analysys mason

30 years

Final model specification for the Norwegian Communication Authority

Conceptual approach to upgrading Nkom's LRIC model of fixed access networks in Norway

April 2016

James Allen and Matthew Starling

Ref: 2003395-162

www.analysysmason.com

Contents

Analysys Mason Limited
St Giles Court
24 Castle Street
Cambridge CB3 0AJ
UK
Tel: +44 (0)1223 460600
Fax: +44 (0)1223 460866
cambridge@analysysmason.com
www.analysysmason.com
Registered in England No. 5177472

1 Introduction

The Norwegian Communication Authority (Nkom) has commissioned Analysys Mason to update the existing long-run incremental cost (LRIC) model in relation to wholesale services on fixed access networks. There are two relevant markets in this context: Market 4 (wholesale physical network infrastructure access) and Market 5 (wholesale broadband access). These markets have been defined by both the European Commission (EC) and the European Free Trade Association Surveillance Authority (EFTA Surveillance Authority, or ESA).[1]

Analysys Mason and Nkom have agreed an approach to update the existing cost model, which will be used by Nkom as one of the inputs to future pricing decisions. The agreed approach presents industry participants with the opportunity to contribute to the project. This paper sets out the conceptual approach to this update.

The starting point for the specification of the updated model is the previous model specification developed by Analysys Mason and Nkom which was published in February 2010 (the 'original specification').[2] Although we refer to the principles from that original specification, it is possible to read this new paper as a fully standalone document. Modelling principles specific to the update of the LRIC model of fixed access networks, numbered A1–A29, are presented throughout this paper. Where these principles are derived from those in the original specification, the wording changes are highlighted in red text). Where principles were discussed and/or revised following the consultation on the draft specification, this is also described in this paper. The final principles to be applied are further summarised in Section 8.

In this introduction we provide:

- the overall timeline of the project and opportunities for industry to contribute
- an explanation of the scope of the project
- the structure of this paper
- an overview of the industry feedback to the draft specification.

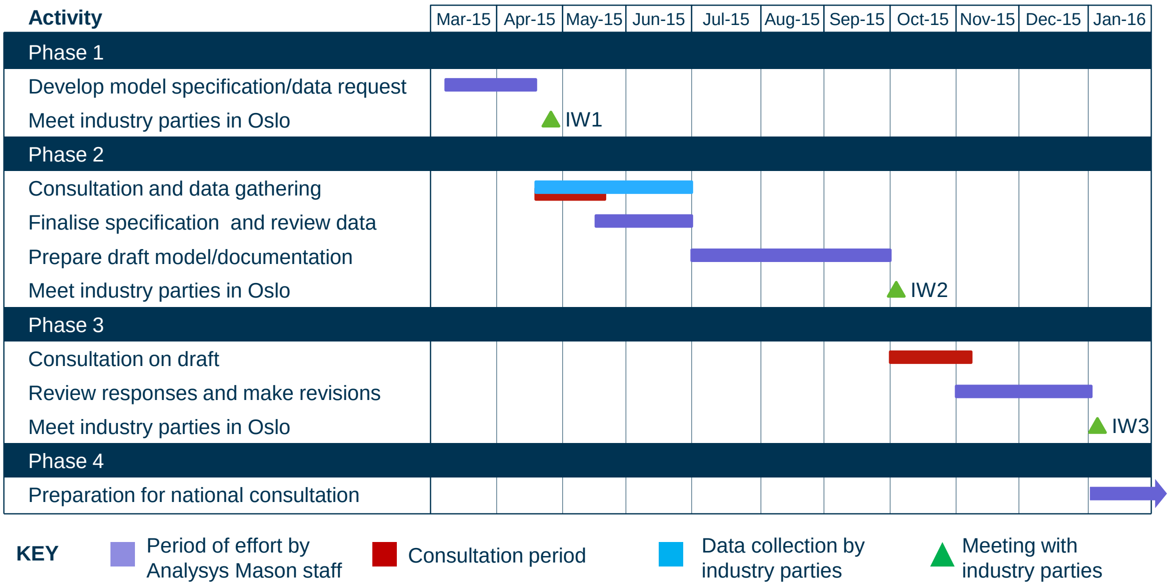
1.1 Timeline

An overview of the phases of the project timeline is shown in Figure 1.1 below.

1 For the EC definition, see its Recommendation on relevant markets 2007/879/EC. For the corresponding ESA document of November 2008, see http://www.eftasurv.int/media/esa-docs/physical/15344/data.pdf

2 See http://eng.nkom.no/home/_attachment/1805?_download=true&_ts=139100f7b30

Figure 1.1: Project timeline [Source: Analysys Mason, 2015]



Industry participants have been invited to contribute to the first three phases of this project:

1. **Model specification**: This paper presents the conceptual approach to upgrading the LRIC model. Industry has been given the opportunity to submit comments on the recommendations in the paper, which were taken into account when developing this final specification.

2. **Data collection**: Data requests will be provided to operators. From operators designated as having significant power (SMP) in the relevant markets, information will be sought on their networks, service volumes and cost data. Other industry participants will also be invited to contribute to this phase.

3. **Model consultation**: Following development of the draft updated LRIC model for fixed access networks, versions of the models will be issued for consultation.

1.2 Scope of the project

Between 2009 and 2011, Analysys Mason supported Nkom (NPT at the time) in the development of a LRIC model of fixed access networks. The final version (v1.7) of the model was published on Nkom's website in September 2012, alongside its draft market analysis and decisions regarding Markets 4 and 5.[3]

After this publication, in September 2013, the EC published a Recommendation on consistent non-discrimination obligations and costing methodologies (the '2013 Recommendation').[4] The 2013 Recommendation covers a wide range of issues including the valuation of reused assets and the technologies to cost in relation to services that are relevant to broadband access. Furthermore, in October 2014, the EC released a new Recommendation on relevant markets for sector-specific regulation (the 'New Market Recommendation') that involved a slight change to the definitions of the relevant markets.[5] However, Nkom expects that it will remain the case that the current definitions of Market 4 and 5 in Norway can be retained for the purposes of upgrading the LRIC model for fixed access networks.

In its final decision on Market 4 of January 2014, Nkom stated that: "In connection with the next round of analysis and decision-making in this market, NPT will consider further developing the LRIC model in such a way that this will be more in line with the Commission's Recommendation and the emphasis will therefore also be reassessed."[6]

It is expected that the ESA will approve corresponding documents for the 2013 Recommendation and/or the New Market Recommendation in the near future; these are likely to adhere closely to those published by the EC. Nkom therefore wishes to update the existing LRIC model so that it reflects both the evolution of the Norwegian fixed access markets and these Recommendations, in order to inform its future regulation of Markets 4 and 5.

Our starting point is that the relevant principles from the original specification should be left unchanged unless adjustments are required in order to:

- Comply with the 2013 EC Recommendation
- Reflect changes in the Norwegian market since the original specification was developed
- Reflect enhancements in access modelling best-practice
- Improve clarity.

---

3 See http://www.nkom.no/marked/markedsregulering-smp/kostnadsmodeller/lric-fastnett-aksess

4 Recommendation C(2013) 5761 of 11 September 2013, see http://ec.europa.eu/digital-agenda/en/news/commission-recommendation-consistent-non-discrimination-obligations-and-costing-methodologies

5 Recommendation C(2014) 7174 of 09 October 2014 on relevant product and service markets within the electronic communications sector susceptible to ex ante regulation in accordance with Directive 2002/21/EC. See http://ec.europa.eu/information_society/newsroom/cf/dae/document.cfm?action=display&doc_id=7045

6 For the Norwegian versions, see http://www.npt.no/marked/markedsregulering-smp/marked/marked-4-og-5.
For the English versions, see http://eng.nkom.no/market/market-regulation-smp/markets/market-4-and-5.

1.3 Structure of this paper

The remainder of this document is laid out as follows:

- Section 2 provides an overview of the existing model of fixed access networks developed by Nkom in 2009–2011.
- Section 3 describes important principles of long-run incremental costing and our approach to dealing with these.
- Section 4 defines the principles concerning the technologies to be modelled.
- Section 4 describes the principles concerning the types of operators to be modelled.
- Section 6 sets out the services that we consider relevant to the model.
- Section 7 describes other principles that are relevant to the model implementation.
- Section 8 summarises the principles of the updated LRIC model for fixed access networks identified in this paper.

This paper also includes a number of annexes containing supplementary material:

- Annex A outlines the principles of the offline algorithms to be used for modelling aspects of the fixed access networks.
- Annex B provides a more detailed overview of possible depreciation methods.
- Annex C provides a description of the acronyms used in this document.

1.4 Industry feedback on the draft specification

Following the consultation of the draft specification in May 2015, feedback was received from Telenor, which has been published on Nkom's website.[7] Telenor provided feedback on those draft principles (numbered A1–A29) that it considered had materially changed from the original specification from February 2010. Where principles had not materially changed in their view, Telenor provided no further comments in their response but indicated that this did not mean they necessarily agree with the principle as it stood in the original specification.

Telenor provided detailed feedback on five principles, but subsequently retracted their comment on Principle A19. The four remaining principles (and their corresponding sections) to which Telenor responded are summarised below in Figure 1.2.

[7] See http://www.nkom.no/marked/markedsregulering-smp/kostnadsmodeller/lric-fastnett-aksess/_attachment/18367?_download=true&_ts=14dc3b7c293

Figure 1.2: Summary of principles where Telenor provided detailed feedback [Source: Analysys Mason, 2015]

Principle	Description	Section	Principle	Description	Section
A5	Offline calculations	4.5	A18	Migration from legacy access networks to NGA networks	6.4
A21	Depreciation methods	7.2	A29	Input lifetimes	7.8

In each of these sections, we provide Telenor's response and a subsequent consideration, followed by the final version of the principle. For the remaining principles, we have retained the wording in the draft specification for the final specification.

2 Overview of the existing LRIC model

This section provides an overview of the existing LRIC model for access networks developed by Nkom and Analysys Mason in the period 2009–2011. This model was developed based on the original specification published in February 2010. Section 2.1 summarises the concepts within this document and Section 2.2 provides an overview of the existing model.

2.1 Summary of the original specification

The original specification established the principles for the existing LRIC model of fixed access networks in Norway. The paper contains 49 principles covering the models of fixed core, fixed access and co-location services that were developed.

Figure 2.1 summarises the 33 principles from this specification that we believe are relevant to this update of the existing LRIC model of fixed access networks. Principles [16], [43] and [44] are related to the co-location model. The remaining 13 principles are related only to the core model and are therefore not considered here. For each principle, we state the section in this paper where it is reconsidered in the context of this update. A mapping between the principles in the original specification and the new principles in this document can be found in Section 8.

Figure 2.1: Conceptual decisions from the original specification that are relevant to the update of the LRIC model of fixed access networks [Source: Analysys Mason, 2015]

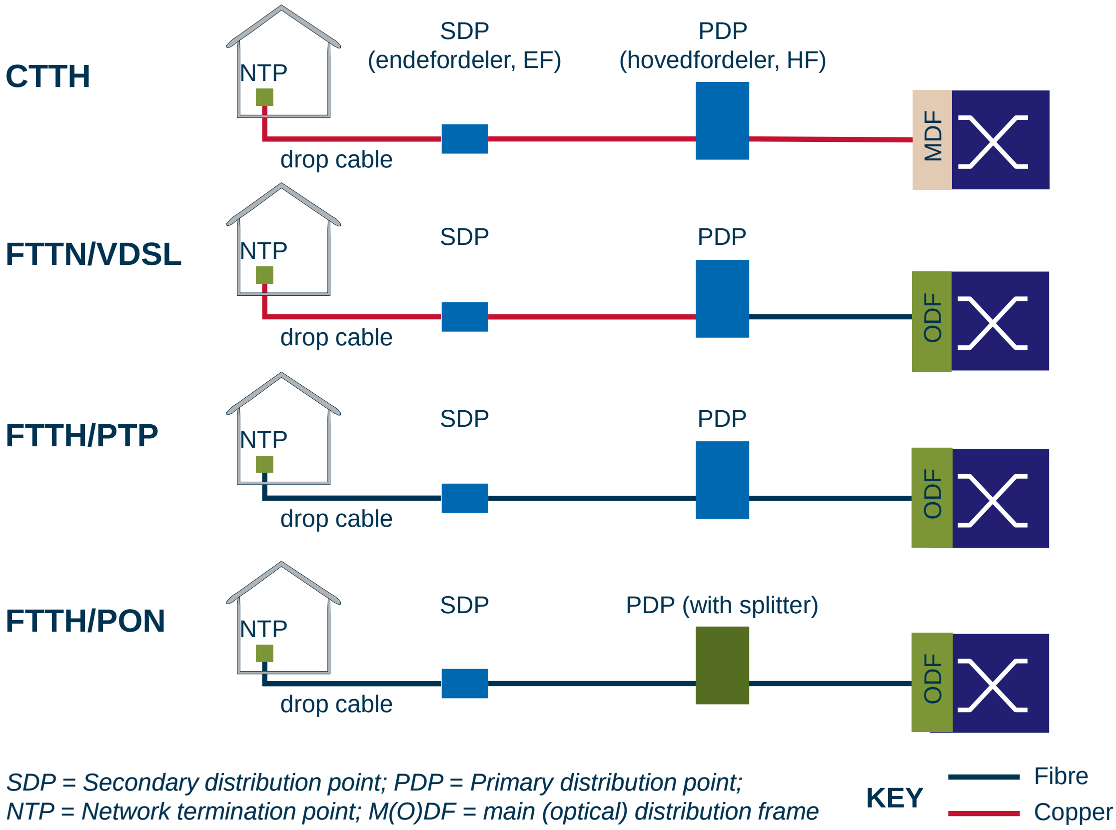
Principle	Summary from the original specification	Section
[2] Definition of increments	Use a LRAIC approach	7.1
[3] Treatment of common costs	Use equi-proportionate mark-up (EPMU)	7.5
[4] WACC	The WACC will be defined by an external consultant	7.4
[5] Access line volumes	Aggregated by copper/fibre and compared to top-down data	4.6
[6] Access line services	Model a variety of services, recover costs over the forecast demand	4.4
[7] Other access services	Capture both duct access and fibre access in the model	6.2
[8] NGA cost recovery	Recover NGA costs over active NGA connections	7.1
[14] Wholesale copper services	Calculate costs of both full/shared loops and sub-loops	6.3
[15] Wholesale NGA services	Model SLU in FTTN/VDSL and unbundling for FTTH/PTP	6.3
[17] Network configurations modelled	Network configurations are modelled using separate sets of parameters (for national incumbent, pure access leaser, pure access owner, pure VoIP player)	4.1
[18] Building data	Use a database of Norwegian building locations in the access network modelling	4.5
[19] Partition	Use Telenor's service areas	4.5
[20] Geotypes	Define based on average road per location	4.5

Principle	Summary from the original specification	Section
[21] Sampling	Define stratified sample	4.5
[22] Current architecture	Model a copper deployment	5.1.1
[23] NGA architectures	Model FTTN/VDSL, FTTH/PTP and FTTH/PON	5.1.2
[24] Node scorching	Use the modified scorched-node principle	4.3
[25] Network scope	Exclude Jan Mayen, the dependencies, Antarctica and Svalbard	4.2
[26] Node hierarchy	A clustering algorithm will be employed to determine the locations served by network nodes	4.5
[27] Cabling layout	Modified Prim and Dijkstra algorithms will be used to determine the layout of cabling in the access network	4.5
[28] Distance measure	Define a p-function	4.5
[29] Aerial deployment	Capture aerial calculations in the active model	5.2
[30] Trenching costs	Use operator data to inform costs of digging trench	5.3
[31] Duct	Model one size of duct	5.3
[32] Access network boundary	The boundary between access and core networks will be the same for all modelled networks	5.4
[33] NGA geotypes	Use the same geotypes for all modelled architectures	5.1.2
[35] Network migration	Model NGA as standalone, with a reasonable utilisation profile over time, rather than an explicit migration	6.4
[42] Level of trench sharing	Trench sharing is considered using a parameter-based approach, for the testing of a range of inputs	7.6.1
[45] Definition of unit asset costs	Unit equipment costs, installation cost, cost of spares held and cost of decommissioning are all defined	7.6.2
[46] Definition of cost trends	Cost trends are defined for capital and operational expenditures	7.6.3
[47] Asset lifetimes	An economic lifetime is defined for each asset	7.8
[48] Depreciation calculation	Economic depreciation is used	7.2
[49] Modelling period	The period from 1991 to 2050 is modelled	7.3

2.2 The existing LRIC model

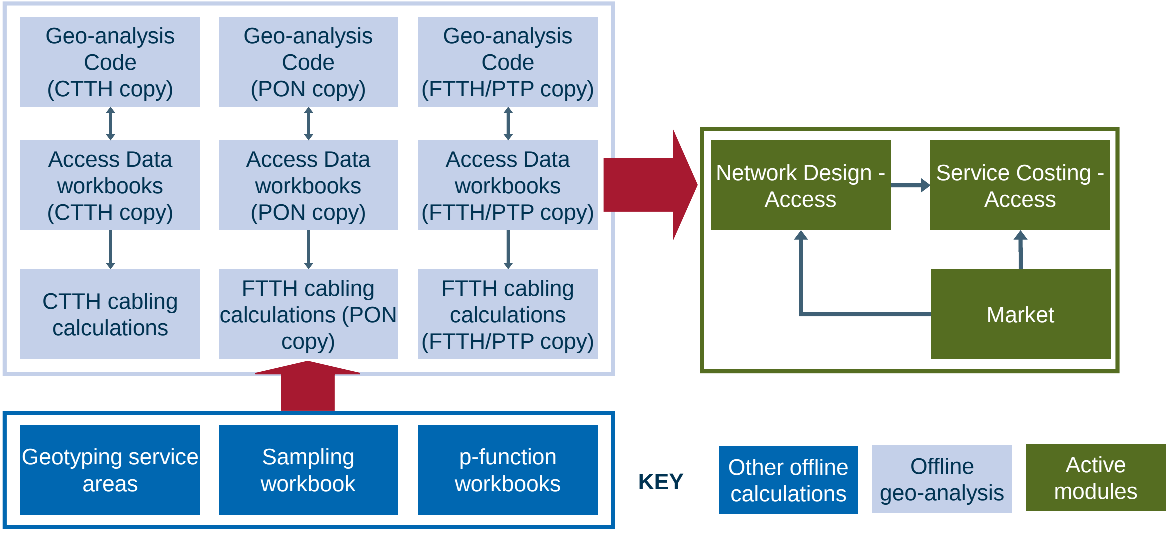
The draft ('v1.3') model was released for consultation in August 2010, and the final ('v1.7') version was published alongside the decisions for Markets 4 and 5 in September 2012. The model has the capability to consider multiple access network architectures, namely copper-to-the-home (CTTH), fibre-to-the-node (FTTN/VDSL), fibre-to-the-home passive optical network (FTTH/PON) and FTTH point-to-point (PTP). These architectures are all assumed to connect buildings in an area back to a single network node containing a distribution frame, via a hierarchy of intermediate distribution points, connected by copper and/or fibre cabling, as illustrated below in Figure 2.2.

Figure 2.2: Illustration of access architectures [Source: Analysys Mason, 2015]



The model consists of three active modules, each implemented as a single Excel workbook: the *Market* module, the *Network Design – Access* module and the *Service Costing – Access* module. These three modules take parameter values from detailed offline calculations, which are confidential and cannot be shared with industry parties without some redaction. The calculations include a detailed geographic analysis (geo-analysis) of the CTTH, FTTH/PTP and FTTH/PON architectures (inputs for FTTN/VDSL are derived from the geo-analysis for CTTH). The offline and active components within the model are shown schematically in Figure 2.3 below, and described in more detail in the following subsections.

