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TSLRIC price review determination for the Unbundled Copper Local Loop and Unbundled Bitstream Access services

Model Specification

Commerce Commission
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Public Version

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Summary

0 Introduction

0.1 Background

Unbundled Copper Local Loop (UCLL) and Unbundled Bitstream Access (UBA) are services that allow alternative operators' access to the local loop infrastructure of Chorus.

The Telecommunications Act 2001 (the Act) requires the Commerce Commission (the Commission) to determine a price for the UCLL and UBA services. In the first instance the Commission is required to benchmark prices against comparable countries under the 'initial pricing principle' (IPP). If an access seeker or Chorus Limited is not satisfied with the price (either the UCLL or UBA) determined under the IPP, the Act provides that the party can ask the Commission to calculate a price for that service in accordance with the 'final pricing principle' (FPP), which is Total Service Long Run Incremental Cost (TSLRIC) for UCLL and UBA.

The Commission reviewed the benchmarked UCLL price on 3 December 2012 and determined the UBA benchmarked price on 5 November 2013. However, the Commission has received FPP requests both for UCLL and UBA: the UCLL FPP requests were received in February 2013, the UBA FPP requests were received in January 2014. Therefore, the Commission needs to determine a price for the UCLL and UBA services in accordance with the FPP.

TERA Consultants (TERA) has been engaged by the Commission to assist in determining a price for the UCLL and UBA services in accordance with the FPP which is TSLRIC.

A consultation paper on conceptual issues of UCLL cost modelling was issued by the Commission in December 2013. A further consultation paper focusing on UBA[1] was also issued in early February 2014. Responses from interested parties were received in February 2014.

The Commission issued a paper which set out its preliminary views on its proposed regulatory framework for the UCLL and UBA TSLRIC cost modelling exercises and its preliminary views on a number of fundamental assumptions for the development of a TSLRIC cost model for the UCLL and UBA services[2]. Having reviewed the Commission paper, TERA has provided its views on some key methodological choices related to the calculation of TSLRIC in the document "Modern Equivalent Assets and relevant scenarios".

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[1] Commerce Commission, Determining a TSLRIC price for Chorus' unbundled bitstream access service under the final pricing principle, (7 February 2014)

[2] Commerce Commission, Consultation paper outlining our proposed view on regulatory framework and modelling approach for UBA and UCLL services, (9 July 2014)

The Commission sought the view of interested parties on all topics and has reviewed the submissions and the cross-submissions sent by all the interested parties.

Based on these consultations and on the papers previously published, the Commission has made a number of decisions regarding the modelling and the pricing of the different regulated services. These decisions define the criteria for developing the access network cost model and the core network cost model. They are listed in the Model Reference Paper.

Based on the Model Reference Paper, this document is describing the specifications that have been followed to derive the price of the different regulated services.

The details of the modelling are described in the Model Documentation.

A draft version of these documents was published in December 2014. The Commission sought the view of interested parties on these documents and models including the present document and has reviewed the submissions and the cross-submissions sent by all the interested parties. This draft version has been updated to produce the current version.

A second draft version of this document was published in July 2015. The Commission sought the view of interested parties on several documents and models including the present document and has reviewed the submissions and the cross-submissions sent by all the interested parties.

The earlier draft versions of this Model Specification Paper have been updated to produce the current final version.

0.2 TERA Consultants experience and approach

TERA Consultants is an international economic consulting firm. Founded in 1996, we have acquired a solid expertise in strategy, regulation, competition, litigation and transfer pricing. We have worked with regulatory authorities, industry players, law firms and financial organisations in more than 50 countries.

TERA Consultants has indeed a strong track record in bottom-up cost modelling of regulated activities. These include determining fixed and mobile interconnection costs, calculating cost-based tariffs for local loop unbundling, determining the cost of Universal Service, etc. For both core network cost models (called here "UBA model") or access network cost models ("UCLL" model), TERA Consultants has developed innovative solutions which have increased the accuracy of the cost assessment process.

For the UCLL and UBA modelling process, TERA Consultants has applied similar types of approaches, in line with best practices, that have been applied for other regulatory authorities such as ComReg (Ireland), DBA (Denmark), ARCEP (France), HAKOM (Croatia), etc. over the past few years.

The models developed for the Commerce Commission reflect the Commerce Commission decisions and modelling choices. Inputs used to calculate costs have

been verified at several stages of the project including during the last stage where several reviews of the inputs data have been performed. These inputs are the most relevant inputs available. Formulas used in the cost models have been verified at several stages as explained in section 9.

Comments from the industry on inputs or formulas, when relevant, have been implemented in the models.

