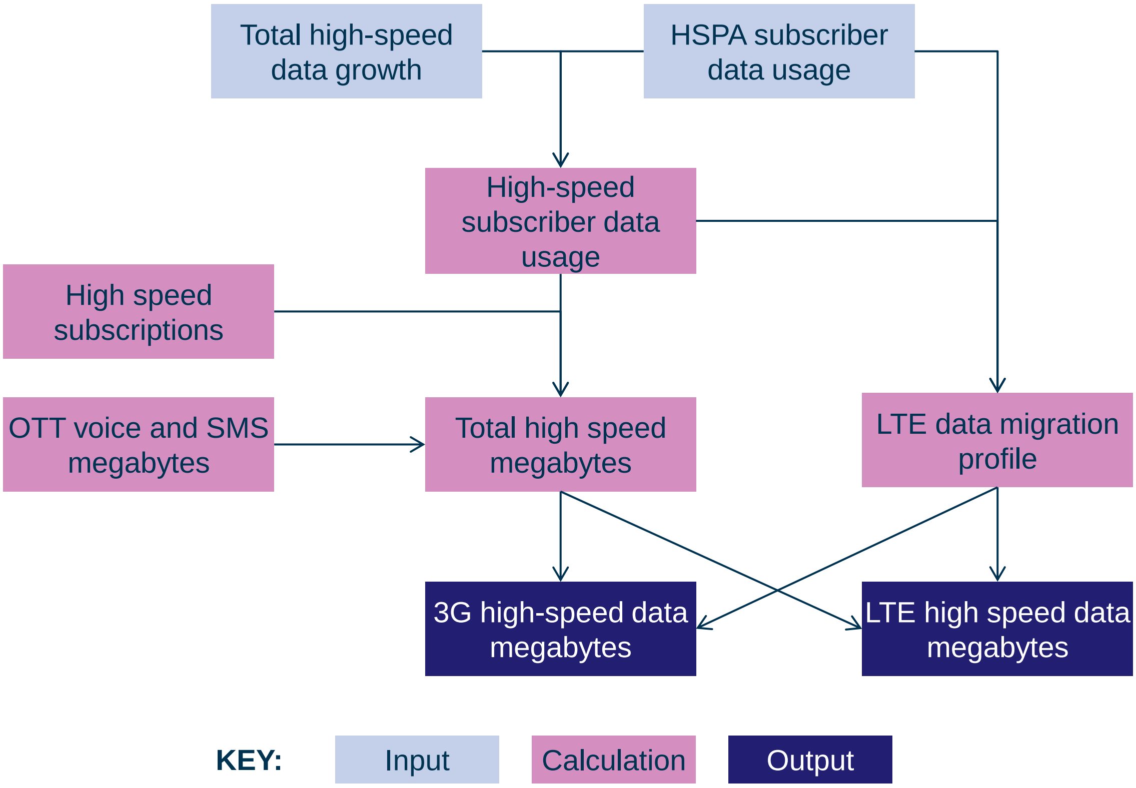
Inputs for the total high-speed data traffic (across all technologies) have been added to the model with these figures derived from historical operator data on the proportion of total mobile

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

broadband traffic carried over LTE and year-on-year growth in data usage per connection derived from NPT market data . Our modelled migration of data traffic to the LTE network begins in 2009, reflecting the launch of TeliaSonera's LTE network.

The LTE high-speed data traffic is therefore calculated as the difference between this total NPT v8D model forecast and the existing NPT v7.1 model HSPA forecast, which has been forecast to remain stable from 2016 onwards, as illustrated in Figure 3.12. 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 NPT v8D model [Source: Analysys Mason, 2013]



3.2 Over-the-top (OTT) traffic

OTT services are carried by third-party clients using data bearers. This traffic is therefore 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 are therefore 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.

In our consideration of OTT voice and SMS traffic, we have continued to forecast *total* voice usage by service, and *total* SMS by service. We have then separated the OTT voice and SMS traffic out from the total, technology-neutral, traffic projections in the model using a modelled proportion of this traffic in each year that is carried by OTT. This proportion is derived from operator data, as well as information from NPT's "*The population's use of electronic communications in 2011*" survey.[21]

Figure 3.3 below indicates that in 2011 few users surveyed made regular use of OTT services. This suggests very low current levels of take-up for OTT services in Norway, and this conclusion is supported by operator data. Use of OTT services is 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.

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

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

Therefore, we have used a conservative forecast for OTT take-up in the NPT v8D model, with a slow increase in the proportion of voice/SMS traffic carried as OTT to 15% in the long term.

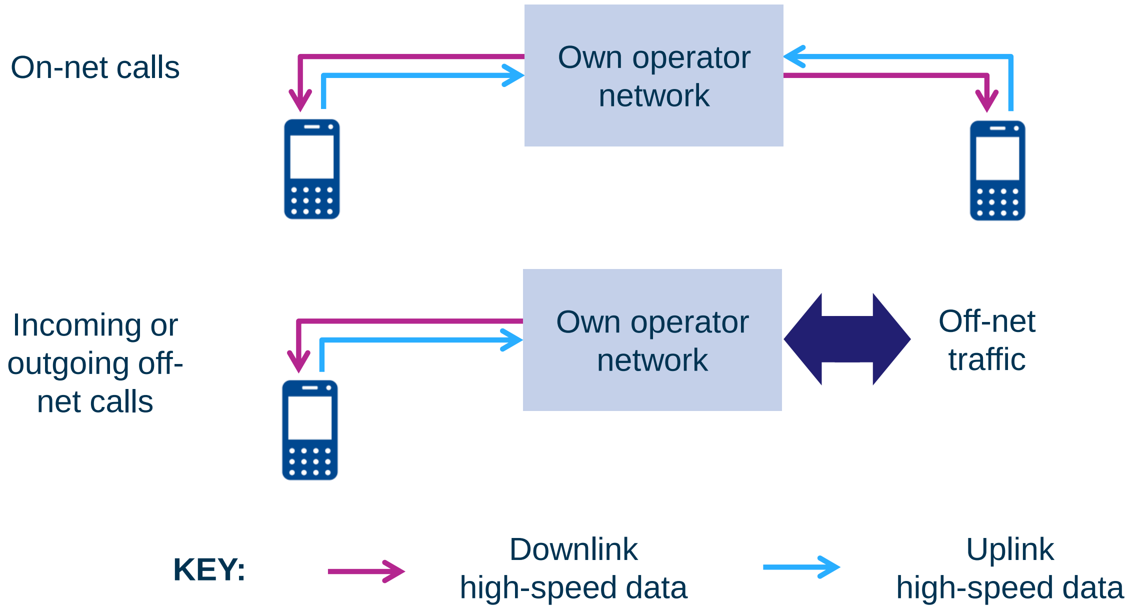
The OTT traffic is then converted to high-speed megabytes and included in the modelled service demand as HSPA and LTE traffic. The conversion rate used for the OTT voice traffic is derived from the Skype figures for both the minimum and recommended download and upload speeds for calling, as reported on its website.[22] Meanwhile, the conversion factor for OTT SMS traffic uses the bytes per SMS factor from the NPT v7.1 model.

The calculated megabytes of data traffic are then included into 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.