Figure 2.3: Schematic overview of the existing LRIC model of fixed access networks [Source: Analysys Mason, 2015]



2.2.1 Geotyping, sampling and definition of distance functions

In this section, we describe the geotyping approach taken for the purposes of our model, the definition of the sample, and the 'p-function' that the model uses. These calculations are one-off calculations that do not need to be repeated. They use four geographic datasets covering the whole of Norway:

- StreetPro Norway, which contains the national road/rail network represented as line segments
- Bygningspunkter, which contain the locations of buildings in Norway
- locations provided by Telenor corresponding to the exchange buildings housing its remote concentrators (RSXs) and main distribution frames (MDFs) for its copper network ('RSX locations')
- a digital boundary corresponding to the area served by each RSX location ('RSX service area'), again provided by Telenor.

Approach to geotyping

The diverse topography of Norway cannot be accurately captured in a bottom-up model using a single value for each parameter in the asset dimensioning calculations. At the other extreme, to calculate parameter values using data for the whole of Norway would be computationally expensive. Therefore, the model uses geographical classifications, or *geotypes*, defined by taking a partition of the Norwegian land mass and then grouping together regions which have similar geographical characteristics. The parameter values in the model can then be varied by geotype where necessary.

Using Telenor data, we defined a set of 3948 RSX locations and corresponding service area boundaries as our partition. For each RSX service area, the following were calculated:

- road kilometres within the RSX services area (using StreetPro data)
- buildings assumed to be connected
- 'as-the-crow-flies' distance from each of these buildings to its parent RSX location
- distribution of these distances (in 1 kilometre groupings).

An RSX service area is defined as 'clustered' if 98% of locations are within 4 kilometres of the RSX location (as-the-crow-flies); all other service areas are defined as 'spread'. 16 geotypes were then defined using the ratio of road distance per connected building, and whether RSX service areas were clustered or spread. This approach is illustrated in Figure 2.4 below.[8] For example, geotype 1 is defined as all clustered RSX service areas with an average road distance per connected building greater than zero and less than or equal to 0.04 kilometres.

Average road per connected building

Min	Max	Clustered	Spread
	0	16	16
0.00000	0.01000	1	
0.01000	0.01414	1	
0.01414	0.02000	1	
0.02000	0.02828	1	8
0.02828	0.04000	1	8
0.04000	0.05657	2	9
0.05657	0.08000	2	9
0.08000	0.11314	3	10
0.11314	0.16000	3	10
0.16000	0.22627	4	11
0.22627	0.32000	4	11
0.32000	0.45255	5	12
0.45255	0.64000	5	12
0.64000	0.90510	6	13
0.90510	1.28000	6	13
1.28000	1.81019	7	14
1.81019	2.56000	7	14
2.56000	3.62039	7	15
3.62039	5.12000	7	15
5.12000	7.24077	7	15
7.24077	10.24000	7	15
10.24000	14.48155		
14.48155	20.48000		
20.48000	28.96309		
28.96309	1,000,000,000		

Figure 2.4: Definition of geotypes in the existing LRIC model [Source: Analysys Mason, 2015]

Definition of the sample

In order to use a sample of areas to derive parameters for the active calculations, a representative sample was selected. We defined a stratified sample, with each geotype representing a stratum. A random sample of each particular size was then taken for each stratum. At its simplest, the sample sizes for each stratum should be proportional to the number of elements in the stratum ('proportionate stratified sampling'). However, if the variances of a particular variable differ significantly across strata, then sample sizes should also be proportional to the stratum standard deviation. We defined a total sample size of 400 RSX service areas, with the number of sampled RSX service areas for a geotype weighted by both the total number of connected lines within the geotype and the standard deviation of the average road distance per connected building.

[8] Geotype 16 contains a small number of RSX service areas, and these have no roads and very few buildings.

Geotype 16 was not included in the sample since none of the RSX service areas in this geotype have any roads; it was also omitted from subsequent analysis. The sample defined contained 10% of all RSX service areas and more than 10% of buildings – see Figure 2.5 below.

Figure 2.5: Summary of stratified sample [Source: Analysys Mason, 2015]

Geotype	Comment	Areas	Road	Locations	Demand	S.d. of road per building	Stratum size (demand)	Proxy for s.d. of cost	Proportion of sample	Sample size
1	Clustered	470	14,536	485,664	1,065,517	0.0067	1,065,517	0.0067	11.47%	46
2	Clustered	403	14,922	270,994	469,230	0.0118	469,230	0.0118	8.81%	35
3	Clustered	388	13,646	123,414	175,448	0.0230	175,448	0.0230	6.44%	26
4	Clustered	348	11,961	54,245	70,291	0.0450	70,291	0.0450	5.05%	20
5	Clustered	207	7,359	17,178	21,513	0.0911	21,513	0.0911	3.13%	12
6	Clustered	56	2,167	2,620	3,178	0.1734	3,178	0.1734	0.88%	4
7	Clustered	30	1,686	897	1,114	1.0999	1,114	1.0999	1.96%	8
8	Spread	10	952	29,454	58,580	0.0042	58,580	0.0042	0.39%	2
9	Spread	95	8,261	135,567	210,112	0.0108	210,112	0.0108	3.63%	14
10	Spread	313	22,421	187,317	252,254	0.0225	252,254	0.0225	9.04%	36
11	Spread	625	41,911	185,022	237,107	0.0436	237,107	0.0436	16.51%	66
12	Spread	554	38,214	88,512	109,673	0.0895	109,673	0.0895	15.66%	63
13	Spread	293	24,394	28,352	33,952	0.1805	33,952	0.1805	9.78%	39
14	Spread	108	11,388	6,919	8,330	0.3366	8,330	0.3366	4.48%	18
15	Spread	33	4,125	1,160	1,507	1.1540	1,507	1.1540	2.78%	11
16	No road	15	-	398	489	-	489	-	0.00%	-
		3,948	**217,944**	**1,617,713**	**2,718,295**		**2,718,295**	**3.29**	**100%**	**400**

Description of the p-function

In order to analyse the stratified sample of RSX service areas to derive parameters for the active calculations, the road distance between any two points is an important input to the calculation. A straight-line (also called 'crow-flies') approach to calculating direct distance from one point to another effectively ignores topography and street-level clutter. We defined and calibrated a more general 'p-function' using three parameters *j*, *k* and *p* such that the distance between two points $\underline{x}=(x_1,x_2)$ and $\underline{y}=(y_1,y_2)$ is given by the following formula:

$$\left\|\underline{x}-\underline{y}\right\|_{k,p} = j \times k \times \left(\left|x_1 - x_2\right|^p + \left|y_1 - y_2\right|^p\right)^{\frac{1}{p}}$$

The presence of two coefficients (*j* and *k*) reflects the fact that a single trench can actually hold multiple cables, as illustrated below.

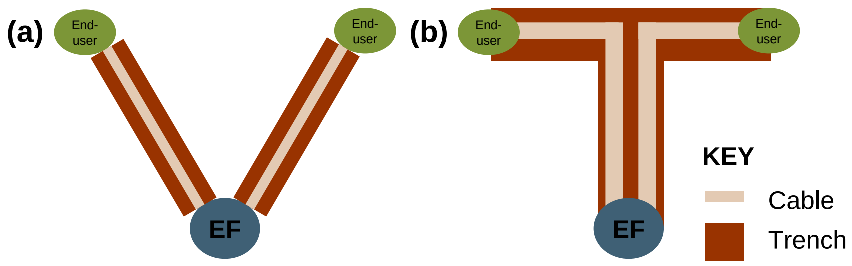


Figure 2.6: Illustration of trench sharing between links [Source: Analysys Mason, 2015]

Figure 2.6 shows two links joining end-users to their parent node. Diagram (a) indicates how these links would be viewed if trench and cable used the same distance measure. Diagram (b) shows what is actually happening between these links: they share part of the total trench as the locations lie across a junction. Using only *k* would get the cable lengths correct, but would over-estimate the actual trench length. Therefore we calibrated a separate trench-sharing coefficient, *k*, which is used only when calculating trench lengths. Moreover, the p-function is not used at all when two points lie along a straight road (in which case cable and trench length are assumed to be the same).

A p-function for each geotype was derived based on a calibration exercise using the locations within the sampled RSX service areas.

2.2.2 Geo-analysis

The offline geo-analysis is encoded using Visual Basic (VB). Detailed documentation of the code used within these algorithms can be found in the report entitled *Description of the Visual Basic used in the offline geo-analysis*, published on Nkom's website.[9] The key features are that, for each RSX service area in the sample, the algorithms calculate an efficient access-network deployment to connect the building locations within that area to the parent RSX location. Different network design assumptions can be set for each geotype and each access architecture (CTTH, FTTH/PON or FTTH/PTP). For each chosen architecture, the VB can be re-run for all 400 sampled RSX service areas (or a subset of these).

The VB is contained within a single *Geo-analysis Code* workbook that also stores the inputs and parameters assumed for each network design. A total of 26 *Access Data* workbooks store the location information for the 400 RSX service areas in the sample. The flow of information between *Geo-analysis Code* and *Access Data* workbooks is shown below in Figure 2.7.

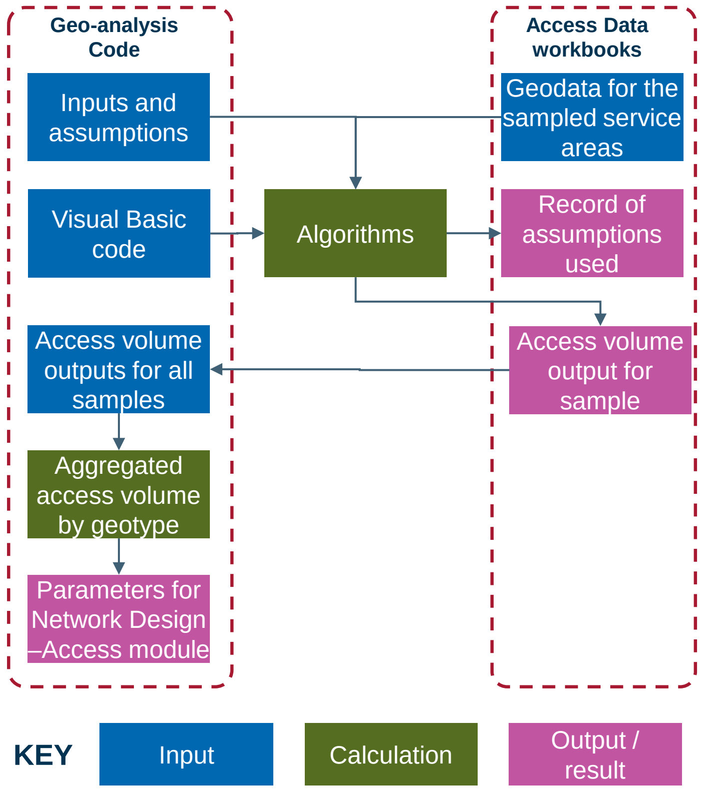


Figure 2.7: Illustration of structure of Geo-analysis Code and Access Data workbooks [Source: Analysys Mason, 2015]

The VB is re-run by pressing a button in the *Geo-analysis Code* workbook. The VB reads in the inputs for the chosen architecture and then, for each RSX service area in turn, opens the

9 See http://www.nkom.no/marked/markedsregulering-smp/kostnadsmodeller/lric-fastnett-aksess/_attachment/3957?_download=true&_ts=13a8856f1c6

corresponding *Access Data* workbook, reads in the location information, calculates an efficient access network (using the chosen architecture) to connect those locations back to their parent RSX location and stores the outputs (and inputs used) in the *Access Data* workbooks. The total asset counts across the entire sample are then summarised by geotype in the *Geo-analysis Code* workbook.

The network dimensioning parameters are then derived, by geotype, for use in the *Network Design – Access* module. Examples of such network dimensioning parameters include the average number of lines per SDP, and the average length of copper cabling between PDP and main distribution frame (MDF).

There are three different classes of algorithm used by the VB to calculate the access network asset requirements for the sampled RSX service areas (see Annex A for more detail):

- Clustering algorithms to group buildings into collections each served by an intermediate distribution point.
- Spanning tree algorithms to connect buildings in a cluster to the intermediate distribution point, and then to connect clusters back to the RSX location.
- Travelling Salesman Problem (TSP) algorithms to calculate resilient ring systems between PDPs in an RSX service area.

2.2.3 Market module

The *Market* module is common to Nkom's LRIC models of fixed networks and fixed access networks. It calculates the volumes of subscribers by service (e.g. retail telephony with and without broadband, wholesale telephony with and without broadband, broadband-only, leased lines etc.) for the purposes of both models, whilst also calculating voice and data traffic volumes for use by the LRIC model of core networks. The current version is the v2.0F model (updated from the v1.7 model), which was published with the updated LRIC model of fixed core networks in April 2014.[10]

The volumes for the Telenor-scale operator in the published version are based on Telenor's volumes as far as possible (to the extent that the information is publically available) for the period 2004–2012, with estimated inputs for all remaining values. In particular, most access-line volumes are based on public sources, including Telenor's or Nkom's reporting.[11]

The output of the *Market* module is a time series for the period 1991–2050 of active access lines by type. The main types modelled are shown in Figure 2.8 below.

---

10 See http://eng.nkom.no/market/market-regulation-smp/cost-model/lric-for-fixed-core-networks/_attachment/13853?_download=true&_ts=146ec4269c7

11 See Section 3.1 of the report published at http://eng.nkom.no/market/market-regulation-smp/cost-model/lric-for-fixed-core-networks/_attachment/13852?_download=true&_ts=146ec4263a5

Figure 2.8: Access-related services modelled [Source: Analysys Mason, 2015]

Service description	
PSTN/ISDN end-user access	xDSL access
Wholesale line rental (WLR)	Bitstream
Full local loop unbundling (LLU)	Leased lines
Shared LLU	Access lines
Full sub-loop unbundling (SLU)	Fibre access lines
Shared SLU	

The module also contains other important inputs including the cost of capital and the working capital allowance.

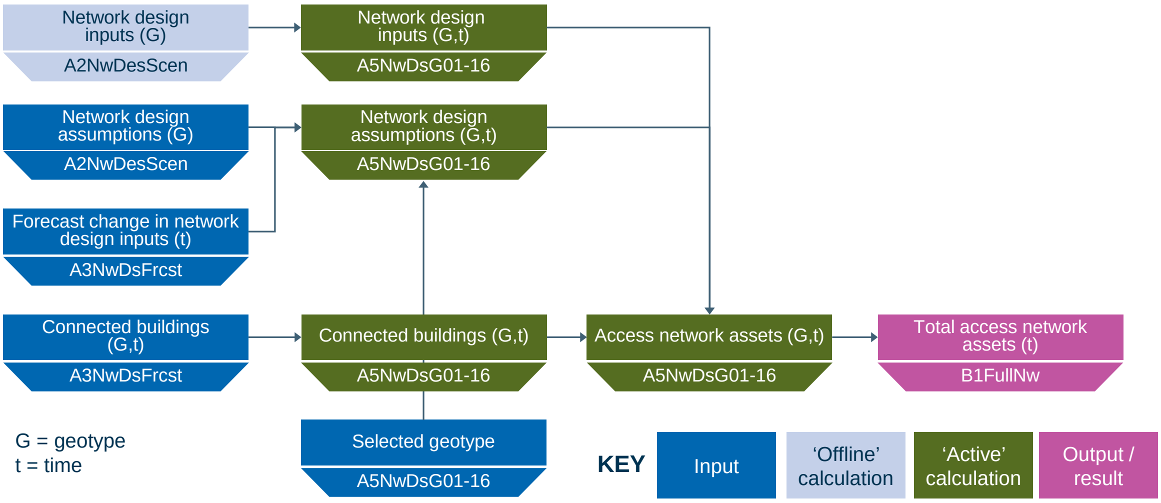
2.2.4 Network Design – Access module

This module uses the measures derived by geotype from the geo-analysis, as well as other user-defined parameters, to dimension the access-network assets required, by geotype, for each year in the period 1991–2050. The assets calculated include trench, cable, joints, distribution points, manholes and poles.

In particular, the geo-analysis calculates the requirements for a fully ducted underground network. The user-defined parameters then allow a proportion of this network to be deployed as aerial (with poles deployed and the corresponding amount of trench and duct removed from the network). Additional parameters are also included to assume a proportion of the remaining trenches contain cables that are buried directly, meaning that the corresponding ducts are then removed from the asset counts.

The structure of the main calculations and worksheets in this module is shown in Figure 2.9 below. In particular, there is one worksheet that calculates the asset counts required over the period, for each geotype. A summary worksheet (*B1FullNw*) contains the total national asset counts.

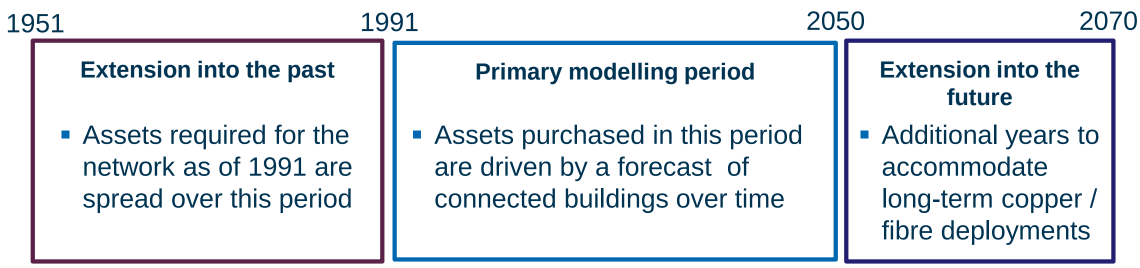
Figure 2.9: Structure of the Network Design – Access module [Source: Analysys Mason, 2015]



This calculation is driven by a time series of households from the *Market* module for the period, split into a time series by geotype.

The national asset counts required in 1991 are then phased in over a period between 1951 and 1991. The model also includes an option of estimating national asset counts required for up to 20 years beyond 2050: this allows the modelled network design to either reflect the historical evolution of the copper network, or alternatively a long-term future deployment of fibre. The *Network Design – Access* module also contains the number of active access lines for the period 1951–1991, as well extending the forecasts beyond 2050 to 2070. This three-part modelling period is illustrated below in Figure 2.10.

Figure 2.10: Illustration of the modelling period in the Network Design – Access module [Source: Analysys Mason, 2015]



Having calculated the asset counts required in each year, the number of new or replacement assets *purchased* in each year can then be calculated based on assumed economic lifetimes.

The module also contains assumed unit capex and unit opex values for the year 2009, as well as historical and forecast cost trends for capex (and also for opex). This allows a unit capex and a unit opex to be defined for each asset in each year in the modelling period. The capex incurred by assets in each year can then be calculated as the product of the number of assets purchased and the unit capex in that year. Similarly, the total opex incurred by assets in each year is calculated as the product of the number of active assets in that year and the unit opex in that year. These total expenditures over time, by asset, are then sent to the *Service Costing – Access* module.

2.2.5 Service Costing – Access module

This module calculates the unit costs of access services using the assumed expenditures calculated in the *Network Design – Access* module. In particular, the module uses a long-run average incremental cost approach including common costs ('LRAIC+'). This approach is consistent with the historical approach in Europe for the costing of access services. Average incremental costs of access are defined in aggregate, and then allocated to various access services using routeing factors.

A large access increment implies that costs common to multiple access services are included in the average incremental cost of access, whilst common costs are included using equi-proportional cost-based mark-ups (EPMU).