0.3 Structure of this document

This Model Specification Paper details the specifications followed when building the cost models. The document has the following structure:

- **Section 1** – Overview of the modelling approach (see §1): it gives a high level view of the approach followed;
- **Section 2** – Opex model (see §2): it describes how the opex part and the non-network costs shall be calculated;
- **Section 3** – Geospatial (see §0): it details the geospatial work that has been carried out as offline calculations and that feeds the access network cost model;
- **Section 4** – Equipping the copper access network (see §4): it details the dimensioning of the copper access network;
- **Section 5** – Equipping the fibre access network (see §5): it details the dimensioning of the fibre access network;
- **Section 6** – Equipping the fixed wireless access network (see §6): it details the dimensioning of the fixed wireless access network;
- **Section 7** – Equipping the core network (see §7): it details the dimensioning of the core network;
- **Section 8** – Network and services costing (see §8): it derives the cost of the network and the different services;
- **Section 9** – Verifications (see §9): it details the cross-checks that have been carried out to validate the modelling; and
- **Section 10** – Prices (see §10): it describes how the prices of the different regulated services are set.

1 Overview of the modelling approach

This section provides an overview the modelling approach of the access network cost model, the core network cost model and the opex model.

1.1 Introduction

The model is a combination of five interlinked parts:

- **Geospatial data-processing** (offline calculation): aims at determining all cable paths from the end-users dwellings to the network nodes (shortest path algorithms), as well as FWA coverage based on RBI base stations. Dedicated geospatial tools (such as QGIS or MapInfo) are used to perform these offline calculations;

- **Access network dimensioning** (Microsoft Access): based on the geospatial data analysis, the access network is dimensioned (cables, civil engineering, etc.). Due to large amount of data to be treated, the calculation is performed within Microsoft Access;

- **Access network costing** (Microsoft Excel): once the dimensioning is performed, costs are derived (multiplying the network inventory by the unit costs). The maximum amount of calculations (including investment calculation) is done in Microsoft Excel as Microsoft Excel is more transparent than Microsoft Access;

- **Opex model** (Microsoft Excel): based on Chorus's financial information, the opex and the non-network costs are derived for each service; and

- **Core network** (Microsoft Excel): dimensions and derives the costs of the core network and derives the price of each service.

1.2 Implementation of the optimisation approach

Consistent with criteria 23 and 24 of the Model Reference Paper, the model takes as a starting point the location of the exchanges of Chorus' copper network, using optimised coverage areas. However when inefficiencies are found, the location of nodes are optimised. These inefficiencies are generally the results of:

- The lack of precision of the data collected; and
- The history of the network roll-out.

Coverage areas (MDF areas) are optimised according to the direct paths from premises to exchanges, i.e. premises will be connected to their closest exchange following the road network.

1.2.1 The optimisation approach for the modeling of the copper network

As described in §4.2, the copper network comprises three layers of nodes:

- The Main Distribution Frame (MDF);
- The Street Cabinet (SC); and
- The distribution point (the Copper Cable Terminal or CCT).

Following the optimisation approach the location of these nodes has been used as the starting point of the geospatial work, except for CCT. The MDF coverage areas stem from an optimization algorithm (see next sub-section on the optimisation approach for the modelling of the fibre network) and are used in order to split the country between the different MDF.

Chorus (like most operators around the world) has been unable to provide the coverage areas of the SC. The determination of the SC coverage areas is therefore part of the geospatial work as described in §3.4.1

1.2.2 The optimisation approach for the modeling of the fibre network

The fibre modelling comprises two layers of nodes:

- The Optical Distribution Frame (ODF); and
- The distribution points (the Fibre Access Terminal or FAT).

Following the scorched node approach, based on the regulated (copper) network and in line with criterion 24 of the Model Reference Paper, the location of the copper nodes have been used as the basis for the fibre nodes as described in the Model Reference Paper. The ODF coverage areas are then optimised according to the shortest path algorithm.

As described in §5.2, the fibre network comprises two layers, the ODF and the FAT. The street cabinets are therefore not relevant, only the location of the MDF.

The fibre modelling scenario includes also the Fixed Wireless Access (FWA) technology (the models have the ability to exclude FWA also, and to calculate the costs for 3 types of coverage: full areas that are unlikely to be unbundled, areas that are unlikely to be unbundled and covered by RBI FWA, and extrapolation of this latter scenario). The FWA modelling requires specification of the location of the base stations and their coverage areas.

The FWA modelling is based on the actual existing FWA sites, i.e. the location of Vodafone's base stations that are part of the RBI program and that are located in exchange areas which are unlikely to be unbundled.