21 See http://data.norge.no/data/befolkningens-bruk-av-elektroniske-kommunikasjonstjenester-2011.

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

Figure 3.4: Data traffic generated by OTT voice calls [Source: Analysys Mason, 2013]



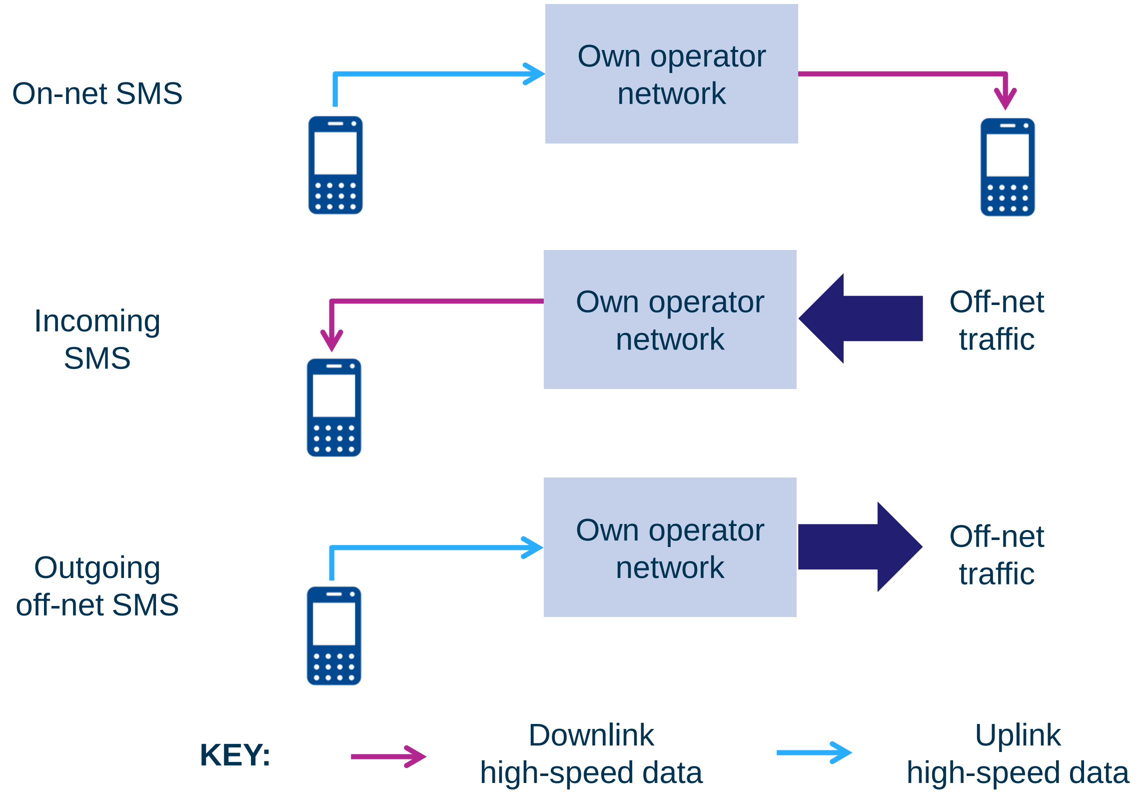
As a result of the difference in treatment of data traffic to voice traffic, the OTT voice traffic is included in the high-speed data forecasts as follows:

$$High - speed\ upload\ data\ OTT\ voice\ megabytes = 2 \times on - net\ OTT\ minutes + incoming\ OTT\ minutes + outgoing\ OTT\ minutes$$

$$High - speed\ download\ data\ OTT\ voice\ megabytes = 2 \times on - net\ OTT\ minutes + incoming\ OTT\ minutes + outgoing\ OTT\ minutes$$

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, 2013]



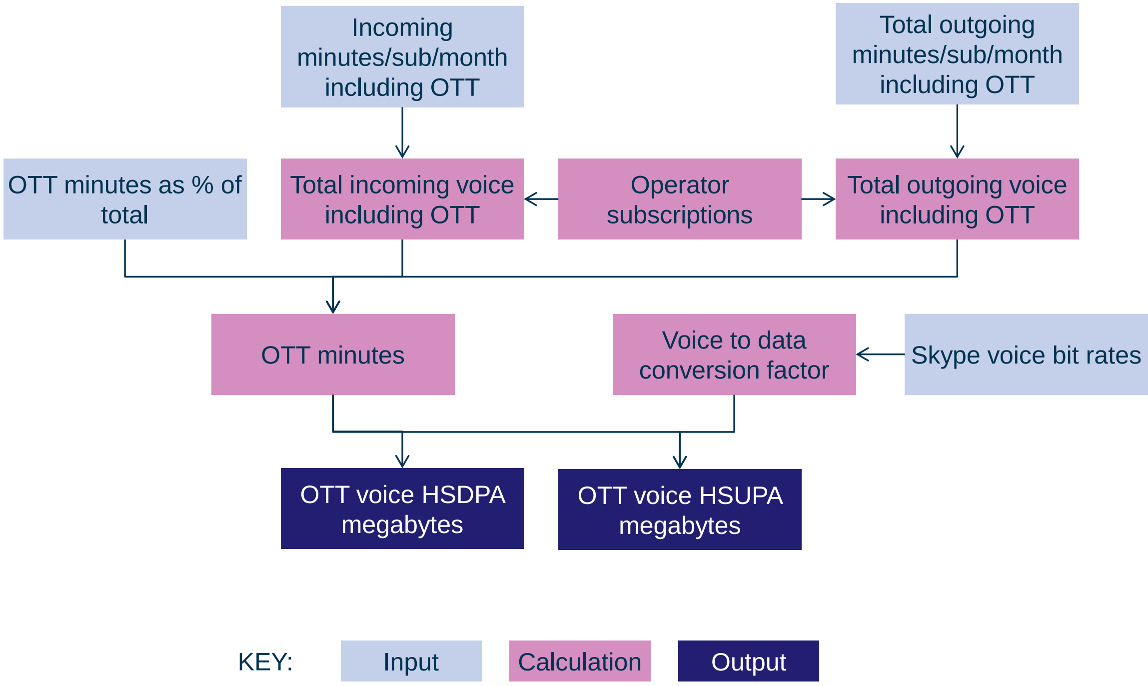
The treatment of OTT SMS traffic means that we use the following formulae in our mapping of OTT SMS traffic onto the modelled high-speed demand forecasts:

$$Highspeed\ upload\ data\ OTT\ SMS\ megabytes = onnet\ OTT\ minutes + outgoing\ OTT\ minutes$$

$$Highspeed\ download\ data\ OTT\ SMS\ megabytes = onnet\ OTT\ minutes + incoming\ OTT\ minutes$$

The changes made and calculations used for deriving the OTT traffic and megabytes are found on worksheet *D3_M8* 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 NPT v8D model [Source: Analysys Mason, 2013]



3.3 Updates of historical demand parameters

Historical demand updates for the years 2009–12 were provided both in the NPT market data and by operators in response to data requests. These have been used in the update of historical demand parameters in the NPT v8D model. The data received was used in the assignment of mobile service providers to a host mobile network operator (MNO) i.e. Telenor, TeliaSonera or Mobile Norway.

A new demand data worksheet (*D3_M8*) has been included in the NPT v8D model and updated in order to align demand inputs (mainly for Telenor, TeliaSonera and Mobile Norway) with the NPT market data. The model can be configured using any of the three market calculations.

Details of the updated demand parameters to be found in the NPT v8D model are shown in Figure 3.7 below.

Figure 3.7: Historical demand parameters in the NPT v8D model updated for the years 2009–12 [Source: Analysys Mason, 2013]

Input	Operators updated	Source used for data update
Digital mobile penetration	Total mobile market	NPT market data
Market share of high-speed subscriptions by operator	All operators	NPT market data
Mobile broadband penetration	Total mobile market	NPT market data
Market share by operator	All operators	NPT market data
Outgoing voice minutes per subscriber per month	All operators	NPT market data
On-net minute proportion	All MNOs	NPT market data

Incoming voice minutes per subscriber per month	All MNOs	Both operator data and NPT market data
Outgoing SMS per subscriber per month	All MNOs	Operator data
On-net SMS per subscriber per month	All MNOs	Operator data
Incoming SMS per subscriber per month	All operators	Both operator data and NPT market data
Low-speed data MB per subscriber per month	All operators	Operator data
Mobile broadband HSDPA megabytes per high-speed subscription per month	All operators	Operator data

3.4 Updates of forecast demand parameters

The population year-end historical data and forecasts have also been updated for the years 2009–41 using data from Statistisk Sentralbyrå (SSB).[23] This forecast is consistent with that contained in NPT's v1.6 fixed model.