The calculation of the average incremental costs of access by asset is determined using economic depreciation. The depreciation method takes into account all the underlying factors influencing the economic value of an asset, namely:

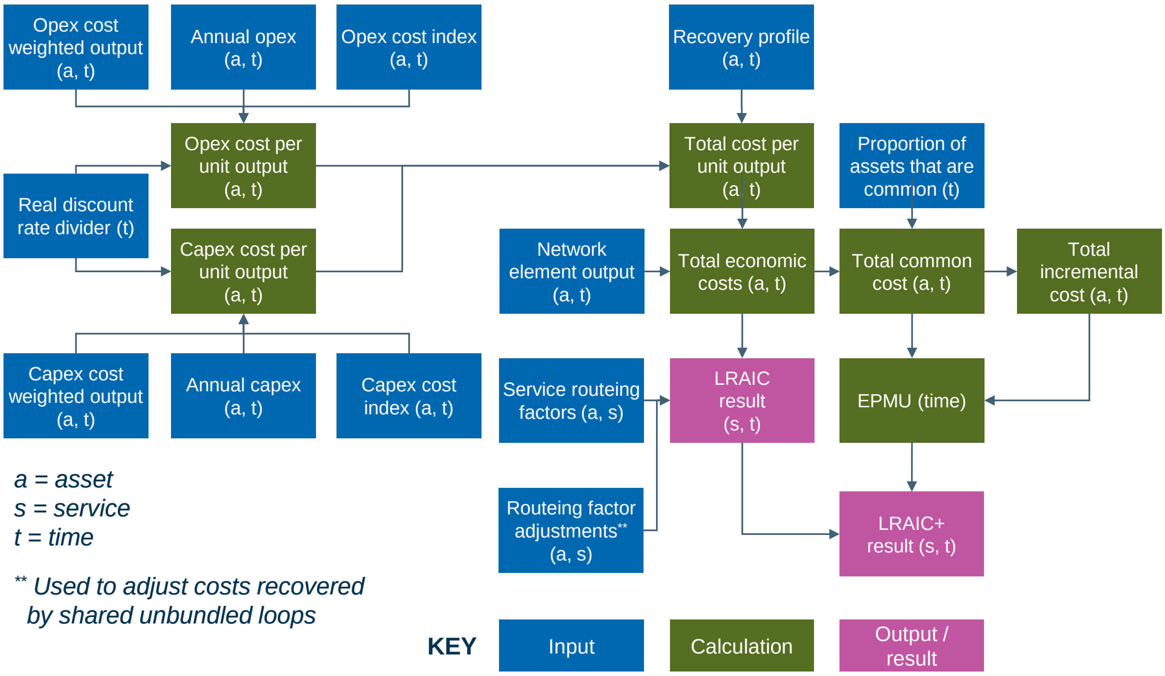
- projected trends in opex associated with the modern equivalent asset ('MEA opex trends')
- projected trends in replacing the asset with its MEA ('MEA investment trends')
- the economic output that can be generated by the network asset over time.

Economic depreciation recovers all efficiently incurred costs in an economically rational way by ensuring that the total of the revenues[12] generated across the lifetime of the business are equal to the efficiently incurred costs, including cost of capital, in present value (PV) terms. This calculation is carried out for each individual asset class, rather than in aggregate, in order to allow the capex cost trends and opex cost trends for each asset to be reflected.

The structure of the economic depreciation calculation, and the subsequent allocation of these costs by asset in order to derive costs by *service*, is shown below in Figure 2.11. As can be seen below, capex contributions and opex contributions are treated separately. The output is a time series of LRAIC+ for each separately modelled service.

[12] Strictly cost-oriented revenues, rather than actual received revenues.

Figure 2.11: Calculation in the Service Costing – Access module [Source: Analysys Mason, 2015]



3 Principles of long-run incremental costing

Long-run incremental costs (LRIC) based on an efficient deployment of a modern asset reflect the level of costs that would occur in a market that is *competitive* and *contestable*. Competition ensures that operators achieve a normal profit and normal return over the lifetime of their investments (i.e. over the long run). Contestability ensures that existing providers charge prices that reflect the costs of supply in a market that can be entered by new players using modern technology. Both of these market criteria ensure that inefficiently incurred costs are not recoverable and that a forward-looking assessment of an operator's cost recovery is required (since a potential new entrant is unconstrained by historical cost recovery).

Efficient costs in a competitive and contestable market are set according to the following principles:

- the LRIC of the service
- often including a mark-up to recover common costs
- earning a normal return on investment
- allowing only efficiently incurred costs
- reflecting the costs of supply using modern technology
- assessed on a forward-looking basis.

These principles can be considered to be intrinsic to a LRIC-based calculation, although there is some flexibility and interpretation in their application. The remainder of this chapter discusses each of these principles in turn.

3.1 Long-run incremental costs

We discuss the principle by defining both *long-run costs* and *incremental costs*.

Long-run costs

Costs are incurred in an operator's business in response to the existence or change in service demand, captured by the various cost drivers. Long-run costs include all of the costs that will ever be incurred in supporting the relevant service demand, including the on-going replacement of assets used.

Consideration of costs over the long run can be seen to result in a reliable and inclusive representation of cost, since all of the cost elements would be included for the service demand supported over the long-run duration and averaged over time in some way. Therefore, in a LRIC method, it is necessary to identify all of the cost elements that are incurred over the long run to support the service demand of the increment.

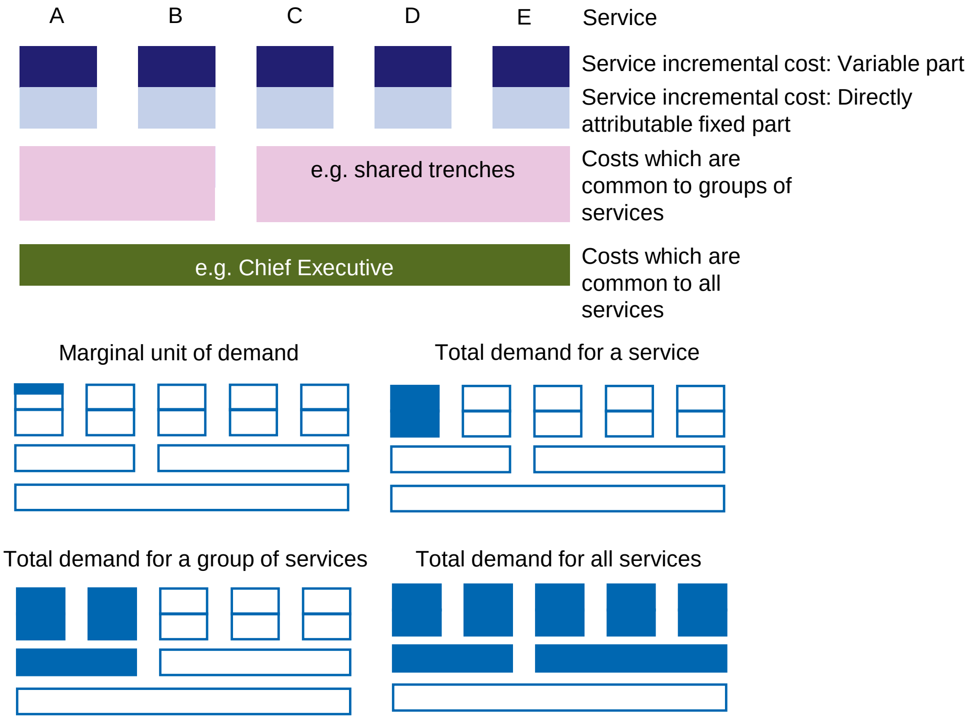
Incremental costs

Incremental costs are incurred in support of the increment of demand, assuming that other increments of demand remain unchanged. Put another way, incremental costs can also be calculated as the avoidable costs of not supporting the increment. There is considerable flexibility in the definition of the increment (or increments) to apply in a costing model, and the choice should be suitable for the specific application. Possible increment definitions include:

- marginal unit of demand for a service
- total demand for a service
- total demand for a group of services
- total demand for all services in aggregate.

Figure 3.1 below illustrates where the possible increment definitions interact with the costs that are incurred in a generic five-service business.

Figure 3.1: Possible increment definitions [Source: Analysys Mason, 2015]



The application of *large* increments maximises the incremental cost and minimises the common cost (see Figure 3.2 below). This approach also requires the large incremental cost to be shared out (allocated) among its constituent services in some way. The application of *small* increments to a cost model with economies of scale means that the calculated incremental costs reflect the economies of scale at current volumes, for each increment applied. The costs related to the growth of the network to current volumes (economies of scale) then need to be considered separately from the incremental costs – i.e. as common costs, which may be recovered by a mark-up.

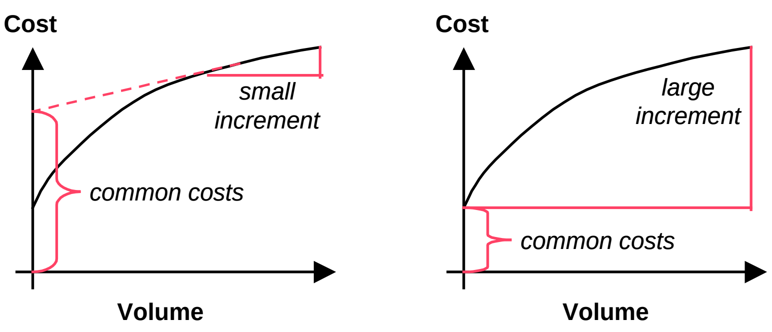


Figure 3.2: Large and small increments [Source: Analysys Mason, 2015]

The adoption of a large increment – in this context, all services using the access network – means that all of the services that are supplied are treated together and 'equally'. Where a subset of those services may be regulated (as in the current situation), the regulated services neither bears excessively, nor benefits excessively from, the higher (or lower) costs arising from economies of scale.

3.2 Efficiently incurred costs

In order to set the correct investment and operational incentives for regulated operators, it is necessary to allow only efficiently-incurred expenditures in cost-based regulated prices. The specific application of this principle to a set of cost models depends significantly on a range of aspects:

- the detail and comparability of information provided by individual operators
- details of the modelling performed
- whether it is possible to uniquely identify inefficient expenditures
- the level of stringency in the benchmark of efficiency that is being applied[13]
- whether efficiency can be distinguished from below-standard quality.

Cost inputs will be collected during the data collection phase (Phase 2) and compared against available cost benchmarks. The costs used in the model will be available for industry assessment during the model consultation phase (Phase 3), subject to confidentiality limitations.

3.3 Costs of supply using modern technology

In a contestable market, a new entrant that competes for the supply of a service would deploy modern technology to meet its needs, since this should be the efficient network choice. This implies two 'modern' aspects: the price of purchasing the infrastructure needed, and the costs of operating and maintaining these assets. Therefore, a LRIC model should be capable of capturing these two aspects:

13 For example, most efficient in the Europe versus most efficient in the world.

- The modern price for equipment and infrastructure should represent the price at which the modern assets can be purchased.
- Operation and maintenance (O&M) costs should correspond to the modern standard of equipment, and represent all the various facility, hardware and software maintenance costs relevant to the efficient operation of a standard modern network.

The definition of 'modern equipment' is a complex issue. Operators around the world are at different stages of deploying next-generation, fibre-based networks, yet a proportion of customers are still being served through legacy copper networks. Therefore in the timeframe being considered, both approaches could be considered reasonable.

3.4 Forward-looking costs

Forward-looking costs are the costs incurred now and in the future, in line with:

- current levels of expenditure
- projected changes in demand volumes
- projected changes in equipment prices
- projected changes in the deployed technology (if any).

Forward-looking costs should not take into account the costs actually incurred by an operator to date.

In a LRIC model, the means of valuation of the assets and the depreciation algorithm need to be forward-looking. Some, but not all, valuation and depreciation methods are forward-looking. The methods that rely on historical levels of expenditure such as HCA are generally considered not to be consistent with a forward-looking calculation.

Particular attention should be given to the 2013 EC Recommendation, since it gives emphasis to differentiating between (a) depreciation methods used specifically for what it refers to as legacy *reusable civil engineering assets* (e.g. poles, trenches with spare duct space and other assets such as cabinet-based distribution points and manholes with spare capacity, that would be unlikely to be replicated for a NGA deployment) compared with (b) the methods used for other assets.

Depreciation methods are discussed in more detail in Section 7.2.

We will collectively refer to these *reusable civil engineering assets* as RCEA in this paper.

4 Principles related to the modelled operators

This section describes the principles concerning the operator that can be captured by the updated LRIC model. In particular:

- Section 4.1 defines the type of operator that will be modelled
- Section 4.2 sets out the definition of the footprint for the modelled network
- Section 4.3 presents the scorching principles that we believe should be applied
- Section 4.4 describes how the asset base should be defined
- Section 4.5 indicates our revisions to the offline calculations
- Section 4.6 states the principle assumed for the market share parameters.

4.1 Type of operator

In the original model specification, Principle 17 stated that *the model will be capable of reflecting a number of network configurations, which are modelled using separate sets of parameters*. This principle was established primarily for considering fixed network operators of different scales and types particularly relevant to the wholesale voice service markets.

In order to analyse potential cost differences for different operator types, it was established that a number of alternative, hypothetical operators would be defined in the existing model. These hypothetical configurations would each use only one type of access to a defined network footprint (e.g. an unbundler, an access owner, a reseller). The configurations included in the model were:

- a Telenor-like operator operating a national access network and a national core network
- access leasers (e.g. unbundlers) which operate only a significant core network
- access owners which operate an access network and a significant core network
- access-independent operators which operate only a limited core network.

The use of the word 'hypothetical' is of significant importance in the context of the 2013 EC Recommendation, since Point 31 states that the methodology should consider *the current cost that a hypothetical efficient operator would incur to build a modern efficient network, which is an NGA network*. Although the word 'hypothetical' was present in the text preceding the principle in the original specification, it was not in the wording of the Principle 17 itself. We now make the wording specific to the access network model. Beyond this, we do not believe any other amendments are required to this principle in order to satisfy the 2013 EC Recommendation or the needs of this project.

Principle A1: The access network model will be capable of reflecting a number of hypothetical access network configurations, which are modelled using separate sets of parameters.

4.2 Network footprint

The coverage of a fixed access network (also known as the network footprint) is a central aspect of its deployment, since the size of the footprint directly affects the asset base. Furthermore, when modelling a fixed access network, premises are classified according to their status with respect to the network footprint:

- **passed** premises, i.e. those that *could* be reached by a final drop cable
- **connected** premises, i.e. those to which a final drop cable has actually been deployed
- **active** premises, i.e. those which are connected and which have an active subscription. These are the premises over which costs are recovered.

If an operator has a universal service obligation (USO), then this can influence the definition of the footprint, since it follows for such operators, their footprint must pass all premises.

In the original specification, Principle 25 stated that *the scope of the access network model will be limited to exclude Jan Mayen, the dependencies, Antarctica and Svalbard*. In the remaining parts of Norway, the existing model assumes that all buildings are passed and that for each geotype an assumed proportion of those buildings passed are also connected. According to the Electronic Communications Act of 2003, the relevant geographical area of Norway includes Jan Mayen, the dependencies, Antarctica and Svalbard. However, according to the 2006 market analyses for Markets 4 and 5:

- Svalbard is excluded from the perspective of these markets as an exception
- Jan Mayen, the dependencies and Antarctica are assumed to not have any significant impact on the market analyses.

This is also the case in the final market analyses published in January 2014.[14] Therefore, we will not revise this principle for the updated model, but instead add wording regarding passed and connected buildings; this wording is consistent with the existing model.

Principle A2: The scope of the access network model will be limited to exclude Jan Mayen, the dependencies, Antarctica and Svalbard. Where the access network in a geotype is modelled for the remaining parts of Norway, it shall be assumed that all locations in that geotype are passed and that an assumed proportion is also connected.

4.3 Node scorching

In the original specification, Principle 24 stated that *a modified scorched-node principle will be used, in which the level of scorching is clearly defined as an a priori assumption at the building locations of the MDF in the network. Consequently, in the current network deployment, all of the*

[14] See Section 3.1 of http://eng.nkom.no/market/market-regulation-smp/markets/market-4-and-5/_attachment/14153?_download=true&_ts=147f814e25b

concentrators and switching elements in such accommodation are assumed to be deployed in efficient locations.

The possible options for node scorching in a bottom-up model are outlined below.

Scorched node	The scorched-node approach assumes that the historical locations of the actual network node buildings are fixed, and that the operator can choose the best technology to configure the network at and in between these nodes to meet the optimised demand of a forward-looking efficient operator. For example, this could mean the replacement of legacy equipment with best-in-service equipment. Scorching at the node also allows a better comparison with top-down data. The scorched-node approach, therefore, determines the efficient cost of a network that provides the same services as the incumbent network, taking as given the current location of the incumbent's nodes.
Modified scorched node	The scorched-node principle can be reasonably modified in order to replicate a more efficient network topology than is currently in place. Consequently, this approach takes the existing topology and eliminates inefficiencies, for example, by rationalising node locations,[15] or changing the role of nodes by simplifying the switching hierarchy (replacing a switch by a remote concentrator), or changing a technological deployment at a node (e.g. revising an active FTTN/VDSL cabinet to be an FTTH cabinet).
Scorched earth	The scorched-earth approach determines the efficient cost of a network that provides the same services as the incumbent network, without placing any constraints on its network configuration, such as the location of the nodes. This approach models what an entrant would build if no network existed, based on the location of customers and forecasts of demand for services. This method gives the lowest estimate of LRIC, because it removes all inefficiencies due to the historical development of the incumbent's network. In practice, it is almost unknown to adopt a scorched-earth approach in regulatory cost models. This is partially because the effort involved in defining an efficient set of network nodes from scratch is significant, but also because the existing node locations are the points of interconnection to the access network, so modifying these would change the nature of the service being provided by moving the boundary between

15 For example, if there were two buildings in close proximity which acted as exchange locations for each other, then rationalisation would lead to only one building being retained in the model.

the core and access networks.

The 2013 EC Recommendation does not provide any specific guidance with respect to the level of node scorching employed in the model. Therefore, we see no need to revise this principle, though we have removed the second sentence (since it refers to core network infrastructure).

> **Principle A3:** A modified scorched-node principle will be used, in which the level of scorching is clearly defined as an *a priori* assumption at the building locations of the MDF in the network.

4.4 Definition of asset base

In terms of defining the asset base for the modelled network, there is one relevant principle from the original specification (Principle 6) that states *a variety of access-related services will be modelled. However, the size of most assets in the access network over time will not be varied on the basis of demand, but rather a forecast driven by locations passed. However, the costs of access will be recovered over the forecast demand*. This means that the access network is dimensioned based on the number of buildings that it is assumed to pass and connect. The network elements used to connect buildings (i.e. the final drop) are separable from the network used to pass buildings.

The 2013 EC Recommendation is very specific as to particular parts of the asset base that should be considered in the recommended approach. It defines a central concept of the Regulated Asset Base (RAB) which, it defines in Point 6(q) as *the total capital value of the assets used to calculate the costs of the regulated services*. We will not use this terminology in this paper, since the use of an asset-related term to refer to a cost is somewhat confusing; instead, we shall refer to the "modelled asset base" and its associated costs.

Point 6(r) in the 2013 EC Recommendation defines 'reusable civil engineering assets' (RCEA) as those *assets that are used for the copper network and can be reused to accommodate an NGA network*. Moreover, Point 33 states that *NRAs should value all assets constituting the RAB of the modelled network on the basis of replacement costs, except for reusable legacy civil engineering assets*. The RCEA in this context are assets such as poles and ducted trenches (at least those that have available space in duct for new cabling), as well as accommodation space within distribution points and RSX/MDF locations from the modelled copper network. All of these assets are currently modelled for the copper network. Therefore, in the updated LRIC model, assumed proportions of these assets will be specified using additional input assumptions, and then modelled separately as making up the RCEA. We will add a reference to this in our new draft principle.

Data from industry stakeholders can inform these proportions, but the expectation is that they will vary from asset to asset. For example, the proportion of poles that are available for re-use could be higher, but the proportion of ducted trench metres that are available for re-use could be lower.

Principle A4: A variety of access-related services will be modelled. The size of most assets in the access network asset base will not be varied on the basis of demand, but rather a forecast driven by locations passed. The costs of access will be recovered over the forecast demand. Assumed proportions of reusable civil engineering assets (RCEA), which include assets such as poles and ducted trenches, will be modelled separately.

4.5 Offline calculations

In the original specification, a number of principles were defined as relevant to the offline calculations. These are summarised in Figure 4.1 below.