These changes made to the 2009–12 parameters in the NPT v8D model 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	v7.1 monthly forecast	v8D monthly forecast
Digital mobile penetration	115%	115%
Mobile broadband penetration	20%	20%
Originated voice	240 min/sub/month	190 min/sub/month
Incoming voice	125 min/sub/month	110 min/sub/month
Incoming SMS	50 SMS/sub/month	50 SMS/sub/month
Outgoing SMS	70 SMS/sub/month	70 SMS/sub/month
Low-speed data usage	10 MB/sub/month	100 MB/sub/month
HSPA data usage	1000 MB/sub/month	1400 MB/sub/month

Figure 3.8: Modelled long-term forecast endpoints in the NPT v7.1 and v8D models [Source: Analysys Mason, 2013]

The most significant of the updated forecasts in the NPT v8D model are described in more detail below, namely:

- Section 3.4.1 discusses the modelled population forecasts
- Section 3.4.2 discussed the modelled mobile broadband penetration forecasts
- Section 3.4.3 discusses the modelled high-speed data traffic forecasts.

23 See http://www.ssb.no/befolkning/

3.4.1 Population

We note that the long-term projected endpoint of 5 million used in the v7.1 model was exceeded in March 2012, according to SSB.[23] The v8D model now projects that the population will continue to grow, reaching 6.461 million in 2041, rather than stabilising at 5 million as was assumed in the v7.1 model. As stated above, this is consistent with the population forecast used in NPT's v1.6 fixed model.

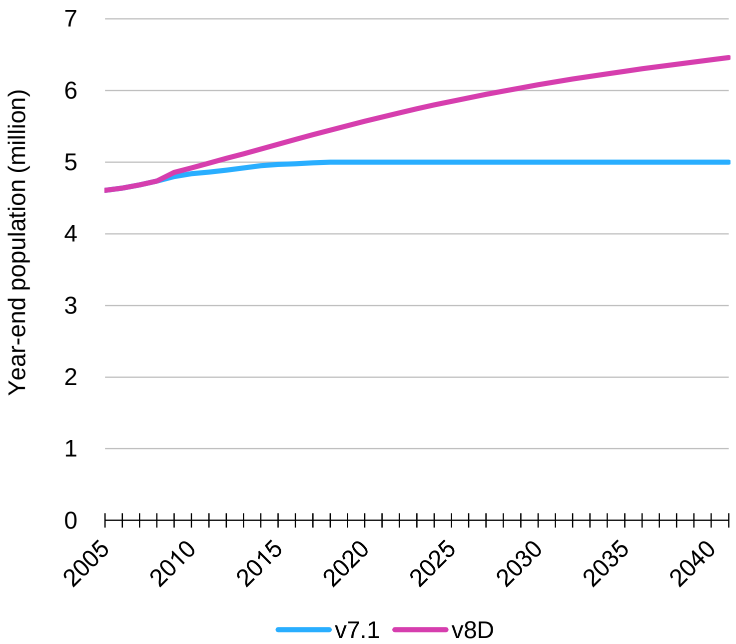


Figure 3.9: Population forecasts in the NPT v7.1 and v8D models [Source: Analysys Mason, 2013]

As a result of this increased population forecast, total voice traffic carried by the mobile networks in the NPT v8D model is actually higher than that in the v7.1 model despite the reduction in voice usage per subscriber per month described in Figure 3.8. While there is population growth forecast across all Fylker, it 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 2020	Fylker
1.51% – 1.00%	Akershus, Aust-Agder, Buskerud, Oslo, Rogaland
1.01% – 1.50%	Hordaland, Møre og Romsdal, Østfold, Sør-Trøndelag, Vest-Agder, Vestfold
0.51% – 1.00%	Finnmark, Hedmark, Nord-Trøndelag, Oppland, Sogn og Fjordane, Telemark, Troms
0.01% – 0.50%	Nordland

Figure 3.10: Compound annual growth rate of population forecasts by Fylker for the years 2012–2020 [Source: Statistisk Sentralbyrå (SSB), 2013]

3.4.2 Mobile broadband penetration

While the long-term demand forecast for mobile broadband penetration in both the v7.1 and v8D models remains the same at 20%, penetration in the v8D model is forecast to fit with the updated data points for the years 2009–12 and reaches this endpoint more slowly. The modelled year-on year growth rates for mobile broadband penetration after 2012 has been cross-checked with NPT market data. The mobile broadband penetration forecasts are shown in Figure 3.11.

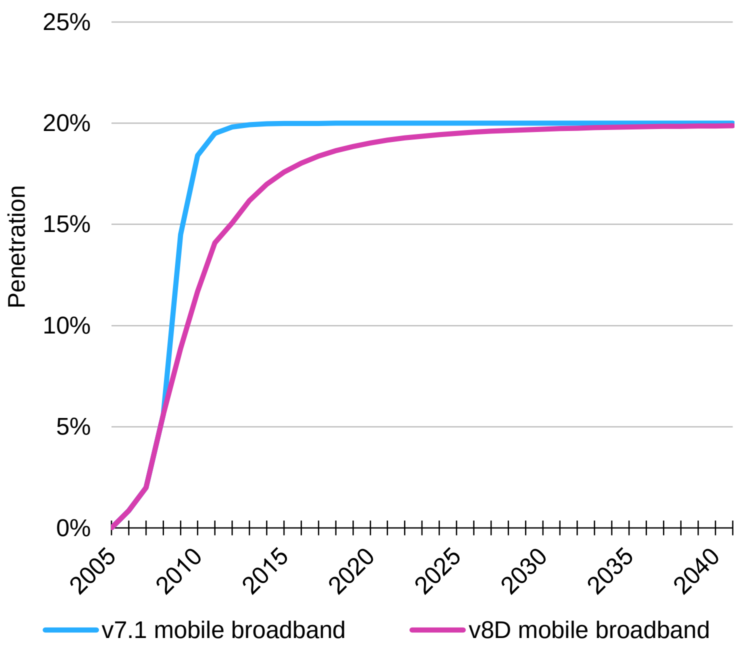


Figure 3.11: Mobile broadband market penetration in the NPT v7.1 and v8D models [Source: Analysys Mason, 2013]

3.4.3 High-speed data traffic

The growth forecasts for total high-speed data traffic discussed in Section 3.1.2 result in a rapid increase in modelled data traffic. While the proportion of this high-speed data traffic carried by LTE networks increases during the modelled time period, as shown in Figure 3.12, the long-term demand forecasts for HSPA services in the NPT v8D model have been set such that traffic over HSPA remains stable at approximately 20 billion megabytes from 2016 onwards.

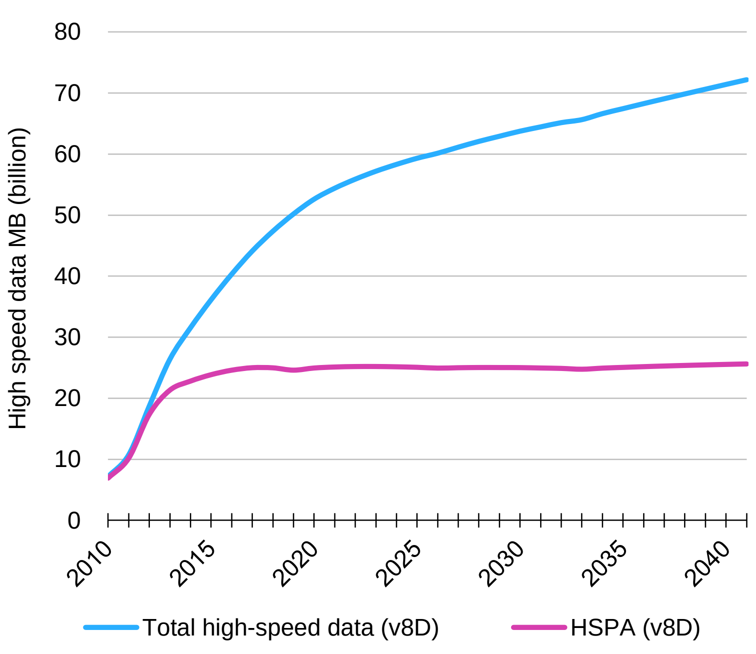


Figure 3.12: Total data consumption in the NPT v8D model [Source: Analysys Mason, 2013]

4 Calculations related to the EC/ESA Recommendations

Both EC[24] and ESA[25] have released recommendations regarding the costing calculations for mobile termination rates. A number of adjustments have been made to both the NPT v7.1 model and the NPT v8D model to consider these recommendations:

- Section 4.1 outlines the structure of the addition to the NPT v8D model 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 NPT v8D model.
- Section 4.4 sets out the existing LRIC and LRIC+++ calculations in NPT's model.

4.1 Structure of the generic operator calculation

The NPT v8D model models a generic Norwegian operator in addition to the three actual MNOs.

The modelling of a generic operator is outlined in the ESA released recommendation for 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.[26]

To create a generic operator calculation, the inputs can be determined as a function of the inputs from the actual MNOs (Telenor, TeliaSonera and Mobile Norway). These actual operator inputs have been calibrated and reconciled to the most recent year of available operator data (2011 or 2012) and are 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 *A0_CTRL* worksheet. The inputs are then selected on the *A9_M*, *A6_NtwDesSlct*, *A8_UtilIn*, and *D4_CostBase* worksheets. When distributed to operators and published, the generic operator inputs will be given as 'pasted values' in the Excel worksheets. This is because the worksheets with confidential operator-specific data (where the generic operator input calculations are undertaken) are redacted prior to distribution of the model. However, as part of the redaction, we leave 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.

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

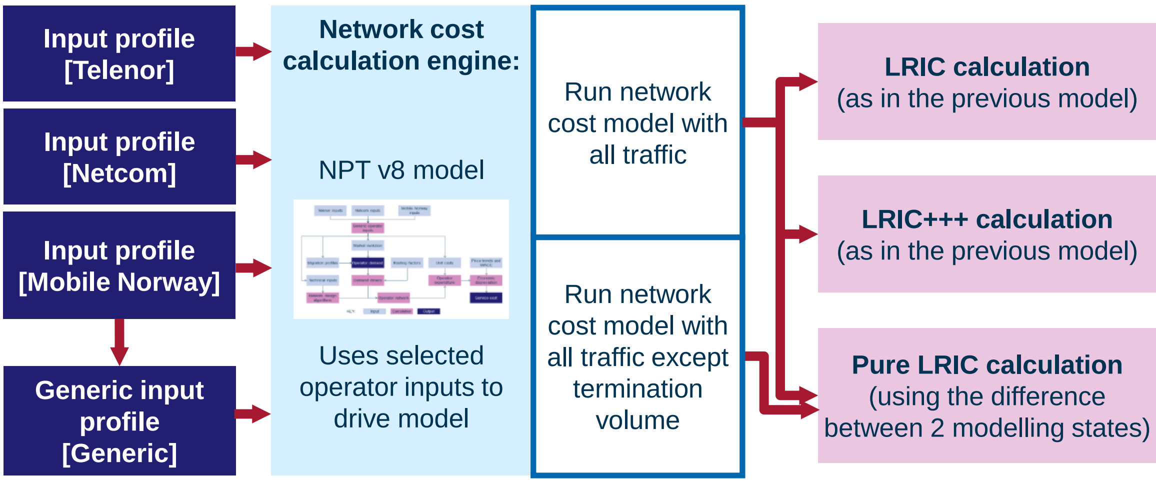
25 See http://www.eftasurv.int/media/internal-market/ESAs-Recommendation-on-termination-rates.pdf.

26 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.

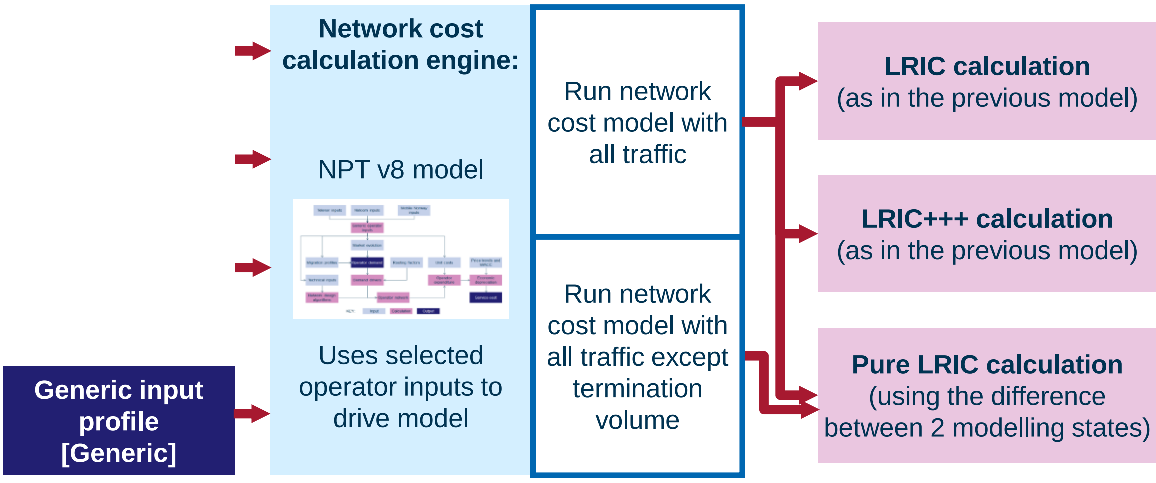
In Figure 4.1 below, we illustrate how the actual operator-specific inputs feed into the generic operator input profile and how any of these input profiles can be used to parameterise the NPT v8D model. The NPT v8D model produces LRIC, LRIC+++ and Pure LRIC service cost outputs for the three actual operators and the generic operator. The model as shown below has been delivered to NPT.

Figure 4.1: Structure of the full model as delivered to NPT [Source: Analysys Mason, 2013]



The NPT v8D model has been redacted in order to be published by NPT. Figure 4.2 below shows the material that will be publicly available.

Figure 4.2: Structure of the redacted NPT v8D model as published by NPT [Source: Analysys Mason, 2013]



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 proposed definition of these inputs is described in Figure 4.3 below. 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 4.3: Key input values for the generic operator [Source: Analysys Mason, 2013]

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 NPT 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 and 3G voice, SMS and data services as currently modelled beginning at launch	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 below in Figure 4.4.

Figure 4.4: Other input values for the generic operator [Source: Analysys Mason, 2013]

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	• TSC 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 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 an UMTS coverage using both 2100MHz and 900MHz spectrum. This coverage is assumed to be for 99.99% of population, with the corresponding area coverage shown by Fylke below in Figure 4.5.

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 4.5: Comparison of total UMTS area coverage by Fylke [Source: Analysys Mason, 2013]

4.2.2 Generic operator subscriber market share

As stated in Figure 4.3, 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 Norway is covered by 2.85 networks, with Telenor/TeliaSonera attaining almost 100% coverage and Mobile Norway 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 NPT.[27] These assumptions give a generic operator voice market share of 100%/285%= 35.1%.