Figure 4.1: Principles from the original specification for offline calculations [Source: Analysys Mason, 2015]

Principle	Statement
18	*A commercially available database of Norwegian building locations will be used for the access network modelling*
19	*Telenor's service area boundaries will be used as a partition for Norway*
20	*Geotypes will be defined on its selected geographical areas using average road per location. This geotyping may be refined, where appropriate, using additional geographical data related to these areas*
21	*As part of the offline calculation, a stratified sample of areas from each geotype will be used to calculate representative access deployments using the network design algorithms. The outputs of this sample will be used to derive the input parameters for the active calculation phase*
26	*A clustering algorithm will be employed to determine the locations served by network nodes. The algorithm will be flexible and able to determine clusters according to a range of capacity and distance constraints. It will use straight-line distance for simplicity, although means to increase the geographical awareness of the algorithm will be investigated, so that the occurrence of unreasonable clusters can be minimised*
27	*Modified Prim and Dijkstra spanning tree algorithms will be used to determine the layout of cabling in the access network. The intention is to use the algorithm to determine a spanning tree for each cluster of locations in the service area. Although not Steiner tree methodologies, these algorithms have several improvements on a simple minimum spanning tree algorithm; in particular they can account for cable tapering*
28	*For the trench and cable calculations for the access network, lengths will be calculated on the basis of p–functions, where the coefficients will be calibrated using geographic analysis of streets and households in Norway. The use of street-distances will take into account topological constraints on the network deployment. […] Elevation effects will be incorporated into the mode as a mark-up on the calculated distances.*

The implementation of these principles has led to extensive offline calculations that can derive network-dimensioning parameters for the four access technologies modelled. The geotyping, sampling and distance function definitions (as outlined in Section 2.2.1) and the VB used to implement these calculations (as outlined in Section 2.2.2) allow for the quantification of the assets required for a range of both legacy copper -based and NGA-based technologies being deployed within areas with similar geographical characteristics.

This approach is also consistent with the v2.0F core model, since the boundary between the modelled core network and modelled access network lies within the same (3948) RSX locations.

It could be argued that FTTH-based networks in Norway need not reflect the service areas and node locations in the copper network, given the better signal attenuation properties of fibre.[16] However, we would observe that:

- By using the existing main copper node locations for the main NGA network nodes, the model is able to reflect the cost savings from using legacy accommodation space for an NGA deployment (i.e. the node locations can be included in the set of RCEA, as described in definition of the asset base in Section 4.4).
- FTTH-based coverage is not contiguous in Norway, meaning that node locations and areas for a national FTTH network would need to be defined from scratch. Whilst theoretically possible, the potential efficiencies given Norway's quite extreme topographic constraints are likely to be small. Moreover, the copper node locations and service areas are established and already account for these constraints.
- The assumed re-use of copper nodes and service areas to model theoretical NGA networks is a modelling simplification that has been used in the development of regulatory cost models of fibre access networks in numerous other countries such as Denmark, Sweden and New Zealand (draft).
- The cost differences from a FTTH network serving larger service areas versus a FTTH network based on Telenor's copper service areas will most likely lie in the number of locations assumed to have active equipment and the level of network opex, rather than any reductions in the passive asset counts (trenches, ducts, distribution points etc.). These differences can be captured by making adjustments in the active calculations, rather than restructuring the geo-analysis.

Assets can still be quantified by geotype using our method, which allows for the calculation of the unit costs of services on all or a subset of geotypes (this is also possible in the existing model). This may be of use to Nkom in the future insofar as the 2013 EC Recommendation indicates in Recital 68 that *where the NRA cannot conclude that the different competitive conditions are stable over time and are such that they could justify the definition of sub-national markets, NRAs should nevertheless consider responding to these diverging competitive conditions by applying differentiated remedies*.

Therefore, we believe that our current geo-analysis and offline calculation methodologies should be retained from the original LRIC model. We will provide Nkom with any enhancements made to the VB since the existing model was delivered. We can also refine the network design inputs for

[16] There is a clearer case for FTTN/VDSL to reflect the copper-based areas, since the network topology is to retain the copper PDP and deploy a fibre cable from the PDP back to the RSX/MDF location.

the modelled access technologies in cases where industry stakeholders can provide improved inputs. Adjustments will be made in the active calculations where it can be demonstrated that there are additional efficiency gains to be captured in the associated costs of the modelled FTTH networks.

Draft principle A5 (restated from draft specification): The methodologies used in the geo-analysis and offline calculations, as well as the raw geographic data (roads, buildings, etc.) from the original LRIC model will be retained, although small improvements to the network deployment algorithms will be made. The network design inputs will be refined if industry stakeholders can provide improved information.

Feedback from Telenor

"Telenor agrees that the geo-analysis, offline calculations and geographic data from the original model should be reused. However, we would find it prudent to revisit the decision not to include geo-type 16 (no roads). For the model to network costs as accurately as possible this geotype can only be excluded if the effects of including it can be shown to be inconsequential."

Analysys Mason response

As part of the draft model preparation, the exchange areas in geotype 16 will be analysed. If it is determined that their asset counts would be a non-negligible contribution to the total asset counts of the modelled network, then an approach to incorporate these asset counts will be implemented.

Principle A5: The methodologies used in the geo-analysis and offline calculations, as well as the raw geographic data (roads, buildings, etc.) from the original LRIC model will be retained, although small improvements to the network deployment algorithms will be made. The treatment of geotype 16 will be reconsidered, and the modelling approach revised for that geotype, if its exclusion is found to have a material impact on the final result. The network design inputs will be refined if industry stakeholders can provide improved information.

4.6 Market share

In the original specification, Principle 5 stated that *in the bottom-up model, active access line volumes will be aggregated by copper and by fibre. These volumes will then be compared to top-down data*. The existing *Market* module, as described in Section 2.2.3, uses Telenor's actual access-line volumes in order to model a national operator for the years 2004–2012 as far as possible, with hypothetical values for remaining inputs. These volumes are then split between the geotypes within the *Network Design – Access* module, so that the active lines can be adjusted to correspond to the modelled geotypes.

Recital 30 in the 2013 EC Recommendation states that *the BU LRIC+ methodology calculates the current costs on a forward-looking basis (i.e. based on up-to-date technologies, expected demand, etc.)*. The use of the phrase 'expected demand' in this excerpt (and elsewhere) could imply the use of either actual or hypothetical volumes, so there are no explicit grounds from the 2013 EC Recommendation to revise our approach.

Therefore, we include a principle that reflects the implementation in the existing LRIC model, making it clear that networks where only a subset of geotypes are assumed to be active have a proportionately smaller level of demand.

Principle A6: Use Telenor's actual service volumes as the starting point for a national operator as far as possible, with hypothetical values for remaining inputs. A network modelled on a subset of geotypes should be assumed to carry a proportionately smaller subset of demand volumes.

5 Concepts related to the modelled technologies

This section describes the principles concerning the technologies that can be captured by the updated LRIC model. In particular:

- Section 5.1 defines the technologies that will be considered in the model
- Section 5.2 provides our intended assumptions on the network topology
- Section 5.3 describes how we capture the savings from the sharing of network assets
- Section 5.4 states our assumptions regarding the boundary of the access and core networks.

5.1 Modelled technologies

The two issues to consider here are firstly whether copper is still a relevant technology to model, and secondly whether the modelled NGA technologies are still appropriate and how should they be modelled. We discuss these in turn below.

5.1.1 Relevance of modelling the legacy copper network

In the original specification, Principle 22 stated that *for the current architecture, a copper deployment will be used (with some fibre) that uses EF and HF to connect all buildings requiring connectivity back to the switch*.

Point 37 of the 2013 EC Recommendation states *when determining the access prices of services that are entirely based on copper, NRAs should adjust the cost calculated for the modeled NGA network to reflect the different features of wholesale access services that are based entirely on copper. For this purpose, the NRAs should estimate the cost difference between an access product based on for example FttC/FttH and an access product based entirely on copper by replacing the optical elements with efficiently priced copper elements, where appropriate, in the NGA engineering model. Where appropriate, NRAs could otherwise obtain the copper cost by modelling an NGA overlay network, where two networks (copper and fibre, either FttH or FttC) share to an extent the same civil infrastructure*.

The EC Recommendation's proposed approach is to estimate the asset counts in a copper network using the modelled fibre network. However, we note that in Nkom's case, this is not necessary. This is because the existing LRIC model uses a copper network calculation to determine the FTTN/VDSL network assets (specifically, the copper cable between the street cabinet and the RSX/MDF location is replaced with a fibre cable). Hence, Nkom does not need to use an approximate method as it can use the copper network calculations directly.

Therefore, we believe that continuing to use the copper network calculation for copper-based services would comply with the 2013 EC Recommendation, provided it is ensured that *efficiently priced copper elements* are used (as referenced above).

Parameters to control the unit capex and opex for copper assets and the sharing of trench and pole assets between copper and other networks are already present in the existing LRIC model, and their values will be reviewed in the context of the principle below.

Principle A7: The copper deployment (with some fibre) that uses EF and HF to connect all buildings requiring connectivity back to the switch will be retained. The calculation will be reviewed to ensure that unit asset costs are efficient and the civil infrastructure is shared with the modelled NGA networks.

5.1.2 Appropriateness of the modelled NGA technologies

In the original specification, it was stated that:

- *The access network model will include the capability to consider the deployment of FTTN/VDSL, FTTH/PTP and FTTH/GPON for a given set of areas.* [Principle 23]
- *We will retain the same geotypes used in the access network in the NGA model. This will support the cost of deployment of a specific NGA architecture across a geotype.* [Principle 33]

Points 31 and 32 of the 2013 EC Recommendation state that *NRAs should adopt a BU LRIC+ costing methodology that estimates the current cost that a hypothetical efficient operator would incur to build a modern efficient network, which is an NGA network […] when modelling an NGA network NRAs should define a hypothetical efficient NGA network, capable of delivering the Digital Agenda for Europe targets set out in terms of bandwidth, coverage and take-up, which consists wholly or partly of optical elements.*

Recital 10 of the 2013 EC Recommendation indicates that it uses the same definition of NGA as its predecessor from 2010, defining NGA as *wired access networks which consist wholly or in part of optical elements and which are capable of delivering broadband access services with enhanced characteristics (such as higher throughput) as compared to those provided over already existing copper networks. In most cases NGAs are the result of an upgrade of an already existing copper or co-axial access network.*[17]

The 2013 EC Recommendation requires the modelled NGA network to meet the targets of the Digital Agenda for Europe, which are set out in terms of bandwidth, coverage and take-up. The targets are to provide download rate of 30Mbit/s for all of citizens in Europe by 2020, and to have at least 50% of European households subscribing to Internet connections above 100Mbit/s by 2020.[18]

We would note that the question of the speed offered on the access network in a bottom-up model impacts the modelled technology: it should be capable of offering this level of service. In 2012, as

[17] COMMISSION RECOMMENDATION 2010/572/EU of 20.9.2010, see http://eur-lex.europa.eu/LexUriServ/%20LexUriServ.do?uri=OJ:L:2010:251:0035:0048:en:PDF, page 6 of 14

[18] See https://ec.europa.eu/digital-agenda/our-targets-0

part of a study on the Digital Agenda for Europe, Analysys Mason concluded that both FTTN/VDSL and fibre-to-the-home technologies would be technically capable of offering not only 30Mbit/s by 2020, but also 100Mbit/s by 2020.[19] Therefore, we believe that FTTH (both PTP and PON) and FTTN/VDSL all comply with the requirements of the Digital Agenda.

Therefore, we conclude that all three NGA technologies from the existing LRIC model remain relevant. The current access obligations in Market 4 and 5 are limited to copper and fibre access networks only. Nkom has at this stage therefore decided to update the existing model for these technologies. The potential need for modelling other NGA technologies will be evaluated at a later stage when Nkom is assessing future regulation in Market 4 and 5.

As described in Section 4.5, we believe that our geotypes should be used for all of the modelled access technologies (both copper-based and fibre-based). Both principles will therefore be retained, although we have clarified some of the wording accordingly.

Principle A8: The access network model will include the capability to consider the deployment of FTTN/VDSL, FTTH/PTP and FTTH/GPON for a given set of areas.

Principle A9: We will retain the same geotypes used in the copper access network for the NGA model. This will support the use of the model to calculate the cost of deployment of a specific NGA architecture across an entire geotype.

5.2 Modelled topology

A fixed access network will have cable deployed in one of three different ways:

- ducted – buried in a trench within a duct
- direct buried – buried in trench without a duct, potentially with a higher-cost and better-protected ('armoured') cable sheath
- aerial – deployed above ground between poles.

In the original specification, Principle 29 stated that *functionality will be included within the active calculations to assume some aerial deployment in the Norwegian access network*. The existing LRIC model has the capability to model direct-buried cabling as well, i.e. it can consider all three forms of cable deployment. The 2013 EC Recommendation provides no guidance on the treatment of cabling. We believe that all three forms of cabling deployment are relevant and should continue to be considered in the updated LRIC model; we include a minor change to the wording of the principle to clarify.

[19] See http://www.rcysostenibilidad.telefonica.com/blogs/wp-content/uploads/2012/06/Policy-orientations-to-reach-the-European-Digital-Agenda.pdf, Figure 3.1. It is noted that FTTN/VDSL will be able to meet the 100Mbit/s capability by using upgrades such as vectoring, dual pair bonding and phantom mode.

Principle A10: Functionality to consider ducted, direct-buried and aerial cabling will be included in the access model.

In addition, Principle 31 stated that *we will model one size of duct used in the access network*. We now believe it would be appropriate to consider several duct sizes, since in other jurisdictions the duct size used in copper networks is often assumed to be larger than in a fibre network, and the duct size used in something like a lead-in can differs from that in the street network. Operator information will be requested to establish whether different duct sizes should be assumed in the network. We believe that the possibility to differentiate duct size between layers of the network and also between copper and NGA networks should be included, and therefore include a change in this principle.

Principle A11: The model will be able to differentiate different duct sizes in the lead-in network and the rest of the route network, as well as differentiating the duct sizes used in the copper network and the fibre network, where this is appropriate.

5.3 Asset sharing

Assuming that an asset is shared between multiple uses leads to efficient cost savings. It is most frequently the civil infrastructure that can be shared in this way, namely trenches, ducts and poles. These assets can be shared in several ways as summarised below.

Figure 5.1: Summary of types of asset sharing [Source: Analysys Mason, 2015]

Type of sharing	Example
Between layers of the same network owned by the same operator	Used by both access network cabling and by core network cabling
Between different telecoms networks owned by the same operator	Used by both legacy copper cabling and NGA fibre cabling
Between different telecoms companies owned by different operators	Shared with a competing HFC network
With a non-telecoms company	Shared with an electricity network owner

In the original specification, Principle 42 stated that *a parameter-based approach will be taken to quantify the level of trench sharing between the access and core network layers (and hence quantify the zero-cost trench), allowing testing of a range of inputs*. The existing *Network Design – Access* module has inputs that can capture all the types of asset sharing listed above, not only for trenches but also for aerial routes (i.e. poles). We will retain this functionality, but the inputs will be reviewed as part of the update. This will include gaining input from stakeholders as to the level of asset sharing that is possible. We have therefore reworded the principle to reflect this expanded functionality.

Principle A12: A parameter-based approach will be taken to quantify the level of sharing of trenches and poles within the various network layers (and hence quantify their lower costs), allowing the testing of a range of inputs.

5.4 Boundary between the access and core networks

In a legacy network, access-related costs are assumed to only occur downward of the first point of traffic concentration, within the MDF at the RSX location of the copper network. This demarcation point is shown in Figure 2.2 on page 8.

However, for NGA architectures, the boundary may lie at a different point. For FTTN/VDSL, the first point of traffic concentration is at the distribution frame in the PDP, while for FTTH it is at the optical distribution frame (ODF), where the active electronics connect the fibre (this could be further from the end-user in the network, beyond the 3948 locations). In these two cases, the core network can be respectively larger (for FTTN/VDSL) or smaller (for FTTH) than that assumed for the legacy copper network.

In the original specification, Principle 32 stated that *when modelling current and next-generation networks, the default assumption will be that the boundary between the access and core network will not be moved. Changes in the position of the boundary can be tested through simple scenarios*.

As described in Section 4.5, we have retained the geotype design and service areas from the existing LRIC model for all the modelled access technologies. We do not believe this principle needs to be changed.

Principle A13: When modelling current and next-generation networks, the default assumption will be that the boundary between the access and core network will not be moved. Changes in the position of the boundary can be tested through simple scenarios.

6 Concepts related to the modelled services

This section describes the principles concerning the services that will be considered in the updated LRIC model. In particular:

- Section 6.1 defines the list of line-related services that will be considered in the model
- Section 6.2 sets out the other services that will be included
- Section 6.3 describes the wholesale services that it will be possible to derive a cost for
- Section 6.4 states our treatment of migration from legacy to NGA networks.

6.1 Line-related service set

Fixed access networks convey a number of services to subscribers, both residential and business, retail and wholesale. Economies of scope, arising from the provision of many services across a single infrastructure will result in a lower unit cost for these services. This is particularly true for fibre networks, as these are capable of carrying all services (whereas copper networks may need a fibre overlay for high-speed leased lines, etc.). In the existing LRIC model, the line-related services shown in Figure 6.1 are modelled.

Figure 6.1: Line services over which access costs can be recovered [Source: Analysys Mason, 2015]

Service	Description
Voice access	Provision of a line suitable for voice and sold through either Telenor's retail arm or as a wholesale product. May be provided over a copper pair or fibre (in both cases, multiple services may be provided over the same line), or a fixed wireless solution
Retail broadband access	Provision of a line suitable for data and sold through Telenor's s retail arm. May be provided over a copper pair or fibre (in both cases, multiple services may be provided over the same line)
TV access	Provision of a line suitable for TV (using either unicast or multicast) and sold through Telenor's retail arm. May be provided over a copper pair or fibre (in both cases, multiple services may be provided over the same line)
Wholesale broadband ('bitstream')	Provision of a data service to an end user, where a connection of specific quality can be set up from the subscriber to an access point in Telenor's network, from where the access seeker can route traffic to its own network. Telenor carries traffic over the line, installs and operates the necessary broadband equipment, and ensures transmission up to the access point
Full local loop unbundling (LLU)	Full LLU allows an access seeker to provide services, including voice and broadband over the loop using its own equipment co-located at Telenor's distribution frame location. The unbundled line runs from the NTP in the premise to a terminating block within the distribution frame location
Shared LLU	As for full LLU, except that an access seeker can only use the high frequencies
Sub-loop unbundling (SLU)	The full service for SLU allows access seekers to provide services, including voice and broadband, over the sub-loop using its own equipment deployed in the vicinity of a Telenor street cabinet

Service	Description
Shared SLU	As for full SLU, except that an access seeker can only use the high frequencies. Also, the access seeker must provide splitters at both the street cabinet and the NTP
Leased lines	Provision of one or more local tails for a permanent connection from a location, for retail customers, other operators, or internal use
Access lines	In addition to the above services, other lines in the access network which may be deployed can be quantified

Since the existing LRIC model was released, a virtual unbundling local access (VULA) product has been developed by Telenor and has been commercially available since January 2015.[20] We have included this in the list of services as well, which we reflect in the following (new) principle.

Principle A14: The access model will continue to model all relevant access line services from the existing LRIC model. For the purposes of the NGA calculations, the access network cost elements of a VULA product will also be modelled.

6.2 Other services in the service set

In the original specification, Principle 7 stated that *services covering access to both ducts and fibre in the access network can be included in the Market 4 service set*. These two services are defined below.

Figure 6.2: Other services over which access costs can be recovered [Source: Analysys Mason, 2015]

Service	Description
Duct access	Provision of dedicated capacity within a duct in the access network, where an access seeker can deploy its own cabling
Dark fibre access	Provision of access to a fibre (or fibres) between two locations. The access seeker can deploy its own electronics at these locations in order to light the fibre and use it for its own point-to-point transmission

We believe that these are still relevant and will be retained for the updated LRIC model.

Principle A15: Services covering access to both ducts and fibre in the access network can be included in the Market 4 service set.

6.3 Modelled wholesale services

The relevant wholesale products for Market 4 can include unbundled access to both shared and full loops and sub-loops, for either copper or FTTH/PTP services. Sub-loop unbundling is relevant to FTTN/VDSL. A VULA product, as Telenor is now offering, is also feasible over all the relevant

20 The principle of VULA is the provision of a wholesale service that allows an access seeker to deliver services over a NGA network with a degree of service control that is similar to that achieved when a line is physically unbundled

NGA architectures. In the context of Market 5, bitstream access would also be possible on all copper and fibre architectures.

The costs of the *access-related* elements for all of these services could be calculated using the existing LRIC model of fixed access networks, which would allow comparison between the unit costs of services on the NGA networks and the legacy copper network.

In the original specification, Principle 14 stated that *the costs of both full and shared access to both copper loops and sub-loops will be calculated for the current network*. As described in Section 5.1.1, we will retain the copper model capability and therefore this principle is still relevant.

Principle A16: The costs of both full and shared access to both copper loops and sub-loops will be calculated for the copper access network.

In the original specification, Principle 15 stated that *the costs will be calculated for copper SLU for a FTTN/VDSL deployment, and fibre unbundling for a FTTH/PTP deployment*. As described above, VULA is also now a relevant product and will be added to this principle.

Principle A17: The costs will be calculated for copper SLU for a FTTN/VDSL deployment, fibre unbundling for a FTTH/PTP deployment and the access-related costs of VULA for all NGA architectures.

Calculation of the full cost of bitstream/VULA services over any of these architectures will not be possible using this model alone, since this requires additional knowledge of core network costs.

6.4 Migration from legacy access networks to NGA networks

In the original specification, Principle 35 stated that *we will model the NGA architectures deployed (which may vary across geotypes) as standalone, with a reasonable utilisation profile over time, rather than modelling an explicit migration between the legacy and NGA architectures. Any potential savings in trench/duct would be calculated exogenously. The design algorithms will not be capable of either identifying or using duct from a legacy network.*

Regarding the issue of migration, Recital 49 of the 2013 EC Recommendation states *active copper lines are decreasing due to customers migrating to cable, fibre and/or mobile networks. Modelling a single efficient NGA network for copper and NGA access products neutralises the inflationary volume effect that arises when modelling a copper network, where fixed network costs are distributed over a decreasing number of active copper lines. It allows for progressively transferring the traffic volume from copper to NGA with deployment of and switching to NGA. Only traffic volume moving to other infrastructures (for example cable, mobile), which are not included in the cost model, will entail a rise in unit costs.*

Our interpretation of this part of the 2013 EC Recommendation is that the modelled network should always be assumed to carry both the copper demand and fibre demand calculated by the *Market* module for the hypothetical incumbent operator. This means that active copper access lines should be converted into active fibre-equivalent access lines (when modelling a NGA network) and vice versa (when modelling a copper network). We further note that:

- Telenor has announced plans to migrate customers away from parts of the copper network to either fibre or HFC, where this is the most commercially sensible choice.[21] This is a logical approach, since it reduces the cost of inefficiently running multiple parallel architectures.
- Local operators (other than Telenor) have deployed wired NGA networks in parts of Norway. It is therefore unlikely that Telenor will deploy a competing NGA network in such areas.

When modelling an NGA network (as set out in Section 5.1), it would appear that, in order to get consistency between scale and demand, there are two options:

- When defining the modelled footprint, exclude the parts of the network that in the long term Telenor will either serve with HFC, or to which it will not deploy NGA. The corresponding demand of these parts of the network would also be excluded.
- Alternatively, the national footprint can be retained, but the corresponding demand from Telenor's HFC network and the local wired broadband networks should be included.

We intend to model a national NGA network that carries all of this demand (i.e. Telenor's copper/fibre/HFC subscribers and local fibre operator subscribers).

We note that the last sentence in recital 49 could be interpreted as saying that subscribers moving to a cable network should be excluded from the cost model. However, the discussion of cable infrastructure in that sentence appears to imply a competing fixed broadband infrastructure. For both Telenor's HFC network and the local fibre networks, it does not appear to be the case that they will have a competing NGA broadband infrastructure. Demand on non-Telenor-owned cable networks will not be included.

As described in Section 4.4, the assets to be reused in the RCEA will be specified exogenously (i.e. by assumptions within the active calculations rather than the offline calculations). Therefore, the last sentence in the original principle will still apply, but for clarity we will add an explanation as to how reused assets will be handled in the model.

[21] See http://www.telenor.com/wp-content/uploads/2012/09/05_CMD-2012-Telenor-Norway_FINAL.pdf), page 9

Draft principle A18 (restated from draft specification): We will assume that the modelled network carries as a minimum the forecast copper demand and fibre demand for the hypothetical Telenor-scale operator, but also the Telenor active HFC connections and active connections served by the local operators in rural areas. This will ensure consistent economies of scale are achieved by the modelled network. The design algorithms will not themselves be capable of either identifying or choosing to use duct from a legacy network; instead the existence of reusable civil engineering assets (RCEA) will be allowed for by assuming some fraction of reuse for appropriate asset types.

Feedback from Telenor

"Telenor does not agree in that a model likely used to regulate fixed access prices should assume the modelled network always carry both copper and NGA demand, as this will result in an efficiency level a real operator can never hope to achieve. This thus precludes recovery of all efficiently incurred costs given the actual constraint we are facing.

However, Telenor acknowledge the 2013 EC recommendation seems to intend such an approach. We further recognize that the Recommendation is unlikely to be deviated from in the specification of this model. Under these circumstances Telenor agrees that the chosen approach of modelling a national footprint with added demand from Telenor's HFC and other operator's NGA is reasonable.

Telenor emphasizes that local operators are indeed very active offering NGA also in urban areas. Given this approach, it is important to reflect some of the reduced efficiencies in areas where Telenor does not offer NGA. Most important of these is the lack of infrastructure re-use. In the vast majority of cases alternative fibre providers use their own civil infrastructure rather than Telenor's, and as a result the re-use factor for RCEA in these areas should approach zero.

Telenor recommend this to be reflected in the model."

Analysys Mason response

We would clarify that in a given area, the modelled NGA provider has three options when deploying their networks:

- Build new infrastructure
- Re-use existing infrastructure that they own
- Re-use existing infrastructure from other companies (e.g. via a lease, reciprocal or other commercial agreement).

In the context of Nkom's model, only infrastructure in the second category will lie within the RCEA. We acknowledge Telenor's observations regarding variation in network characteristics where Telenor does not deploy NGA networks. The behaviour by actual NGA operators (both Telenor and other providers) will be one of the contributing inputs to the modelling implementation. We would observe that NGA operators other than Telenor (e.g. utility companies) can have existing infrastructure that they own and can re-use. If the modelled operator builds new infrastructure then this would be modelled at replacement cost. If its re-uses existing infrastructure that it does not itself own, then this would be modelled as a rental agreement of some sort.

The model will be able to capture possible variations in the extent of RCEA usage by geotype, provided the assumptions can be supported by evidence. The principle has been refined to reflect this.

Principle A18: We will assume that the modelled network carries as a minimum the forecast copper demand and fibre demand for the hypothetical Telenor-scale operator, but also the Telenor active HFC connections and active connections served by the local operators. This will ensure consistent economies of scale are achieved by the modelled network. The design algorithms will not themselves be capable of either identifying or choosing to use duct from a legacy network; instead the existence of reusable civil engineering assets (RCEA) will be allowed for by assuming some fraction of reuse for appropriate asset types. This fraction will be assumed to vary by geotype if data can be identified to support this variation.

7 Concepts related to the model implementation

This section describes the concepts that are related to the implementation of the updated LRIC model. In particular:

- Section 7.1 defines the increment for the purposes of the model
- Section 7.2 discusses the options for depreciation methods to use in the model
- Section 7.3 sets out the period of years that the model will consider
- Section 7.4 states how the weighted average cost of capital (WACC) will be calculated for the model
- Section 7.5 indicates our treatment of common costs
- Section 7.6 describes how input costs should be derived for the model
- Section 7.7 provides our treatment of the State Aid scheme in Norway
- Section 7.8 outlines the principles for asset lifetimes assumed in the modelling.

7.1 Definition of increments and cost recovery

In the original specification, Principle 2 stated that *the increment in the access network will be defined as the total volume of all services using the access network – a LRAIC approach*. In line with this approach, we therefore defined a specific increment for the access network to cost the services relevant to Markets 4 and 5. In assessing an incumbent operator's cost base, this leads to the identification of costs common to the other service increments for its business, as illustrated in Figure 7.1. The treatment of these common costs is discussed below.

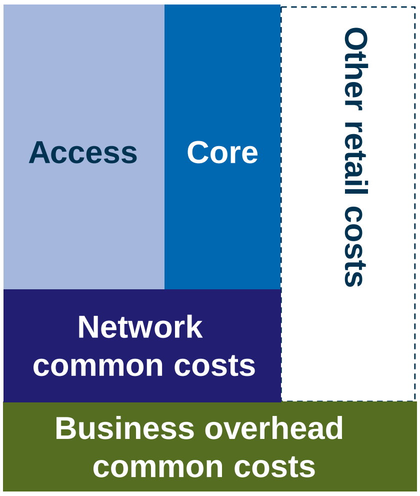


Figure 7.1: Access and core increments for a fixed business, as well as common costs [Source: Analysys Mason, 2015]

In the legacy copper network considered in the existing LRIC model, the boundary between the access network and the core network will be between the equipment side of the main distribution frame and the PSTN concentrator. In an NGN, the border is similarly located between the access line and the active electronics using the line. This is further explained in Section 5.4.

Applying a specific access increment implies that focus is required on the definition of network elements as being part of the core network or the access networks (or common to both). The level of costs recovered in total is not affected by the definition of increments – the increment definition affects which services recover those costs.

For Markets 4 and 5, and the costing of the unbundled local-loop service in particular, it is reasonable to include other services delivered over the copper network that use shared resources. This implies that all services using the access network duct and trench, including copper loops, fibre links and duct access itself, should be costed and included in the increment.

Such an approach will allow cost-causality principles to lead to the allocation of costs on a per-line basis. This can be considered a LRAIC approach. Recital 29 of the 2013 EC Recommendation indicates that *the bottom-up long-run incremental costs plus (BU LRIC+) costing methodology best meets these objectives for setting prices of the regulated wholesale access services. This methodology models the incremental capital (including sunk) and operating costs borne by a hypothetically efficient operator in providing all access services*. This is consistent with the principle in the original specification and we will therefore retain it.

Principle A19: The increment in the access network will be defined as the total volume of all services using the access network - a LRAIC approach.

Furthermore, in the original specification, Principle 8 stated that *consistent with the approach for the current network, the costs of NGA connections will be determined through the recovery of the total cost of a NGA architectural deployment over the active access connections in that architecture*. We retain the wording of this principle from the original specification, but we shall generalise it so that it can be applied to any modelled access network architecture.

Principle A20: The costs of access connections will be determined through the recovery of the total cost of an architectural deployment over the active access connections in that architecture.

7.2 Depreciation methods

The different depreciation methods are described in Annex B, but in summary they are as follows:

The models developed for fixed access networks will produce the relevant network capital and operating expenditures. These expenditures must be recovered over time, ensuring that price-regulated operators can also earn a return on investment. There are four main types of depreciation method for defining cost recovery:

- **historical cost accounting (HCA) depreciation**, where the capital expenditure recorded in the fixed asset register (the gross book value, GBV) is depreciated over the defined financial lifetime of the asset at a uniform rate, usually with a constant depreciation charge per year.

- **current cost accounting (CCA) depreciation**, where the straight-line depreciation calculation is modified to take into account the changes in replacement cost for an asset i.e. its modern equivalent asset (MEA) price. We further note that CCA has two variants:
  - **operating capital maintenance (OCM)**, which seeks to maintain the operating or output capacity of the asset
  - **financial capital maintenance (FCM)**, which seeks to maintain the value of the originally invested capital
- **annuities**, where an annualised cost is derived to allow for full recovery of both the investment and the capital employed, There are several types of annuity calculation:
  - **tilted annuities**, where the recovery of investment and return on capital is tilted with the forecast price trend of the asset (an annuity without such a tilt is a **standard annuity**)
  - **modified tilted annuities** include an additional tilt to take into consideration the change in economic output. When the economic output is not changing significantly, this approach closely mimic economic depreciation
- **economic depreciation**, which is theoretically the appropriate method for regulatory costing since it takes into account all the underlying factors that influence the economic value of an asset, that is:
  - projected trends in operating expenditures associated with the asset
  - projected trends in replacing the asset with its modern equivalent unit
  - the output that can be generated by the asset.

In the original specification, Principle 48 stated that *For the core network model, we will make explicit use of an economic depreciation calculation. For the access model, we will investigate appropriate adjustments in the access network model to accommodate changing demand profiles. This will take the form of either a tilted annuity or an economic depreciation calculation*.

For the purposes of the v2.0F core network model, the first sentence in the principle is still applied, since it is consistent with the 2009 EC Recommendation on termination rate costing.[22] We will not consider this part of the principle in this document, since we are concerned here only with the access network model.

Points 34 and 35 of the 2013 EC Recommendation states *NRAs should value reusable legacy civil engineering assets and their corresponding RAB on the basis of the indexation method. Specifically, NRAs should set the RAB for this type of assets at the regulatory accounting value net of the accumulated depreciation at the time of calculation, indexed by an appropriate price index, such as the retail price index. NRAs should examine the accounts of the SMP operator where available in order to determine whether they are sufficiently reliable as a basis to reconstruct the regulatory accounting value. They should otherwise conduct a valuation on the basis of a benchmark of best practices in comparable Member States. NRAs should not include reusable legacy civil engineering assets that are fully depreciated but still in use. When applying the method for asset valuation set out in point 34, NRAs should lock in the RAB corresponding to the*

22 European Commission C(2009) 3359 07.05.2009 on the regulatory treatment of fixed and mobile termination rates in the EU. See http://ec.europa.eu/smart-regulation/impact/ia_carried_out/docs/ia_2009/c_2009_3359_en.pdf

reusable legacy civil engineering assets and then roll it forward from one regulatory period to the next.

The existing LRIC model contains a full multi-year economic depreciation calculation (over a period of 120 years) in an attempt to capture the changing costs and demand on both historic/current copper deployments and future fibre deployments. This leads to both the Network Design – Access module and Service Costing – Access modules being large and complex.

Neither the 2013 EC Recommendation nor the preceding 2010 EC Recommendation provides guidelines as to the depreciation method that should be used, except for the above guidelines on valuing the RCEA.

For the purposes of calculating the capital costs of assets except those that are RCEA, we believe that the model should be simplified to use a one-year depreciation method. The modified tilted annuity formula is the most appropriate implementation in our opinion given its flexible capability to reflect forward-looking changes in both cost trends and asset utilisation (i.e. assumed demand) in the tilt. We therefore remove the reference to economic depreciation in the principle.

Although this means that Nkom's core network model and access network model would be using different depreciation methods, this is not an inconsistency (and was in fact allowable in the original specification). It is important that the depreciation method reflect the aspects that can influence the economic value of an asset i.e. changes in the modern equivalent asset costs over time and changes in asset utilisation described above. A modified tilted annuity is considered a good reflection of these aspects where there are only moderate changes in demand over time. Given our assumed demand profile described in Section 6.4 should have this property (since it neutralises most of the effects of migration between different access networks), a tilted annuity is an appropriate approach to use for our access network modelling. This is not the case in the core network model, where the traffic levels are changing significantly over time and a more comprehensive economic depreciation calculation is required (as is currently implemented).

Other countries have used different depreciation methods for their cost models of fixed core and fixed access networks. For example, the UK, Belgium and the Netherlands all use economic depreciation for their cost models of fixed core networks, but different approaches when modelling fixed access networks. The draft model published in 2011 by the Belgium regulator used a combination of HCA and economic depreciation for the modelling of the access network. A different choice of depreciation method can merely lead to a different cost recovery profile.

This implementation of a titled annuity (or modified tilted annuity) is consistent with the access network costing approach currently taken in numerous jurisdictions including Denmark, Sweden, Luxembourg, Croatia and Malta (with Denmark and Croatia in particular having taken account of the 2013 EC Recommendation in their most recent modelling).

For the purposes of calculating the capital costs of the RCEA i.e. to derive an accounting value net of the accumulated depreciation at the time of model development, we will:

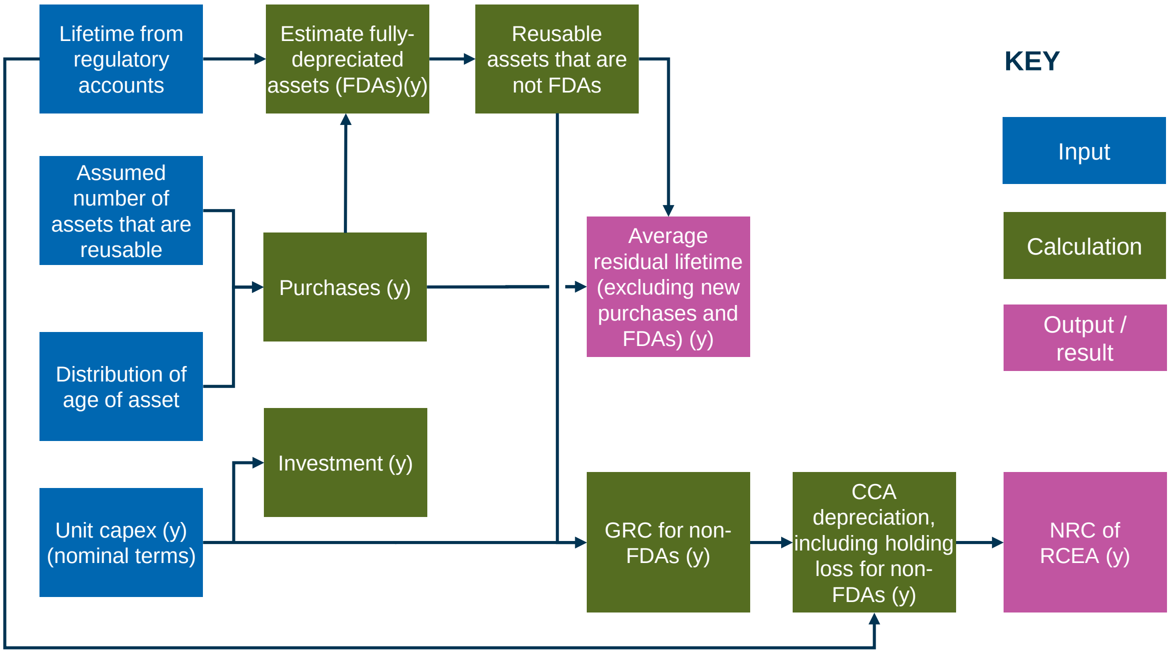
- Seek information from Telenor on the average age and spread of the age of each asset type within the RCEA
- Calibrate a purchasing schedule over historic years for these assets
- Calculate the number of elements that are in the RCEA in each historic year
- Revalue these assets using a CCA FCM approach as set out in Annex B.2, using the economic lifetimes assumed in the existing LRIC model as a starting point.

In order to comply with the 2013 EC Recommendation, the number of elements that are in the RCEA in each historical year will not be determined by the economic lifetime in the LRIC model, but according to whether the assets have already exceeded the lifetime from Telenor's regulatory accounts. Only those remaining assets will then be used in the CCA valuation. This is because Telenor should have already recovered the costs of the assets which are older than this lifetime.

Historical cost trends for these assets will also be required for the calculation. The existing LRIC model also contains real-terms historic capex cost trends for these assets, which we believe (when converted into nominal capex cost trends) could be an appropriate price index for the calculation. The 2013 EC Recommendation itself suggests the domestic retail price index as another possibility. The model will include the capability to test different indices for this part of the calculation.