For the market share of data, we first of all account for the 450MHz operator ICE[28], which has approximately a 5% market share. On the remaining 95% of the market, we then use the same calculation as for voice to give a generic operator data market share of (100%–5%)/(100%+100%+85%) = 33.3%. We remove ICE since it is unlikely that their current spectrum holdings will allow them to carry a significant market share of data traffic in the long-term.

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

28 According to http://www.ice.no/privat/dekning.aspx, ICE currently has approximately 90% population coverage.

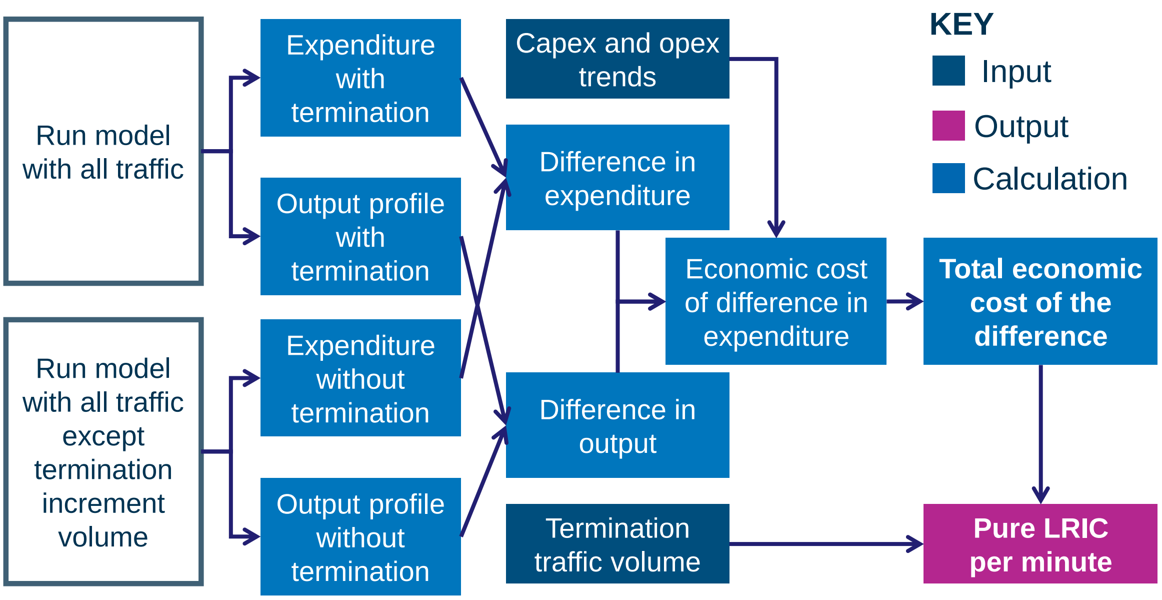
4.3 The Pure LRIC calculation

The NPT v7.1 model was updated 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 NPT v7.1 model documentation.[29] 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 NPT v8D 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 *A0_Ctrl* worksheet will result in the model calculating twice, with the necessary information from both runs stored as values on the *D1_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, 2013]



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.

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

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 termination is excluded. The Pure LRIC calculation has been further refined in the modelling in terms of two technical adjustments detailed 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 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 NPT v7.1 model documentation.

4.3.1 Technical adjustments to the network design to increase traffic sensitivity

The calculation has been adjusted to include specific traffic sensitivity in parts of the network design where assets are not avoided, but where it can be expected that assets would be avoided in the case of a 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 NPT v8D model are:

- a smaller-scale deployment of GSM in-fill sites
- a slight increase in the 3G cell radii for the six most urban Fylker.[30] 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 NPT v8D model includes 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

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

is then used to derive a blended contribution per minute, which is added to the calculated Pure LRIC.

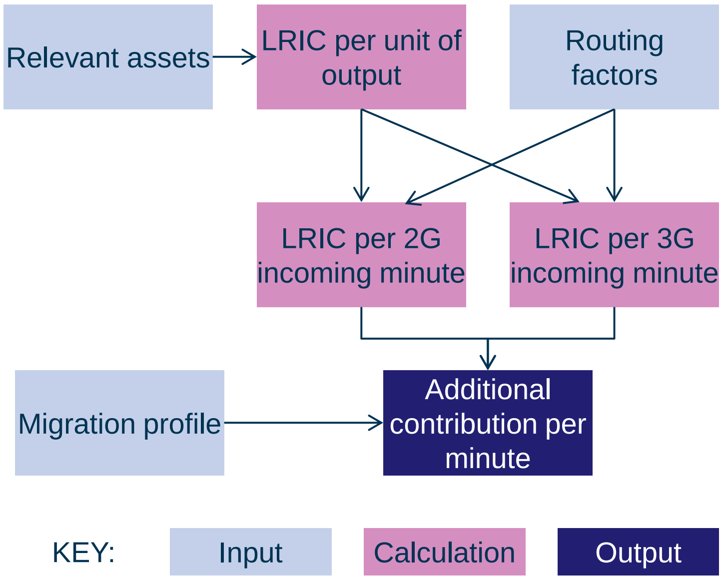


Figure 4.7: Calculation of an additional contribution to the Pure LRIC to capture non traffic-sensitive costs [Source: Analysys Mason, 2013]

4.4 The LRIC and LRIC+++

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

For the LRIC, as detailed in Section 7.1 of the NPT v7.1 model documentation,[31] 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. These include:

- network common costs (including the mobile coverage layer)
- location updates
- administrative overheads.

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

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

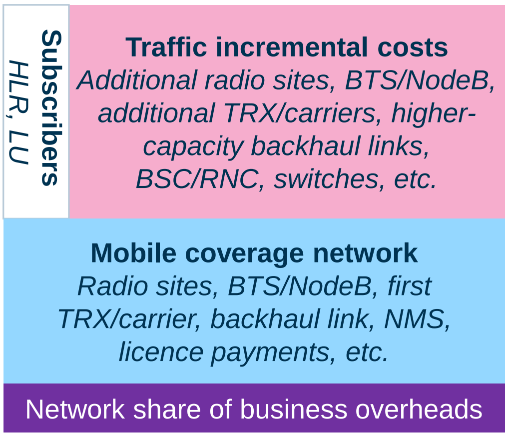


Figure 4.8: Illustration of the costs relevant to the LRIC+++ [Source: Analysys Mason, 2013]

5 Mobile network design

For full details of the network design in the NPT v7.1 model, please refer to Section 4 and Annex A of the NPT v7.1 model documentation.[32] The majority of the mobile network design remains the same as in this model. The small numbers of changes that have been made are described below.

5.1 HSPA upgrades

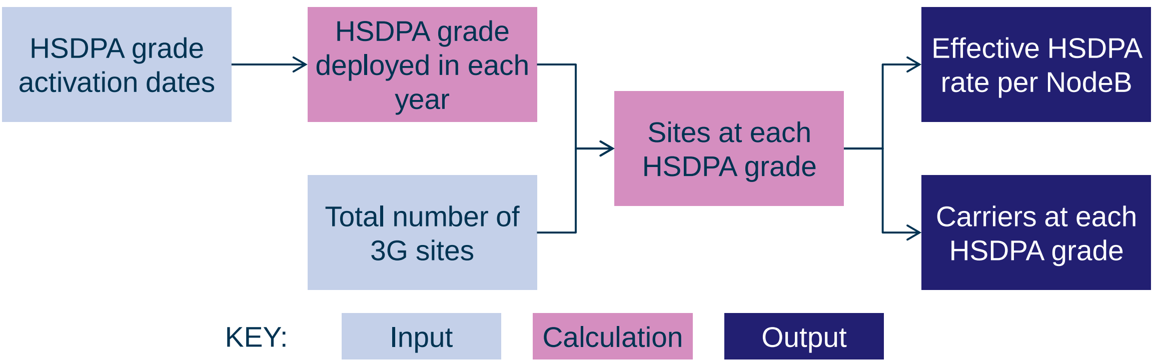
For full details of the HSPA network design, please refer to Annex A.2.3 of the NPT v7.1 model documentation.[33] In addition to the four grades of HSPA deployed in the NPT v7.1 model, three further HSPA software upgrades have been included in the NPT v8D model. The grades that are now modelled are shown below in Figure 5.1.