This will allow the calculation of both the CCA FCM depreciation charge and net replacement cost (NRC) for 2015, with the NRC being the residual value for the RCEA. This would be calculated for each asset. Our valuation in future years for each asset type within the RCEA will extend the calculation above into future years, but assuming that the nominal capex cost trend in the future is equal to the chosen price index. This calculation is illustrated below in Figure 7.2.

Figure 7.2: Illustration of our RCEA valuation [Source: Analysys Mason, 2015]



Draft principle A21 (restated from draft specification): For the access model, we will investigate appropriate adjustments in the access network model to accommodate changing demand profiles. This will take the form of a flexible tilted annuity calculation. The RCEA will be valued according to a CCA depreciation calculation, but with fully depreciated RCEA excluded from the revaluation.

Feedback from Telenor

"Telenor observes that in the discussion preceding this principle, Nkom/Analysys Mason sets out a methodology where only assets that are within their financial life are included, as seen in this quote (page 41 of the draft specification):

In order to comply with the 2013 EC Recommendation, the number of elements that are in the RCEA in each historical year will not be determined by the economic lifetime in the LRIC model, but according to whether the assets have already exceeded the financial lifetime from Telenor's accounts. Only those remaining assets will then be used in the CCA valuation. This is because Telenor should have already recovered the costs of the assets which are older than their financial lifetime.

Telenor does not believe this in line with the methodology laid out by the 2013 EC Recommendation. The Recommendation says (in article 34):

Specifically, NRAs should set the RAB for this type of assets at the regulatory accounting value net of the accumulated depreciation at the time of calculation, indexed by an appropriate price index, such as the retail price index.

It further defines "Regulatory accounting value" in article 6p as: *`Regulatory accounting value' is the value of an asset as recorded in the audited regulatory accounts of an undertaking which considers actual utilisation and lifetimes of the assets, which are typically longer than those recorded in statutory accounts and which are more in line with technical lifetimes.*

In the preamble of the Recommendation (point 35) it is furthermore clarified that:

In the recommended costing methodology the Regulatory Asset Base (RAB) corresponding to the reusable legacy civil engineering assets is valued at current costs, taking account of the assets' elapsed economic life and thus of the costs already recovered by the regulated SMP operator.

From this, it is clear that regulatory accounting value should be calculated considering actual/economic lifetimes of the assets, not the shorter financial life times as outlined in Nkom/Analysys Mason's methodology.

Telenor suggest amending the methodology to properly reflect the Recommendation, by using economic lives to determine which elements are part of the RCEA asset base. Additionally, this will make it more reasonable to assume Telenor can have recovered the cost of the asset before it is excluded from the valuation base than is the case when using financial lives.

On a separate point, the methodology outlined in the discussion preceding this principle, like the 2013 EC Recommendation itself, does not take into account reinvestments in what is labelled RCEA. This includes replacement poles, and refurnishment [sic] of poles and ducts. This is unfortunate, as omitting reinvestment costs in civil engineering from recoverable cost will negatively impact incentives to make these investments.

Telenor suggests two options for addressing this without going against the Recommendation:

- Classify assets in need of (re-)investments as non-reusable. This means that the input variable(s) deciding what fraction of civil engineering assets are reusable should be changed such that assets that have been/or are in need of being replaced or refurbished are not included.
- Treat re-investments as opex in the model, albeit Telenor's accounts treat them as capex. This means in opex per unit of relevant equipment should increase to account for periodic replacement - first and foremost for poles."

Analysys Mason response

Based on Telenor's feedback and a review of the 2013 EC Recommendation, Analysys Mason intends to amend the text from the draft specification (as quoted by Telenor) below:

In order to comply with the 2013 EC Recommendation, the number of elements that are in the RCEA in each historical year will not be determined by the economic lifetime in the LRIC model, but according to whether the assets have already exceeded the ~~financial~~ lifetime from Telenor's ***regulatory*** *accounts. Only those remaining assets will then be used in the CCA valuation. This is because Telenor should have already recovered the costs of the assets which are older than* ***this*** *~~their financial~~ lifetime.*

The principled view now taken by Nkom and Analysys Mason is that the key sentence in the 2013 EC Recommendation is from recital 35, where the RAB should take account of the *"costs already recovered by the regulated SMP operator."* In Norway, LLU services have been historically priced based on Telenor's regulatory accounts (using HCA depreciation principles) submitted to Nkom. Therefore, we believe the lifetime assumptions within those accounts should be used to determine the fully depreciated assets. Furthermore, our view is now that HCA depreciation should be used to determine the remaining value, in line with those regulatory accounts. However, we will build into the model the option to use either HCA depreciation or CCA depreciation to determine the residual value of RCEA, so that all stakeholders can understand the impact of the two options.

We also seek to clarify that this residual value of RCEA must then be recovered over the average remaining *economic* lifetime of the RCEA in question, with fully-depreciated assets excluded entirely. Let us take the example of reused poles, which in the model are assumed to have an economic lifetime of 20 years. If we assume that poles have a lifetime of 15 years in Telenor's regulatory accounts and that the poles reused *that are not fully depreciated* have an average age of 12 years, then the remaining value of the poles would be recovered over a period of 20–12=8 years. The principle has been clarified to make this point clear.[23]

With regards to the refurbishment of re-useable assets for NGA purposes, we would consider that if a new pole is placed at the location then this is not being re-used. Our asset re-use inputs will be assumed to only cover assets that require refurbishment (not replacement). An appropriate cost of refurbishment will be included as additional one-off capex to the residual value of the re-useable assets, so that it can then be recovered over the remaining lifetime of the asset.

With regards to periodic replacement of re-useable assets, we will include the functionality in the model to include the replacement cost of an assumed proportion of RCEA as in-year opex. The proportion assumed can be determined in the model development.

Principle A21: For the access model, we will investigate appropriate adjustments in the access network model to accommodate changing demand profiles. This will take the form of a flexible tilted annuity calculation. The RCEA will be valued according to either a HCA or a CCA depreciation calculation (both will be encoded in the model), but with fully depreciated RCEA excluded from the revaluation. The residual value of the revalued assets will then be recovered over the average remaining economic lifetime of the non-fully-depreciated assets. Fully depreciated assets will be determined based on the lifetimes from Telenor's regulatory accounts. The copper assets reused for the FTTN network (and the remaining value of the entire copper network) will also be calculated in this way.

Costs of refurbishment will be included as a capex item (in addition to the residual value), so that it can be recovered over the remaining lifetime of the RCEA.

7.3 Modelling period

In the original specification, Principle 49 stated that *for the access network model, the model will cover, at minimum, the period 2008 to 2015.*

The final version of the existing LRIC model was in fact able to calculate the network asset counts, expenditures and unit costs of services for the period 1951–2070. However, since we have removed the economic depreciation calculation in Section 7.2, we find this functionality in both the Network Design – Access module and Service Costing – Access module to be superfluous to the requirements of the updated model. In order to simplify the workings of the updated model, we will remove the multi-year functionality. The network design, expenditure and service costing calculations will now be constructed for only one selected year. Since the model needs to be forward-looking and has forecast market volumes available for all years between 2015 and 2050,

[23] We also observe, as described in Section 7.8, that the copper assets re-used in the modelled FTTN network must also be treated in this way. The value of the copper network itself can also be considered in this way, which is the approach used for past LLU pricing in Norway.

the Network Design – Access module and Service Costing – Access module will be able to calculate outputs for any year in this period.

We observe that removing the time dimension in the calculations leaves a 'spare dimension'. Whereas the existing model does not simultaneously calculate outputs for each geotype individually, this spare dimension now makes this possible. We include this functionality in the updated model. Understanding the costs of services in different geotypes of Norway may be useful to Nkom in future market analyses. For example, as stated in point 50 of the 2013 EC Recommendation, geographically differentiated remedies may be of relevance in future regulation.

As described in Section 7.2, the valuation of the RCEA will most likely need to be multi-year in order to properly revalue these assets in accordance with the 2013 EC Recommendation. There will therefore be a multi-year side calculation included in the Network Design – Access module to revalue the RCEA for the selected year.

Principle A22: The access network model will be able to calculate the network assets and associated expenditures for a single selected year from 2015 to 2050 i.e. the current and future years in the Market module, from where the relevant demand volumes shall be taken. A multi-year side-calculation will be included within the Network Design – Access module to revalue the RCEA.

7.4 Weighted average cost of capital (WACC)

In the original specification, Principle 4 stated that *a WACC will be used in the model in order to provide a return on investments. The approach to defining the WACC will be determined by an advisor*.

A requirement of prices in a competitive market is that the operator earns a normal, rather than super-normal, return on investment. This must be earned over the long run, rather than over the short run, since there would need to be a consideration of a terminal value and its associated earning power in a short-run return calculation.

The WACC represents the opportunity cost of capital invested in the business, and therefore the return on investment required to compensate for this opportunity cost.

Nkom has separately appointed an external advisor to determine the approach and the appropriate value for the WACC to be used in the model.

The model will include WACC as a parameter and Nkom will employ the same approach to its calculation as before. Although the 2013 EC Recommendation makes no specific comments on how the WACC is calculated, the 2010 EC Recommendation does and will be considered by the external advisor. In particular, point 6 of Annex 1 describes how a risk premium could be incorporated into the cost of capital in the costing of NGA services.

Principle A23: A WACC will be used in the model in order to provide a return on investments. The approach to defining the WACC will be determined by an advisor.

7.5 Common cost mark-ups

In the original specification, Principle 3 stated that *where required, an EPMU approach will be employed for marking-up common costs*.

The calculation of incremental costs for a fixed operator will identify some costs as common to the increments. These are likely to include:

- network common costs – parts of the deployed network that are common to all network services (e.g. the voice platform for a small increment approach; local exchange space, which is common to core and access, for the larger increment definitions)
- non-network common costs, or 'business overheads' – activities that are common to all functions of the business (e.g. the CEO).

For some services (and depending on the pricing approach to be taken by Nkom, which is outside the scope of this paper) common costs may be allocated to the increments. Where rational allocations cannot be made on cost-causality principles, then mark-ups are required.

If all common costs are borne by one increment, the increment's LRIC is marked up to the efficient stand-alone cost (SAC) of providing that increment. The SAC therefore represents the ceiling to the marked-up cost of any increment: in such a situation, the mark-up on the LRIC of other increments would be zero by definition. In the situation where organisation-level common costs are shared among increments, a mark-up mechanism needs to be defined that will produce the relevant marked-up LRIC (i.e. the LRIC+). These situations are illustrated in Figure 7.3 below.

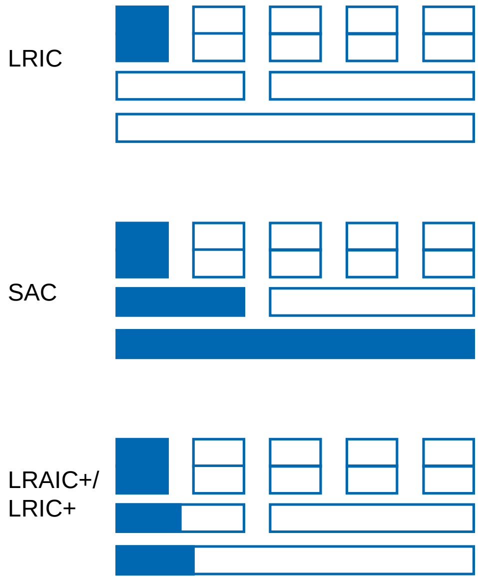


Figure 7.3: Illustration of LRIC, SAC and LRIC+ [Source: Analysys Mason, 2015]

Equi-proportionate mark-up (EPMU) is a commonly adopted approach for the allocation of common costs. In the EPMU approach, a unique percentage is used as an uplift for the incremental cost of all the increments. The percentage is calculated as the ratio of total common costs to total incremental costs. Applying an EPMU is straightforward, results in uniform treatment of all of the service costs in the business, and does not require any additional information to calculate.

Point 30 of the 2013 EC Recommendation states *there should be the addition of a mark-up for the recovery of common costs*. EPMU is supported on the grounds that it is objective and easy to implement. It is also consistent with regulatory practice elsewhere. Therefore, we the principle from the original specification shall be retained.

> **Principle A24:** Where required, an EPMU approach will be employed for marking-up common costs.

7.6 Input costs

The operation of a fixed network is characterised by expenditures over time. These expenditures will be accounted for as either:

- **capital expenditures (capex)**, which are booked in the asset register and depreciated over time, also earning a return on investment due to the opportunity cost of tying up capital in the tangible and intangible assets. The level of these costs should be assessed on the modern basis. Specifically, these should reflect the level of expenditures prevailing at each point in time. We would expect that the capital investment cost of an asset should include the capitalisation of operating expenditures associated with its installation and testing. An asset type may also need to include an additional cost for spares which may be need to be held and a decommissioning cost associated with removing the asset from the network.

- **operating expenditures (opex)**, which are expensed in the profit and loss account in the year they are incurred, thus not tying up any capital (other than monthly on-going working capital). Operating expenditures should relate to the level of rental, power, staffing, maintenance and other costs associated with an asset once it has been activated in the network.

In this section, we think there are three issues to consider, namely the specific case of unit costs of trenching, other unit costs and cost trends. We discuss each of these in turn below.

7.6.1 Trenching unit costs

It is known that the cost to dig trenches is dependent on the type of terrain (i.e. rock/soil/road type) in which it is being deployed. Moreover, the cost of trenching can be high in Norway. In the original specification, Principle 30 stated that *assuming sufficiently detailed costs and geographical data related to trenching is available, the data will be used to inform the costs of digging trench in an efficiently deployed network according to terrain*.

We believe that this principle still applies and will not change the wording.

Principle A25: Assuming sufficiently detailed costs and geographical data related to trenching is available, the data will be used to inform the costs of digging trench in an efficiently deployed network according to terrain.

A priority of the data gathering process will be to seek as many reference costs from digging projects from as many stakeholders as possible. The existing framework of inputs (using five terrain types) may be restructured so that the modelled unit costs are able to reflect the efficient costs of digging in Norway whilst preserving confidentiality of stakeholder datapoints.

7.6.2 Other unit costs

In the original specification, Principle 45 stated that *costs for each asset will be defined in terms of unit equipment costs, installation cost, cost of spares held and cost of decommissioning. The decommissioning cost will be set to zero by default unless a value can be substantiated. For each asset an operating expenditure will be defined relating to the operation and maintenance of that asset*.

In the 2013 Recommendation, there are references to 'efficient' costs; for instance, in point 37 (*efficiently priced copper elements*) and recital 29 (*recovery of the total efficiently incurred costs*). Cross-checks will be made to the unit costs assumed in the existing model are at efficient levels and industry stakeholder input will be sought to substantiate whether these values are efficient (or, if not, what an efficient level should be). We have therefore amended references to 'costs' to say 'efficient costs' in the principle.

Both capital and operating costs will need to be assessed in the context of efficiency, especially for the fibre network. For example, Telenor has been investing in platforms to improve the efficiency of running its fibre network, which will need to be accounted for when calculating the operating costs for the NGA network.[24]

Principle A26: Efficient costs for each asset will be defined in terms of unit equipment costs, installation cost, cost of spares held and cost of decommissioning. The decommissioning cost will be set to zero by default unless a value can be substantiated. For each asset an efficient operating expenditure will be defined relating to the operation and maintenance of that asset.

7.6.3 Cost trends

The MEA price for purchasing and operating network elements will vary over time as the price of hardware capacity decreases, and other costs (e.g. rents) increase. As such, the model should

24 See http://www.tmcnet.com/tmc/whitepapers/documents/whitepapers/2014/10448-telenor-achieves-competitive-advantage-ultra-broadband.pdf

reflect the MEA trend of capital and operating expenditures, assessed in real terms to remove the underlying effects of inflation.

In the original specification, Principle 46 stated that *cost trends will be defined for capital and operational expenses. Consideration of the cost-trends with and without inflation shall be made*.

There are no specific references in the 2013 EC Recommendation with respect to treatment of cost trends for assets. Therefore, we will leave this principle unchanged.

Principle A27: Cost trends will be defined for capital and operational expenses. Consideration of the cost-trends with and without inflation shall be made.

However, we expect to revisit the cost trends assumed, and identify whether values should be revised. In particular, industry stakeholder input will be sought and the values in the existing model will be compared to other models in the public domain.

7.7 Treatment of State Aid

In June 2014, the ESA approved a broadband state aid scheme that Nkom will oversee from 2014 through to 2017.[25] In 2014, Nkom was allocated NOK160 million for the scheme and awarded NOK159.4 million to 35 projects (from 171 applicants).[26] In 2015, Nkom has been allocated NOK110 million for assignment to projects.[27] The budgets for 2016 and 2017 are not currently known. There have also been a number of other projects with public funding, such as the NGA deployment in Tromsø undertaken by Nordix as of 2012.[28]

We will request data from stakeholders as to the NGA network deployments being used in remote areas, as it will help inform what could be an efficient and feasible NGA solution in these areas.

Should Telenor (as the SMP operator in Market 4) have received any public subsidy for NGA deployments (e.g. through successful tendering for such projects), then this will need to be netted off the cost calculation for the NGA networks. We will do this in a geographically de-averaged manner, provided sufficient data is available i.e. we geocode the project with the subsidy to a particular geotype and then net off the subsidy for that geotype. In order to be consistent with Section 6.4, it will most likely be necessary to net off all public subsidies (since by modelling a national NGA network all subsidised local networks will implicitly be captured within that footprint). We would not include subsidies provided for wireless broadband networks, since a competing (wired) NGA architecture could still be deployed in these areas.

25 See http://www.nkom.no/aktuelt/nyheter/bredb%C3%A5ndsst%C3%B8tteordningen-godkjent-av-esa

26 See http://www.nkom.no/teknisk/bredb%C3%A5nd/utbygging/tildelingar-av-breibandstilskot

27 See http://www.nkom.no/aktuelt/nyheter/tilskuddsordning-for-bredbånd-2015

28 See http://www.tromso.kommune.no/bredbaand-i-distrikts-tromsoe-resultat-etter-tredje-anbudsrunde.5068042-110070.html

As many sources of (NGA-related) public subsidies to Telenor and the local fibre network operators as are available at the time of the final model development will be geocoded to their corresponding location (it should be possible to identify it with being in a specific geotype). The value of subsidy that is provided to the operator should then be included as a negative capex, with a lifetime consistent with that of civil assets in the model, and a nominal cost trend of 0%. This capex can then be annualised using the depreciation method (for non-RCEA) as described in Section 7.2.

The lifetime will be at least 40 years on the basis that point 36 of the 2013 EC Recommendation indicates that the lifetime of the civil engineering assets should be set corresponding to the expected period of time during which the asset is useful and to the demand profile (not less than 40 years in the case of ducts). We would assume that, since civil engineering assets form the bulk of access network costs, that the aid can be reasonably assumed to subsidise this part of the network.

Principle A28: If a public subsidy is relevant to a NGA (i.e. wired) network deployment in a particular area of Norway, then in the bottom-up model that subsidy should be netted off the valuation of the asset base, by including the subsidy as a negative capital cost with a lifetime consistent with that of the civil assets in the model and a nominal cost trend of zero.

7.8 Input lifetimes

Network asset lifetimes are used for replacement purposes and can be used for depreciation purposes depending on the type of depreciation method selected. Whereas accounting (financial) lifetimes reflect the number of years that an asset will appear in a company's accounts, an economic lifetime also consider the estimated average physical/technical lifetime and other exogenous lifetime effects, such as early retirement or technological changes.

In the original specification, Principle 47 stated that *economic lifetimes will be defined for each asset*. We believe that this is consistent with Point 36 of the 2013 EC Recommendation, which refers to the case of the civil engineering assets (*NRAs should set the lifetime of the civil engineering assets at a duration corresponding to the expected period of time during which the asset is useful and to the demand profile. This is normally not less than 40 years in the case of ducts*). We note that the existing LRIC model already assumes that trenches and ducts have a lifetime of 40 years.