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

Figure 5.1: Grades of HSPA modelled [Source: NPT v8D model, 2013]

In the NPT 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 HSDPA14.4). In the NPT v8D model, all Fylker are upgraded to an HSDPA grade in a specified year of activation. An equivalent approach is used for HSUPA deployments.

Figure 5.2: HSDPA element deployment [Source: Analysys Mason, 2013]

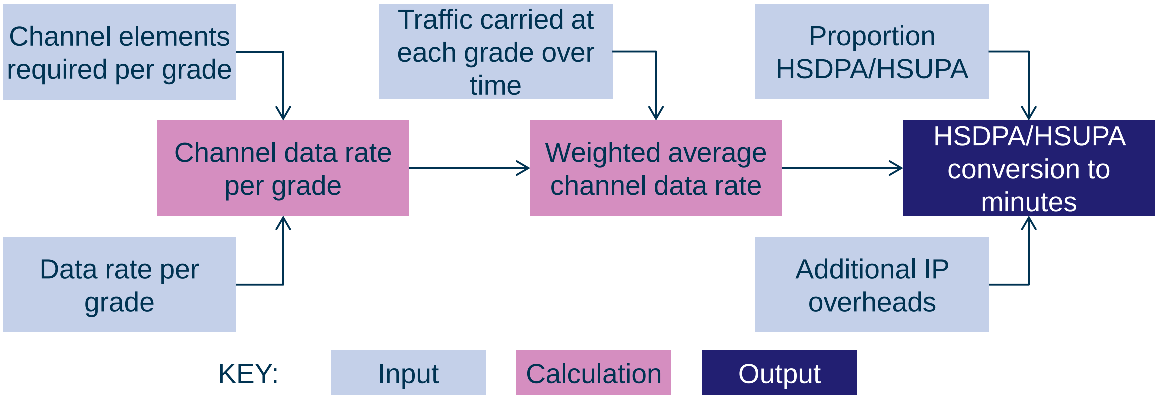


32 See http://www.npt.no/marked/markedsregulering-smp/kostnadsmodeller/lric-mobilnett/_attachment/1804?_ts=1390fd85d55

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

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 has been updated in the NPT v8D 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 5.3.

Figure 5.3: Modelling flow of HSDPA and HSUPA conversion factors [Source: Analysys Mason, 2013]



5.2 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 NPT v7.1 model documentation.

As with the NPT v7.1 model, 3G backhaul is assumed to be logically and physically separate from 2G backhaul in the NPT v8D model. The NPT v8D model now contains 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 NPT v7.1 model.

The NPT v8D 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 necessary 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 below in Figure 5.4.

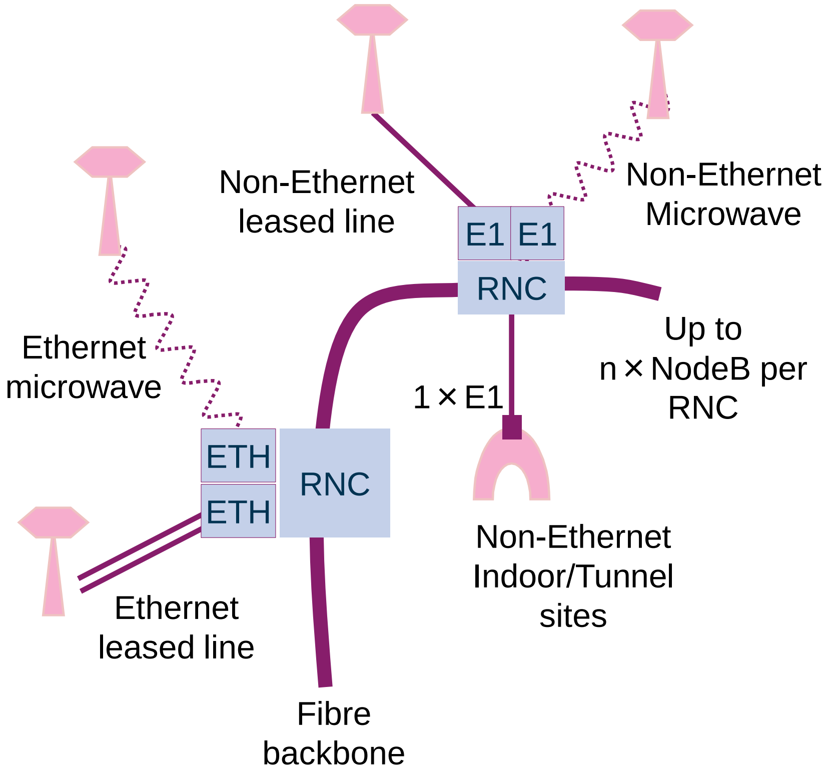


Figure 5.4: 3G backhaul physical configuration [Source: Analysys Mason, 2013]

5.3 Spectrum licences

The spectrum allocations and spectrum fees for the 2100MHz spectrum licences have been updated for the NPT v8D model in line with the results of the auction in November 2012,[34] with a renewal period of 20 years. Furthermore, both of Mobile Norway's 2100MHz licences are renewed separately.

NPT 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 by the relevant level of forecast inflation. The 2100MHz licences are modelled as being renewed after 20 years.

34 See http://www.npt.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 NPT v7.1 model, please refer to Section 4 and Annex A of the NPT v7.1 model documentation.[35] Revisions have been made to the network design concerning HSPA software upgrades (and subsequent channel kit requirements), as well as the determination of the 3G backhaul.

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

A.1 Radio network: Channel kit (CK) and carrier requirements

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

CK requirements for voice/R99

To calculate channel element (CE) requirements for voice and R99 data, the inputs required are:

- total voice and R99 BHE traffic by Fylke
- total NodeB sectors and sites by Fylke (as previously calculated)
- channel element utilisation.

Figure A.1 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.

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

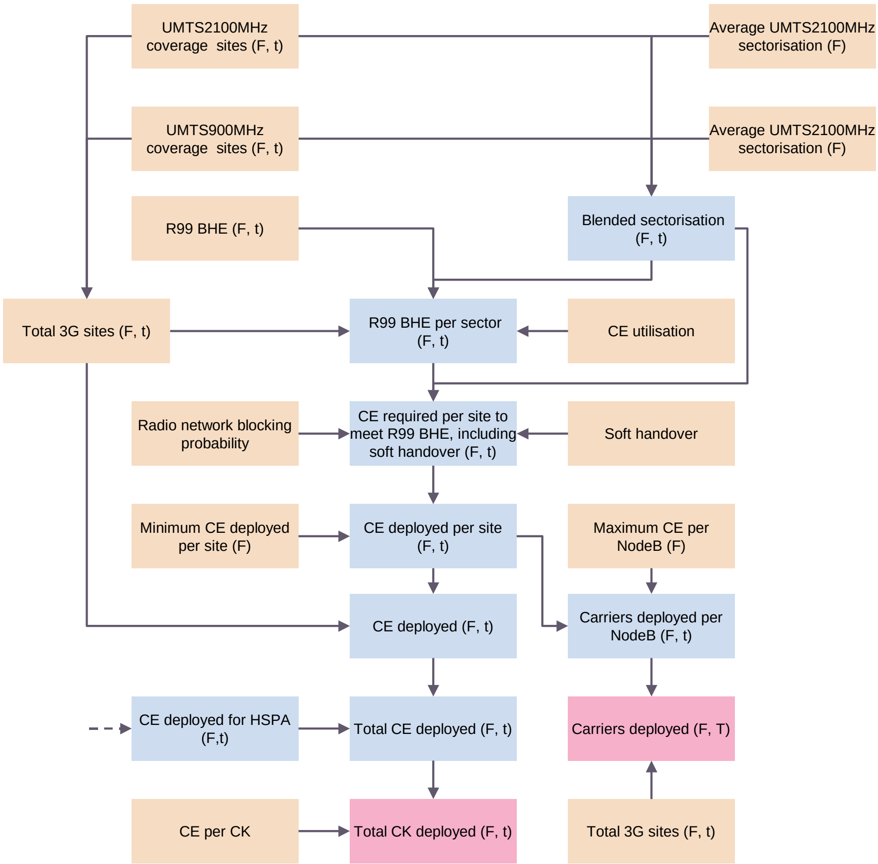


Figure A.1: Channel kit deployment [Source: Analysys Mason]

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).