Point 6(p) states '*Regulatory accounting value' is the value of an asset as recorded in the audited regulatory accounts of an undertaking which considers actual utilisation and lifetimes of the assets, which are typically longer than those recorded in statutory accounts and which are more in line with technical lifetimes*. As described further in Section 7.2, the regulatory accounting value should be used for the valuation of the reusable legacy civil engineering assets, net their accumulated depreciation. Therefore, we will amend the principle to consider the averaged expected remaining lifetimes for these assets (where they have not already been fully depreciated) as an exceptional case.

With specific regard to FTTN/VDSL, recital 41 states *when setting the economic life time of the assets in a modelled FttC network NRAs should take into account the expected technological and network developments of the different network components*. Given that we will still be modelling FTTN/VDSL, we will also amend the principle to reflect this exceptional case.

Draft principle A29 (restated from draft specification): Economic lifetimes will be defined for each asset. For the specific case of the reusable legacy civil engineering assets and FTTN network assets, the lifetime value should be the average expected remaining lifetime of the non-fully depreciated assets.

Feedback from Telenor

"Telenor agrees that economic lives should be defined for each asset type, and that reusable civil engineering assets should be valued based on their remaining lives. Telenor does not agree FTTN network assets should be valued using average expected remaining lives. Apart from RCEA Telenor cannot see that the Recommendation provides any guidance on FTTN network assets as such, and accordingly FTTN network assets should be treated as other non-RCEA assets. Telenor suggests deleting the insertion "and FTTN network assets " from this principle.

While Telenor can agree to the wording of this principle as stated in its short form apart from the mention of FTTN network assets, we do not agree with the methodology indicated in the discussion preceding the principle. In particular, the sentence "Therefore, we will amend the principle to consider the lifetimes assumed in the audited regulatory accounts for these assets as an exceptional case" shows an intention to use financial lives in order to determine which assets are part of the value for RCEA, as financial lives are used in Telenor's regulatory accounts. This is not according to the 2013 EC Recommendation, as shown in our comments to Principle A21.

The Recommendation does not suggest the regulatory accounts are to be used for the valuation of the RCEA without due consideration. This can be seen in Point 34 of the Recommendation: *NRAs should examine the accounts of the SMP operator where available in order to determine whether they are sufficiently reliable as a basis to reconstruct the regulatory accounting value.*

This clearly opens for reconstruction of regulatory accounting value, something that is necessary if financial lives rather than economic lives are used in the existing accounts. As under principle A21, Telenor suggest the methodology is amended to reflect the Recommendation, by avoiding the use of financial lives."

Analysys Mason response

When considering recital 41 in the draft principle, it should be made clear that by FTTN network assets we meant only those assets reused from the copper network (i.e. copper cable between end-user and the street cabinet / distribution points). The fibre that would be deployed in the primary network between street cabinet and MDF, as well active street cabinet equipment, would be included at replacement cost and a full economic lifetime. With regards to trenches/poles used for the FTTN fibre cable, we would assume a proportion is also deployed as new at replacement cost and a full economic lifetime, with the remainder reused using space in ducts deployed for the copper network, or existing poles deployed. We have added the phrase "reused from the copper network" in the principle to reflect this point.

For those assets reused from the copper network, we believe that the approach described in Section 7.2 and the final version of Principle A21 is appropriate i.e. to recover their remaining economic value over their remaining economic lifetime.

We will also include the capability in the model to calculate the remaining economic cost and lifetimes of the entire copper network, in addition to the calculation of the remaining cost and lifetimes for the copper components re-used for the FTTN network.

> **Principle A29:** Economic lifetimes will be defined for each asset. For the specific case of the reusable legacy civil engineering assets and those network assets reused from the copper network, the lifetime value should be the average expected remaining lifetime of the non-fully-depreciated assets.

8 Summary of principles

Figure 8.1 below summarises the conceptual principles that are presented in this document and, where appropriate, the principle in the original model specification from February 2010.

Figure 8.1: Summary of principles in this specification [Source: Analysys Mason, 2015]

Original principle(s)	New principle	Description	Materially revised?
17	A1	The access network model will be capable of reflecting a number of hypothetical access network configurations, which are modelled using separate sets of parameters.	✗
25	A2	The scope of the access network model will be limited to exclude Jan Mayen, the dependencies, Antarctica and Svalbard. Where the access network in a geotype is modelled for the remaining parts of Norway, it shall be assumed that all locations in that geotype are passed and that an assumed proportion is also connected.	✗
24	A3	A modified scorched-node principle will be used, in which the level of scorching is clearly defined as an a priori assumption at the building locations of the MDF in the network.	✗
6	A4	A variety of access-related services will be modelled. The size of most assets in the access network asset base will not be varied on the basis of demand, but rather a forecast driven by locations passed. The costs of access will be recovered over the forecast demand. Assumed proportions of reusable civil engineering assets (RCEA), which include assets such as poles and ducted trenches, will be modelled separately.	✓
18–21, 26–28	A5	The methodologies used in the geo-analysis and offline calculations, as well as the raw geographic data (roads, buildings, etc.) from the original LRIC model will be retained, although small improvements to the network deployment algorithms will be made. The treatment of geotype 16 will be reconsidered, and the modelling approach revised for that geotype, if its exclusion is found to have a material impact on the final result. The network design inputs will be refined if industry stakeholders can provide improved information.	✗
5	A6	Use Telenor's actual service volumes as the starting point for a national operator as far as possible, with hypothetical values for remaining inputs. A network modelled on a subset of geotypes should be assumed to carry a proportionately smaller subset of demand volumes.	✓
22	A7	The copper deployment (with some fibre) that uses EF and HF to connect all buildings requiring connectivity back to the switch will be retained. The calculation will be reviewed to ensure that unit asset costs are efficient and the civil infrastructure is shared with the modelled NGA networks.	✓
23	A8	The access network model will include the capability to consider the deployment of FTTN/VDSL, FTTH/PTP and FTTH/GPON for a given set of areas.	✗

Original principle(s)	New principle	Description	Materially revised?
33	A9	We will retain the same geotypes used in the copper access network for the NGA model. This will support the use of the model to calculate the cost of deployment of a specific NGA architecture across an entire geotype.	✗
29	A10	Functionality to consider ducted, direct-buried and aerial cabling will be included in the access model.	✗
31	A11	The model will be able to differentiate different duct sizes in the lead-in network and the rest of the route network, as well as differentiating the duct sizes used in the copper network and the fibre network.	✓
42	A12	A parameter-based approach will be taken to quantify the level of sharing of trenches and poles within the various network layers (and hence quantify their lower costs), allowing the testing of a range of inputs.	✗
32	A13	When modelling current and next-generation networks, the default assumption will be that the boundary between the access and core network will not be moved. Changes in the position of the boundary can be tested through simple scenarios.	✗
–	A14	The access model will continue to model all relevant access line services from the existing LRIC model. For the purposes of the NGA calculations, the access network cost elements of a VULA product will also be modelled.	✓
7	A15	Services covering access to both ducts and fibre in the access network can be included in the Market 4 service set.	✗
14	A16	The costs of both full and shared access to both copper loops and sub-loops will be calculated for the copper access network.	✗
15	A17	The costs will be calculated for copper SLU for a FTTN/VDSL deployment, fibre unbundling for a FTTH/PTP deployment and the access-related costs of VULA for all NGA architectures.	✓
35	A18	We will assume that the modelled network carries as a minimum the forecast copper demand and fibre demand for the hypothetical Telenor-scale operator, but also the Telenor active HFC connections and active connections served by the local operators. This will ensure consistent economies of scale are achieved by the modelled network. The design algorithms will not themselves be capable of either identifying or choosing to use duct from a legacy network.	✓
2	A19	The increment in the access network will be defined as the total volume of all services using the access network - a LRAIC approach.	✗
8	A20	The costs of access connections will be determined through the recovery of the total cost of an architectural deployment over the active access connections in that architecture.	✗

Original principle(s)	New principle	Description	Materially revised?
48	A21	For the access model, we will investigate appropriate adjustments in the access network model to accommodate changing demand profiles. This will take the form of a flexible tilted annuity calculation. The RCEA will be valued according to either a HCA or a CCA depreciation calculation (both will be encoded in the model), but with fully depreciated RCEA excluded from the revaluation.	✓
49	A22	The access network model will be able to calculate the network assets and associated expenditures for a single selected year from 2015 to 2050 i.e. the current and future years in the Market module, from where the relevant demand volumes shall be taken. A multi-year side-calculation will be included within the Network Design – Access module to revalue the RCEA.	✓
4	A23	A WACC will be used in the model in order to provide a return on investments. The approach to defining the WACC will be determined by an advisor.	✗
3	A24	Where required, an EPMU approach will be employed for marking-up common costs.	✗
30	A25	Assuming sufficiently detailed costs and geographical data related to trenching is available, the data will be used to inform the costs of digging trench in an efficiently deployed network according to terrain.	✗
45	A26	Efficient costs for each asset will be defined in terms of unit equipment costs, installation cost, cost of spares held and cost of decommissioning. The decommissioning cost will be set to zero by default unless a value can be substantiated. For each asset an efficient operating expenditure will be defined relating to the operation and maintenance of that asset.	✗
46	A27	Cost trends will be defined for capital and operational expenses. Consideration of the cost-trends with and without inflation shall be made.	✗
–	A28	If a public subsidy is relevant to a NGA (i.e. wired) network deployment in a particular area of Norway, then in the bottom-up model that subsidy should be netted off the valuation of the asset base, by including the subsidy as a negative capital cost with a lifetime consistent with that of the civil assets in the model and a nominal cost trend of zero.	✓
47	A29	Economic lifetimes will be defined for each asset. For the specific case of the reusable legacy civil engineering assets and those network assets reused from the copper network, the lifetime value should be the average expected remaining lifetime.	✓

Annex A Conceptual approach for algorithms

This annex describes the principles underlying the algorithms that we will use in both the dimensioning of the fixed access network topologies, as developed for the existing LRIC model of fixed access networks. The classes of algorithms are:

- clustering algorithms, as described in Section A.1
- spanning tree algorithms, as described in Section A.2
- algorithm concerned with the travelling salesman problem (TSP), as described in Section A.3.

A.1 Clustering algorithms

The clustering algorithms we employ are top-down clustering algorithms. These take a set of locations, as well as their associated demand (in terms of access line requirements), and group them into clusters subject to a capacity and a distance criterion. These algorithms are used to aggregate locations into small groups that can be served by a single end distribution point (EF); these groups are then aggregated into larger groups that can be served by a single distribution box (DB). The algorithm uses two phases: a creation phase and a refinement phase.

A.1.1 Creation phase

This phase begins with the full set of points and groups them into a set of clusters. It proceeds as follows:

- the demand-weighted centre is calculated for the 'parent' cluster of all points
- 'child' clusters are grown by adding points from the parent cluster incrementally
- the point that is furthest from the parent cluster's centre is used as the seed for a new child cluster
- points that would not exceed the child's cluster capacity and would not break the distance criterion are then added incrementally until no more additions are possible
- each time a point is added to a child cluster, the demand-weighted centres of both the current child and its parent cluster are re-calculated
- this continues until the parent cluster itself satisfies both the capacity and distance criteria.

This process of clustering fixes the number of clusters.

A.1.2 Refinement phase

The creation phase does not necessarily create an *optimal* set of clusters. To help achieve this, we have designed several refinement algorithms to improve the clusters, some examples of which are described below.

Simple re-assignment

For each point *P* in turn, the algorithm identifies the cluster whose demand-weighted centre is closest to its own. *P* is then moved to this cluster if the following conditions are satisfied:

- *P* is closer to this demand-weighted centre than its own
- the new cluster has sufficient spare capacity
- all points in the new cluster obey the distance constraint with respect to the re-calculated cluster centre.

This process continues cycling through all points (multiple times if necessary) until no more re-assignment is possible.

Full optimisation

For each cluster, the total distance between all the points and the cluster centre is derived. Then, it cycles through all points *P* in turn (multiple times if necessary) until no points have been moved in a whole cycle. The loop:

- identifies the cluster of *P* and the total distance (*d1*) between all points in this cluster and its cluster centre
- temporarily removes *P* from its cluster and re-calculates the demand-weighted cluster centre and the total distance (*d2*) between the cluster points and the new cluster centre
- restores *P* to its cluster and the demand-weighted centre
- for each cluster with spare capacity, stores the total distance (*d3*) between all points in this cluster and its current cluster centre
- adds *P* separately into each cluster with spare capacity, and re-calculates the demand-weighted cluster centre and the total distance (*d4*) between the cluster points and the new cluster centre
- finds the cluster with spare capacity which gives the largest reduction in total distance, i.e. which maximises [*d1*-*d2*]-[*d4*-*d3*]
- the point is moved to this cluster with spare capacity if it maximises [*d1*-*d2*]-[*d4*-*d3*] and would also satisfy the normal distance constraint using its new demand-weighted centre.

Swap For each point *P* in turn, this algorithm:

- identifies the cluster whose demand-weighted centre is closest
- if the cluster is not its current cluster and if moving *P* to the new cluster violates the capacity criterion, then the algorithm tries to find a point in the new cluster which can be swapped with *P* so that:
  - both new clusters satisfy the cluster capacity constraint
  - the sum of the two distances between the points and the old cluster centres is improved compared with before
  - if the first two are true, then the algorithm also checks if the sum of the two distances between the points in their original clusters and their original cluster centres is less than the sum of the two distances between the points in their new clusters and their new cluster centres
  - both obey the distance constraint with respect to the new demand-weighted centre of their new clusters
- if such a point is found, then the algorithm revises the two clusters and re-calculates their demand-weighted centres
- if several such points are found in the new cluster, then the algorithm uses the point which reduces the sum of the distances by the most.

A.2 Spanning tree algorithms

These algorithms take a set of locations and their demand, and derive a set of edges that form a spanning tree between the locations. They derive an efficient trench/cable network to link:

- locations back to their parent EF
- EFs back to their parent HF, using existing trench where possible
- HFs back to the RSX, using existing trench where possible.

The algorithms that we have designed minimise a proxy cost function, which takes the form $k_1*d + k_2*c + k_3*d*c$ for copper or fibre deployment. *d* is the distance between two points and *c* is the number of pairs required between the two points (the capacity). The terms k_1, k_2 and k_3 estimate the costs of trench, jointing and cable respectively.

We use two variations of minimum spanning tree algorithms, which are described in the following subsections:

- a modified version of Prim's algorithm
- a version of Dijkstra's algorithm.

A.2.1 Modified Prim algorithm

This algorithm begins with the individual points and their respective demands. It starts at the central node. For the purposes of this description, we will describe the case of joining EFs back to their parent DB:

- the algorithm adds vertices to the tree incrementally, by joining an unattached vertex to a vertex in the existing tree using an edge
- at each stage, the algorithm stores the identities of all attached EFs and all unattached EFs
- all possible pairs of EFs containing an attached EF and an unattached EF are considered
- for each such pair, the unattached EF is temporarily attached to the tree at the attached EF, and the average cost per unit capacity of the new candidate tree is calculated. The cable size required to serve the unattached EF is calculated for the link:
  - if the average cost per unit capacity is lower than the previous best value, then the tree is temporarily updated with the required cabling all the way back to the DB
  - if the average cost per unit capacity is still lower than the previous best value when the cabling requirements have been fully updated all the way back to the DB, then the pair of EFs is stored as the best pair
- for the pair of EFs that generates the lowest average cost per unit capacity overall, the unattached EF in the pair is joined to the attached EF in the pair
- the edge is added to the spanning tree and the lists of (un)attached EFs are updated
- the throughput capacity and cabling at the DB is also calculated
- the total network proxy cost of the updated tree is calculated for future comparisons
- this process iterates until there are no remaining unattached EFs.

A.2.2 Dijkstra algorithm

This algorithm begins with a set of cluster centres and a set of points contained within the clusters. As a starting point, for each pair of clusters, the cheapest pair of points with which to join a pair of clusters through their centres is calculated using the proxy cost function. The points that a cluster centre passes through on the way to linking to the other cluster centres are also stored, so that the total distance traversed along trench between the two points can be calculated.

The subsequent calculation is strictly the Dijkstra algorithm and starts at the central node. For the purposes of this description, we again describe joining the EFs back to their parent DB. The algorithm then proceeds as follows:

- it is assumed that initially all EFs are joined directly to the DB (in a star formation)
- beginning at the DB, for every other EF the requirements to link it to the DB are recalled, in terms of:
  - extra trench

- — cost of linking the two points in their respective EF clusters (using the proxy cost function)
- — cabling cost of linking the two EFs (i.e. excluding trench cost)
- — total sheath length between them.

Then the algorithm proceeds as follows until all EFs in the DB cluster have been connected to the DB:

- for the given connected EF (note the first stage uses the DB itself), look through the remaining unconnected EFs and decide which of these can be linked directly to this connected EF with the least proxy cost
- having identified the unconnected EF that can be joined to the selected connected EF, test whether it is a cheaper proxy cost to go from this unconnected EF to the DB by going through the selected connected EF, or going via the direct connecting path calculated from the unconnected EF to the DB (i.e. determine whether the EF is connected directly to the DB, or via existing links)
- next, determine, for each unconnected EF in turn, whether it is more cost-effective to get to the DB via the newly connected EF, or use its current path. Again, all unconnected EFs are initially assumed to go directly back to the DB, but this can evolve with each loop of the algorithm. If it is determined that it is more cost-effective, the path for the disconnected EF should be changed to be via this newly connected EF
- check if it is cheaper for any other EF to be connected to the DB via this newly connected EF; if it is cheaper, then change the routeing of these EFs
- set the selected connected EF to be the newly connected EF and recommence the loop.

This process can lead to EFs being 'daisy-chained' back to the DB. These algorithms can also include a refinement to ensure that cables do not double-back on themselves en route to the parent node.

A.3 Travelling Salesman Problem algorithm

In the core network a ring structure will be deployed at most layers of the network in order to ensure resilience of traffic flows, so that if the ring fails at any one link, then the traffic will still be able to be automatically routed. This structure can also be implemented between cabinets in an access network, for example in a FTTN/VDSL deployment. We use an algorithm that seeks to minimise the distance-based cost associated with the deployment of trench and fibre.

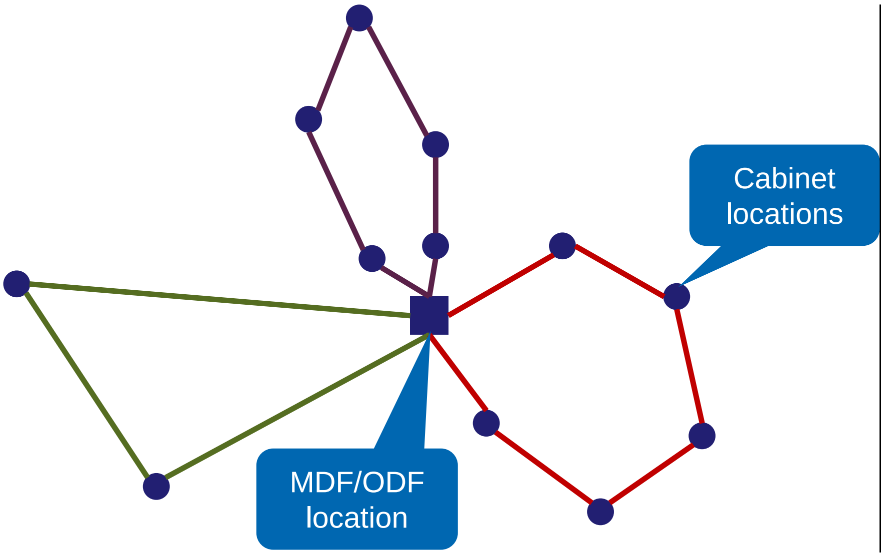


Figure A.1: Ring structures in the access network, joining a cabinet location to an MDF/ODF location in a set of resilient rings [Source: Analysys Mason, 2015]

Figure A.1 above shows the output of the algorithm for joining a set of cabinets together in a set of resilient rings back to an exchange location. This is calculated using a TSP algorithm which adheres to the following principles:

- cabinets may be connected to the parent MDF/ODF location using optimised multiple rings
- each ring may only contain a limited number of cabinets
- each cabinet must be linked back to its MDF/ODF location within a maximum number of links.

Annex B Overview of depreciation methods

The expenditures on long-lived assets that are incurred by an operator must be recovered over time, and any tied-up capital (i.e. expenditures which are not recovered in the year they are incurred) must earn a return on investment. The **annualisation method**, or **depreciation method**, is the mechanism by which these expenditures are recovered over time. Four main methods are used:

- *historical cost accounting (HCA) depreciation*
- *current cost accounting (CCA) depreciation* (with two variants)
- *annuities*, including tilted annuities and modified tilted annuities
- *economic depreciation*.

Each of these methods uses different calculation methods to produce the annualised cost in current and future years. We describe these methods below.

B.1 HCA depreciation

In HCA depreciation, the original capex on an asset recorded in the fixed asset register (the gross book value, GBV) is depreciated over the defined financial lifetime of the asset – usually with a constant depreciation charge per year (*straight line depreciation*). The asset net book value (NBV) decreases over its lifetime as depreciation accumulates, and the corresponding cost of capital employed (the cost of tying up the remaining capital book value) also decreases. These decreases in the NBV (and hence the return on capital employed) are linear if using straight-line depreciation and the WACC is a constant.

Opex is treated separately and expensed in the year it is incurred. The annualised cost is calculated by the formula:

$$AnnualisedCost = Depreciation + Return\ on\ mean\ capital\ employed + Opex$$

The return on mean capital employed will be equal to the period-average NBV multiplied by the WACC.

With HCA depreciation, the annualised cost in any year is not influenced by any future parameter and only by historical spending and depreciation. HCA depreciation must be performed in nominal terms. Opex recovery is not affected by HCA depreciation.

The example in Figure B.1 below assumes an asset with a five-year lifetime purchased in Year 0 at a cost of 1000, with annual operating costs of 100 increasing by 2% per annum, and assuming a WACC of 12%. Figure B.1 shows the features of HCA depreciation, namely:

- constant depreciation charge
- declining cost of capital employed
- operating expenses are expensed in the year they are incurred.

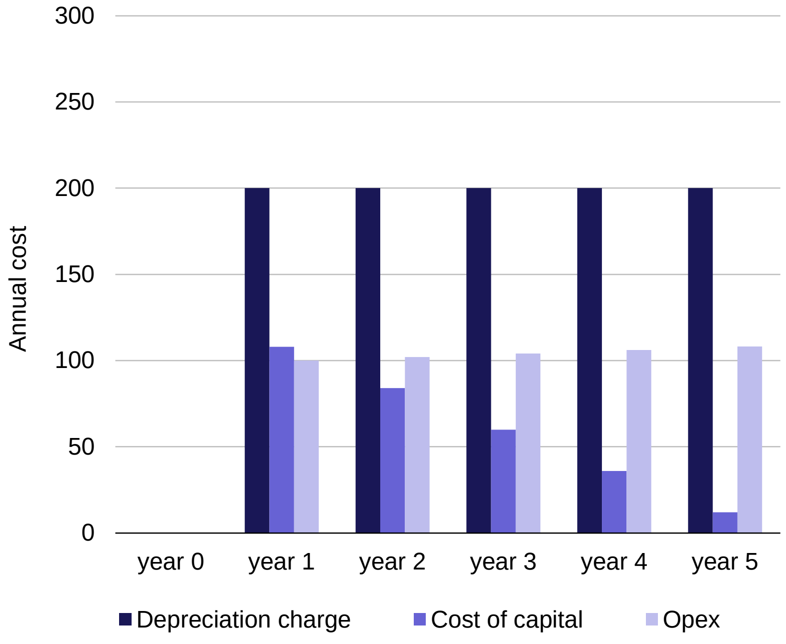


Figure B.1: HCA depreciation [Source: Analysys Mason, 2015]

B.2 CCA depreciation

In CCA depreciation, the straight-line depreciation calculation is modified to take into account the changes in replacement cost for an asset (its modern equivalent asset (MEA) price). If the MEA price decreases (e.g. due to technology evolution), CCA depreciation is front-loaded (i.e. is higher in early years). There are two major types of CCA accounting methods:

- *Financial capital maintenance* (FCM), which seeks to maintain the value of the originally invested capital. Historically, FCM has been used for fixed telecoms operator regulatory accounts in Europe.
- *Operating capital maintenance* (OCM), which seeks to maintain the operating (or output) capacity of the asset. For OCM, the depreciation charge is equal to the gross replacement cost (i.e. the cost of an asset if purchased at its current replacement cost) divided by the assumed lifetime of the asset.

The significant difference between these two types of CCA depreciation is that in FCM there is an additional term that is added. For CCA FCM depreciation using straight-line depreciation, the annualised cost is calculated by the formula:

$$AnnualisedCost = \left(\frac{GRC}{AssumedLifetime}\right) + HoldingChange + (Mean\ NRC \times WACC) + Opex$$

When compared to the HCA formula, the first term of the equation differs in that it is the gross replacement cost (GRC) that is spread over the assumed lifetime of the asset, rather than the GBV. The difference between *GRC/AssumedLifetime* and the HCA depreciation charge can be referred to as supplementary depreciation. As a result, the additional term *HoldingChange* must be added to reflect the gains or losses made by using an asset purchased in earlier (here, higher-priced) years. In CCA OCM, *HoldingChange* is zero whereas in CCA FCM it is calculated as:

$$HoldingChange = -(GRC - Investment) \times ProportionOfLifetimeLeft^{29} \times MEAPriceChange$$

If the MEA price is decreasing over time, this is a negative MEA price change and therefore a positive holding change. The CCA FCM depreciation charge is then higher than the corresponding CCA OCM depreciation charge.

However, if the MEA price is increasing over time, then this is a positive MEA price change and a negative holding change. The CCA FCM depreciation charge is then lower than the corresponding CCA OCM depreciation charge.

The net replacement cost (NRC) is calculated as:

$$NRC = \ Previous\ year\ NRC + Investment\ - \left(\frac{GRC}{AssumedLifetime} + HoldingChange\right)$$

With both types of CCA depreciation, the annualised cost in any year is not influenced by any future parameter, only by historical investments and price changes in the current period. CCA depreciation must be performed in nominal terms; opex recovery is not affected by CCA depreciation.

Figure B.2 below illustrates CCA depreciation using the same example as used for HCA depreciation in Figure B.1 above. In this case, the MEA price decline is assumed to be 5% per annum. As can be seen, depreciation is front-loaded due to the MEA price decline. This is an example of FCM depreciation.

29 This proportion of assumed lifetime remaining excludes new investments made in the current year, which still have 100% of their assumed lifetime remaining.

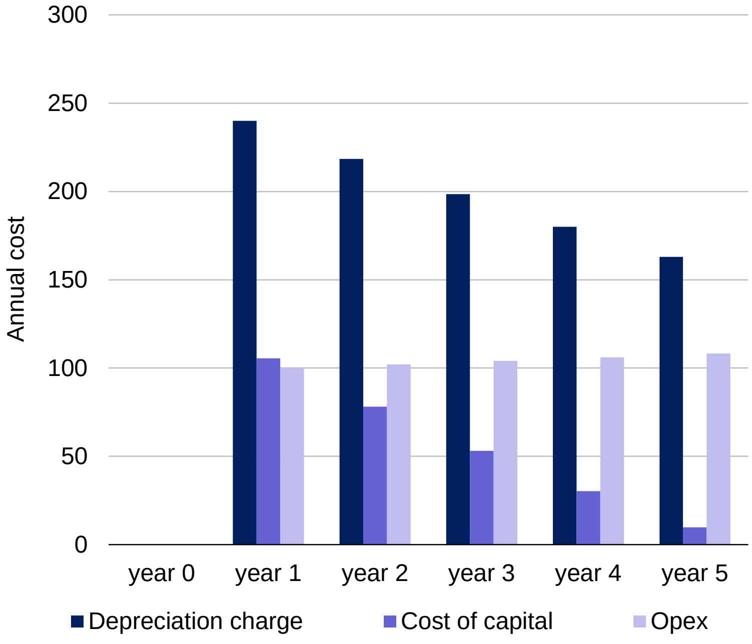


Figure B.2: CCA FCM depreciation [Source: Analysys Mason, 2015]

B.3 Annuities

The annuity depreciation method calculates both the depreciation charges and the cost of capital employed in such a way that the total (the annuity) follows a specific smooth path over time. A standard annuity calculates a constant annualised cost per annum which, after discounting, fully recovers the investment and return on capital employed. Opex is added to the cost recovery in each year it is incurred.

In a *tilted annuity*, the annualised cost of recovering the investment and return on capital is tilted with the forecast price trend of the asset, subject to still fully recovering investment and capital employed. For most telecoms assets, the MEA price of the asset declines over time (note this may not be the case for certain important fixed access network assets such as trenches). Where there is a change in price trend, a tilted annuity is more appropriate.

Tilted annuities are sometimes used as a proxy for economic depreciation, particularly where the output of the asset does not change significantly over the period.

The tilted annuity charge formula is calculated as follows:

$$AnnuityCharge = GRC \times \frac{WACC - MEAPriceChange}{1 - \left(\frac{1 + MEAPriceChange}{1 + WACC}\right)^{Lifetime}}$$

This formula applies to end-of-year payments for an asset purchased at the start of the first year of the model. If the timing of the cash flows is different, this needs to be allowed for by an additional multiplier. In this formula, the lifetime applied should usually be the economic lifetime of the asset.

All annuity calculations can be performed in either nominal terms or real terms (the real-term annuity would require a real-term WACC and real-term MEA price trend, and if there is no real price trend the calculation will give a result that is constant in real terms). Opex recovery is not affected by annuity depreciation.

A modified version of the tilted annuity formula can be implemented, where an additional tilt is applied to front-load or back-load costs to reflect slow, steady exponential changes in demand. A front-loaded tilt (a negative tilt) is appropriate where demand is falling, in order to prevent under-recovery of costs over the lifetime of the asset. This approach will closely mimic economic depreciation (see below) where the economic output is not changing significantly. The *modified* tilted annuity charge formula is then calculated as follows:

$$AnnuityCharge = GRC \times \frac{WACC - Tilt}{1 - \left(\frac{1 + Tilt}{1 + WACC}\right)^{Lifetime}}$$

where *tilt* is defined as $tilt = MEApriceChange + AdditionalTilt$

The additional tilt is a user input, related to the rate of change of demand, and ensures cost recovery.

In the tilted annuity formula on the previous page, the lifetime applied is usually the economic lifetime. Figure B.3 shows the formula applied using the same example as in Figure B.2: the tilted annuity charge can clearly be seen declining by 5% per annum.

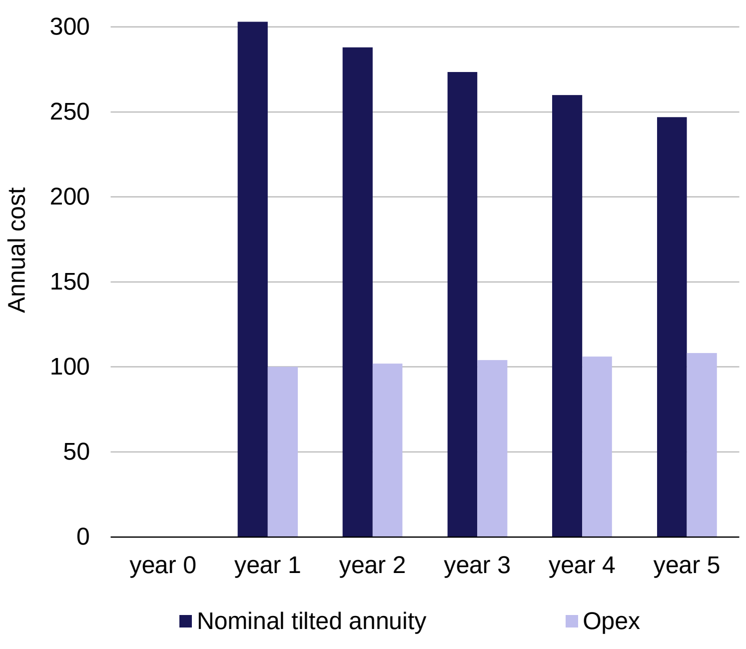


Figure B.3: Tilted annuity depreciation [Source: Analysys Mason, 2015]

When there is a gradual change in the economic output of the network (demand), then an additional tilt can be applied. Figure B.4 illustrates the *modified* tilted annuity using the same example as in Figure B.3 with an additional tilt of 1% annual increase in the economic output during the modelled five years.

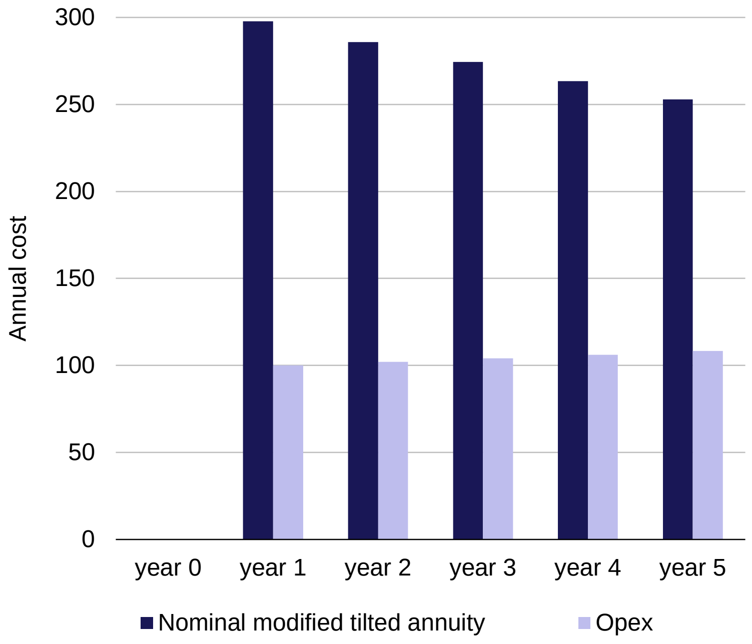


Figure B.4: Modified tilted annuity depreciation [Source: Analysys Mason, 2015]

B.4 Economic depreciation

Economic depreciation takes into account all the underlying factors that influence the economic value of an asset, that is:

- projected trends in opex associated with the asset (MEA opex trends)
- projected trends in replacing the asset with its MEA (MEA investment trends)
- demand changes (the number of subscribers that the asset supports – i.e. its 'output').

It is the output that can be generated by the asset that specifically differentiates economic depreciation from the three previously discussed methods, since both CCA and tilted annuity depreciation take into account the MEA investment trend (albeit in different ways). In the situation where the output of an asset is not expected to change over its lifetime, the result of an economic depreciation calculation is similar to a tilted annuity; whereas if there are only expected to be small changes, then a modified tilted annuity can be used.

However, economic depreciation must be calculated over a long period that considerably exceeds the longest assumed asset lifetime (unless a 'terminal value' calculation is used, which has its own challenges). In the context of an access network, this might mean a modelling period that is a century or more, or alternatively the network is assumed to last for exactly one lifetime of the civil infrastructure, i.e. at least 40 years if all assets have a lifetime that is an integer divisor of that period (20,10,8,5, etc.). This long period can greatly increase the complexity of the access model.

Economic depreciation captures the effects of the increasing output profile in the cost recovery and stabilises the recovery of costs over the network lifetime. If we neglect the asset price trends, it seeks to recover a constant amount per unit of output. The effect of doing this is to distribute proportionately more of the depreciation charges into the years that have higher output. The use of discounting in the economic depreciation calculation ensures that the delay in recovery (the cost of the tied-up capital) is fully compensated.

Figure B.5 illustrates the same example as in Figure B.3 but with the demand growing significantly in years 1–4 before stabilising in year 5. The line in the chart illustrates the change in output over the five-year period. The shape of the economic cost recovery resembles the shape of this line, except that there is the additional effect of the negative 5% cost trend. As a result, the cost recovered in year 5 is lower than in year 4, even though the demand in both years is the same.

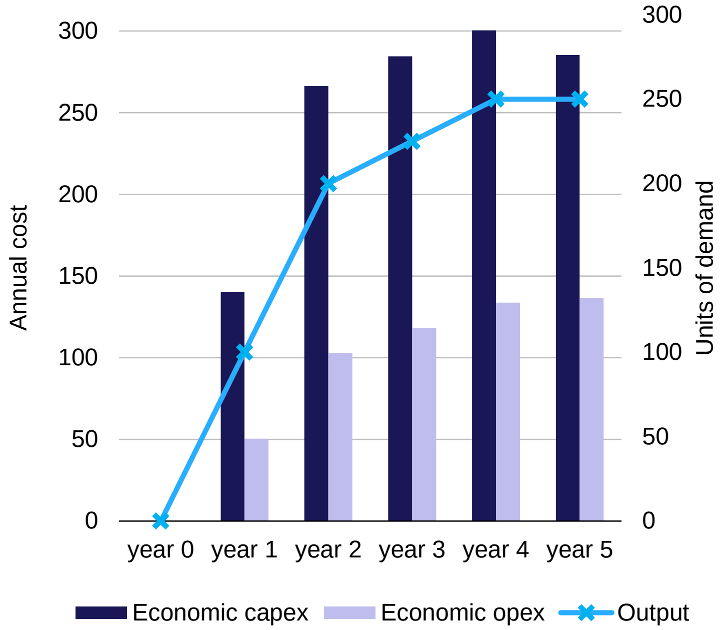


Figure B.5: Economic depreciation [Source: Analysys Mason, 2015]

Annex C Acronyms used in this document

ADSL	Asymmetric digital subscriber line
BU	Bottom-up
CAPM	Capital asset pricing model
CCA	Current cost accounting
CEO	Chief Executive Officer
CPE	Customer premise equipment
CPI	Consumer price index
CTTH	Copper-to-the-home
D/E	Debt/equity
DB	Distribution box
DSL	Digital subscriber line
DSLAM	Digital subscriber line access multiplexer
EC	European Commission
EF	Endefordeler
EPMU	Equi-proportionate mark-up
ESA	European Free Trade Association (EFTA) Surveillance Authority
EU	European Union
FAC	Fully-allocated cost
FTTH	Fibre-to-the-home
FTTN	Fibre-to-the-node
GBV	Gross book value
GPON	Gigabit passive optical network
GRC	Gross replacement cost
HCA	Historical cost accounting
HF	Hovedfordeler
HFC	Hybrid-fibre coax
LLU	Local loop unbundling
LRAIC	Long-run average incremental cost
LRAIC+	Long-run average incremental cost, including mark-ups for business overheads
LRIC	Long-run incremental cost
LTE	Long-Term Evolution
MDF	Main distribution frame
MEA	Modern equivalent asset
MF	Mellomfordeler
NBV	Net book value
NGA	Next-generation access
NGN	Next-generation network
Nkom	Norwegian Communications Authority
NOK	Norwegian krone

NRC	Net replacement cost
NTP	Network termination point
OCM	Operating capital maintenance
ODF	Optical distribution frame
PDP	Primary distribution point
PoI	Point of interconnect
PON	Passive optical network
PSTN	Public switched telephone network
PTP	Point-to-point
RAB	Regulated asset base
RCEA	Reusable civil engineering assets
RSX	Remote switching stage or remote switching unit
SAC	Subscriber acquisition cost
SDP	Secondary distribution point
SLU	Sub-loop unbundling
SMP	Significant market power
TSP	Travelling salesman problem
USO	Universal service obligation
VB	Visual Basic
VDSL	Very high-rate digital subscriber line
VoB	Voice-over-broadband
VoIP	Voice over internet protocol
VULA	Virtual unbundling local access
WACC	Weighted average cost of capital
WLR	Wholesale line rental