CK requirements for HSPA **[this section has been superseded by the information presented in the main body of this report]**

Four grades of HSPA are deployed in the model: HSDPA 3.6, HSDPA 7.2, HSDPA 14.4 and HSUPA1.5. Each is assumed to be activated in the network from a particular year onwards. It is assumed that HSDPA 3.6 is deployed at every NodeB from launch, whereas HSDPA 7.2 are only deployed at a proportion of sites in each Fylke. In addition, HSDPA 14.4 is deployed a certain number of years after HSDPA 7.2 is deployed as an upgrade to some sites. Channel elements for HSDPA and HSUPA are calculated separately, as shown below in Figure A.4.

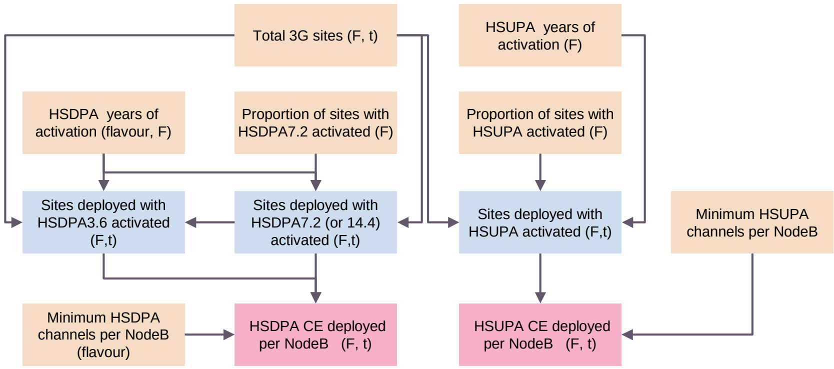


Figure A.2: HSPA channel element deployment [Source: Analysys Mason]

Within each Fylke, the model makes the distinction between sites with HSDPA 3.6 and HSDPA 7.2/HSDPA 14.4.

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. This is illustrated below in Figure A.3.

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 BHE loading of 200% is used in deriving HSDPA CE utilisation.

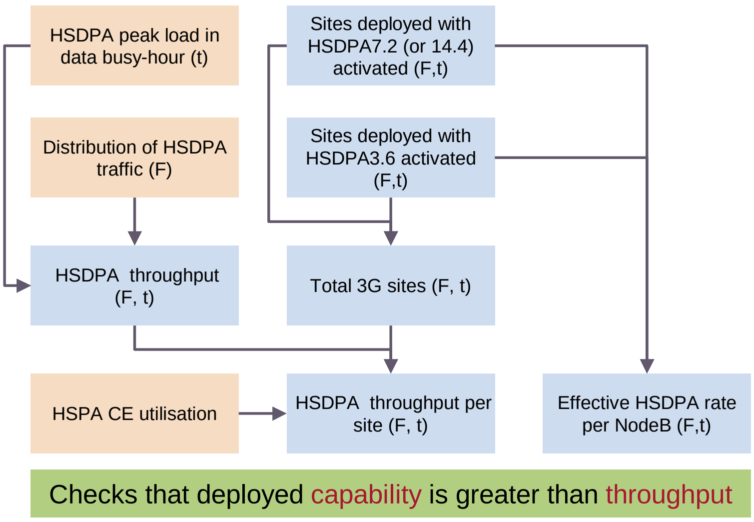


Figure A.3: Verification of sufficient HSPA deployment [Source: Analysys Mason]

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

A.2 Backhaul transmission [this section has been superseded by the information presented in the main body of this report]

The calculation of the number of backhaul links and the corresponding number of E1 ports required is set out in Figure A.4. Requirements for voice/R99 and HSPA are dimensioned separately. The capacity requirements and then the means of deployment are calculated separately.

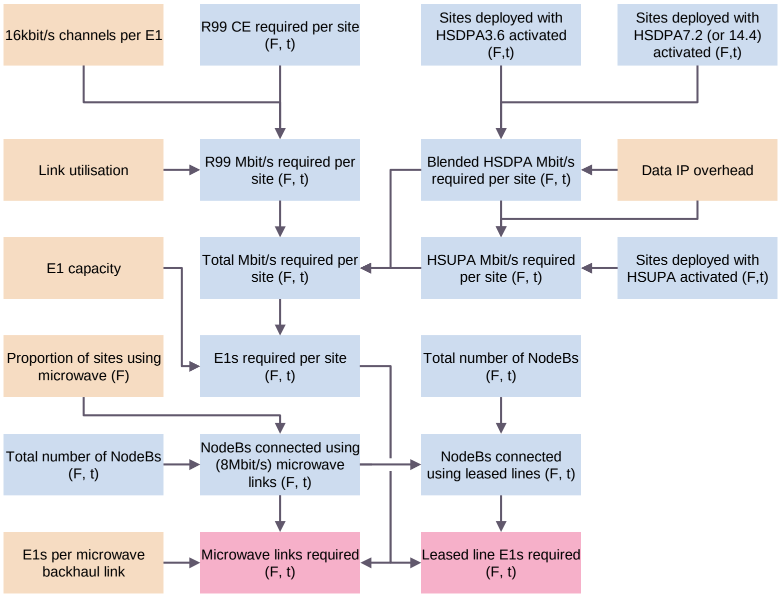


Figure A.4: UMTS backhaul calculation [Source: Analysys Mason]

Step 1: Capacity requirements

The number of E1s required per site is calculated to fulfil the capacity requirements for a backhaul link. The requirements for voice/R99 and HSDPA are considered separately, calculating:

- 120 channels per E1 for voice/R99 CE
- blended Mbit/s requirements for HSDPA/HSUPA, including an overhead for IP.

It is assumed that backhaul requirements for HSDPA are provisioned according to the speed in Mbit/s. In addition, we assume that HSUPA uses the uplink backhaul capacity already deployed for HSDPA, i.e. there is no backhaul deployment dedicated to HSUPA.

The effective capacity per E1 is calculated for voice. The number of E1 links required per site is obtained by simply dividing the circuits per site with the effective capacity per E1 link.

Step 2: Backhaul network design algorithms

There are two types of backhaul to be considered in the network: microwave (8Mbit/s links) and leased lines. The percentage of sites which have microwave backhaul is an input into the model.

The number of microwave 8Mbit/s backhaul links is set to be a minimum of one per site. The model allows for more than one 8Mbit/s link per site. The number of E1 units occupied in each 8Mbit/s microwave link is calculated.

The number of sites using leased lines calculated as the difference between the total sites and the total sites using microwaves. The total number of E1 leased lines required is the product of the total number of NodeB sites using leased line and the number of E1 required per site (from *Step 1*).

Tunnel repeater sites are assumed to use only E1 leased lines and hence are added to the leased-line requirement of the macro NodeB layer.

Annex B Model adjustments from v7.1 to v8D

In this section, we describe the adjustments made to the structural calculations of the v7.1 model, including the correction of some minor aspects of the model.

The step-by-step changes made in the model in order to make the adjustments discussed below are detailed in the change log.

B.1 Model corrections

Corrected high-speed connections

On the *D3_M8* worksheet, the market share calculations for 2009–11 for Telenor's and TeliaSonera's high-speed connections were corrected to account for the portion of the market covered by ICE Nordisk.

Corrected effective average HSDPA rate calculation

On the *B6_NwDes* worksheet, the effective average HSDPA rate calculations were changed to only include the additional sites at each rate when calculating the weighted average.

Corrected calculation for "Infill cell radius – after 2008"

On the *A6_NtwDesSlct* worksheet, the IF() statement adjusting the in-fill cell radius after 2008 was corrected so that the correct value was obtained for both pure and purest LRIC cases.

B.2 Revised input parameters and other decisions

Developed Mobile Norway calculation

Inputs were developed for a Mobile Norway-specific calculation, in the same way as Telenor and TeliaSonera, allowing for asset calibration and cost reconciliation against Mobile Norway's submitted data.

These Mobile Norway-specific inputs have been derived from data received from Mobile Norway, Tele2, Network Norway and NPT, and can be found in the following worksheets: *D3_M8, B7_LifeIn, A8_UtilIn, A4_NtwDesBase* and *D4_CostBase*.

Changed third operator to generic operator

The hypothetical third operator entry was completely reworked to be a calculation for a generic operator (in addition to the three actual MNOs). The demand, network and cost inputs for the generic operator are derived from the inputs used in the model for the Telenor, TeliaSonera and Mobile Norway-specific calculations.

The changes made and calculations used for deriving the generic operator inputs are discussed in more detail in Section 4.2 above.

HSPA site upgrades

On the *B6_NwDes* worksheet, the number of sites which are upgraded with different HSDPA and HSUPA rates, has been changed from just 2100MHz sites to all 3G sites. This is to reflect operator information which shows that both 2100MHz and 900MHz NodeBs are equipped with faster HSPA grades.

Added HSDPA21 and HSDPA42 software assets

Two additional upgrades of HSDPA were added to the modelled asset list, representing 21Mbit/s and 42Mbit/s respectively:

- the definition of minimum channel deployments, speeds, and network deployment timing of these assets were added to the *A4_NtwDesBase* worksheet
- routing factors for the new assets were added to the *B9_RF* worksheet
- links to the asset counts were included on the *C02_FullNw* worksheet.
- the calculation of the number of HSDPA assets required in the network was added to the *B6_NwDes* worksheet, in a similar fashion to the other HSDPA assets
- in addition the HSDPA deployment profiles, HSDPA average throughput and checks, and the LMA requirement calculations, were updated on the *B6_NwDes* worksheet to include the new assets.

The new HSDPA calculations are discussed in more detail in Section 5.1.

Added a second HSUPA upgrade asset

A second HSUPA upgrade was added to the modelled asset list, in a similar fashion to the HSDPA assets described above. In addition, the calculation of HSUPA channels per NodeB was deleted from the model.

The new HSUPA infrastructure is discussed in more detail in Section 5.1.

Updated operator market shares

Based on NPT market data, the market shares of 'registered and hosted subscribers (excluding telemetry)' and 'high-speed data subscriptions by operator' have been updated for each operator in 2009–12.

Updated Telenor/TeliaSonera network design inputs

As part of the calibration of the Telenor/TeliaSonera operator models for the period 2009–2012, several revisions were made to their operator-specific inputs on the *A4_NtwDesBase* and *A8_UtilIn* worksheets. In particular, the inputs related to the 3G coverage of these operators were updated.

Updated Telenor/TeliaSonera unit costs

As part of the reconciliation of the Telenor/TeliaSonera operator models for the period 2009–2012, several revisions were made to the inputs on the *D4_CostBase* worksheet. In particular, the unit costs assumed for the following assets were all reduced:

- layered core equipment
- HSPA software upgrades
- radio site (opex only).

The lifetimes for radio sites were also extended by five years.

Updated capex/ opex cost trends

As part of the reconciliation of the Telenor/TeliaSonera operator models for the period 2009–2012, several revisions were made to the inputs on the *C01_CostTrends* worksheet. In particular:

- the capex trends were revised in 2009–2012 for BTS, NodeB, channel kit, sites/ancillary, BSC and microwave backhaul
- the opex trends were revised for BTS/NodeB, BTS/NodeB transmission, network billing system, IN and radio sites.

Introduced migration to LTE network for voice, SMS and high-speed data traffic

Migration profiles for voice, SMS and high-speed data services to an LTE network have been added.

Inputs for the total high-speed data traffic (across all technologies) have been added to the model, with the LTE high-speed data traffic being derived as the difference between this total forecast and the established HSPA forecast. It is assumed, however, that the previous NPT v7.1 model's minute and SMS forecasts were derived on a total, technology-neutral basis, with the new NPT v8D model's 3G voice and SMS traffic profiles consisting of a proportion of this total traffic profile.

The changes made and calculations used for deriving the services carried over the LTE network are found on the *D3_M8* worksheet and are discussed in more detail in Section 3.

Adjusted voice and SMS forecasts to account for OTT traffic

A consideration of OTT voice and SMS traffic has been added to the model, separating this traffic out from the total (technology-neutral) traffic projections. This OTT traffic is then converted to high-speed megabytes and included in the modelled demand as HSPA/LTE traffic.

The changes made and calculations used for deriving the OTT traffic and megabytes can be found on the *D3_M8* worksheet and discussed in more detail in Section 3.2 above.

Update of operator demand data for 2009–12

In 2012, Analysys Mason updated a copy of the v7.1 model for a separate piece of work for NPT related to asymmetric termination.[36] The updates to the demand calculation, as described in Section 3.1 of the technical report,[37] were incorporated into the NPT v8D model.

Operator data and NPT market data for the period 2009–12 have been used to update the demand in these years for each operator. These can be found in a new market calculation worksheet in the NPT v8D model (*D3_M8*). More detail on these demand-related updates can be found in Section 3.3.

Update of demand forecasts

The updated historical data received for the period 2009–12 from the operators and NPT has resulted in some forecast volumes diverging from those forecast in the v7.1 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.

Addition of Ethernet backhaul for 3G sites

The backhaul calculations were enhanced to include Ethernet backhaul options for 3G sites. This reflects changes in the Norwegian mobile networks towards increased deployment of IP backhaul, as a result of increasing HSPA speeds and LTE deployments. The new network design calculations are described in more detail in Section 5.2.

2G and 3G spectrum licences

Following the November 2012 auction, both the spectrum allocations and spectrum fees for the modelled 2100MHz spectrum have been updated.

Update of the modelled WACC

The WACC in the NPT v8D model has been altered to the value that has been calculated in parallel to the model update.

36 See http://www.npt.no/marked/markedsregulering-smp/marked/marked-7/anmodning-om-omgj%C3%B8ring

37 See http://www.npt.no/marked/markedsregulering-smp/marked/marked-7/_attachment/2349?_ts=139b9c507e1

Annex C Expansion of acronyms

2G	Second generation of mobile telephony
3G	Third generation of mobile telephony
4G	Fourth generation of mobile telephony
BSC	Base station controller
BTS	Base (transmitter) station
EC	European Commission
ESA	EFTA Surveillance Authority
EDGE	Enhanced data for global evolution
EPMU	Equi-proportionate mark-up
ETH	Ethernet
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
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
NMS	Network management system
NPT	Norwegian Post and Telecommunications Authority
NodeB	Denotes the 3G equivalent of a BTS
PTS	Swedish Post and Telecom Authority
R99	Release-99
RNC	Radio network controller
SMS	Short message service
SMSC	SMS centre
TRX	Transceiver
TSC	Transit switching centre
UMTS	Universal mobile telecommunications systems
WACC	Weighted average cost of capital