FWA coverage is based on the aforementioned RBI sites coverage. Within each site coverage, the number of customers which are assumed to be covered by the site (and not by FTTH) is determined by the capacity of the site and by the throughput allocated to each customer. This means that not all homes covered by a RBI site are connected by this RBI site. FWA base stations are filled with premises furthest from the exchange. Throughput demand for each premise is based on the ADSL 2+ quality of service the

premise could have received in a copper network (distance following copper paths from premises to first active node (either non-RBI active cabinet or MDF))[3].

1.3 Opex modelling approach

The Opex model implements the allocation to the UCLL and UBA services of a proportion of Chorus' expenses related to their regulated and unregulated activities, adjusted for the greater efficiencies of a new network. The depreciation costs fall within the scope of the network cost models themselves.

The information to develop a bottom-up model for operating costs is not always available. It is available for expenses such as power costs or space rental costs. However, the majority of opex are either supplier costs or staff costs. For those costs, the best practice is generally to use top-down data. Hence, a mixture of bottom-up approach and top-down approach with evolution over time (forecasts) is carried out.

In addition, it must be underlined that a bottom-up model assesses the cost of a 'new' network (with potentially high capex and low opex) whereas top-down costs reflect the costs of an older network (with potentially lower capex and higher opex).

The opex modelling is mainly based on Chorus' 2014 accounts. Expenses related to network activities have to be distinguished from expenses related to "non-network" activities. Opex related to FWA network are based on Vodafone data.

Chorus provided separate network opex and non-network opex files.

As a consequence, the following steps are followed in the Opex model (see the figure below):

- Identify the relevant network opex for the network cost models;
- Allocate these costs between the different services by splitting those operating expenses to the different equipment;
- Adjust top-down costs to reflect relevant costs for bottom-up modelling;
- Identify the relevant non-network opex for the bottom-up model and allocate those costs to the different relevant services;
- Calculate specific costs (indirect capex) that are inputs for the core network cost model.

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[3] This is based on New Zealand copper local loop preliminary interference management plan, part 2, spectral compatibility determination process, November 2007

Figure 1 – Model opex approach
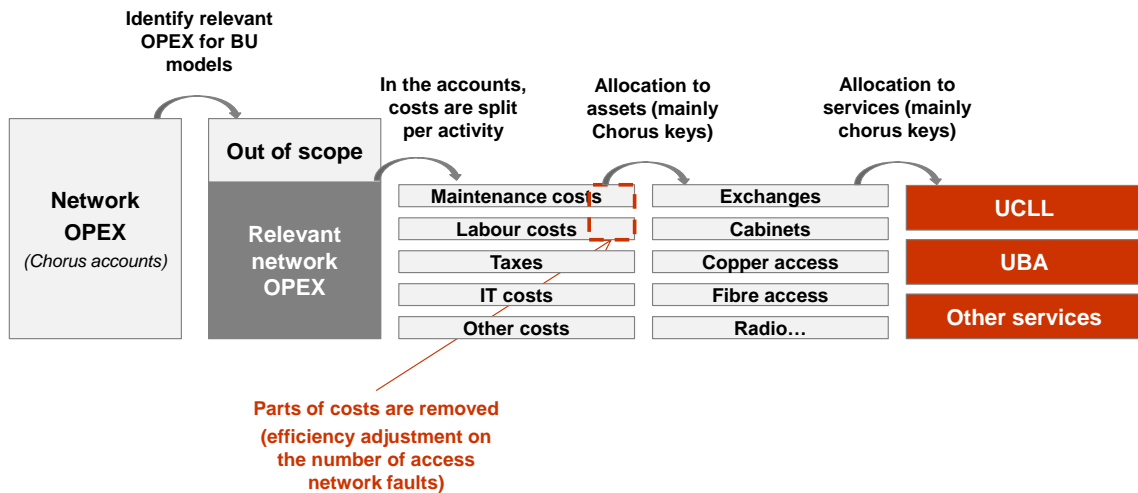
Source: TERA Consultants

Once costs are allocated to equipment, these are then allocated to the different regulated services using a routing matrix.

1.4 Demarcation point between access and core

In line with criterion 1 and criterion 2 of the Model Reference Paper, the core network cost model contains the dimensioning of all the active assets required to provide the UBA service whereas the access network cost model contains the dimensioning of all the passive assets. The access network cost model therefore contains the dimensioning of all the passive assets located between the customers' dwellings and the MDF/ODF located in the exchanges.

Some of the passive assets are used by the UBA service but are dimensioned in the access network cost model because there are some economies of scope that should be taken into account.

E.g. the fibre cables used to link core sites together are part of the core network. However they are using the same trenches as the access network. These cables are therefore modelled in the access network in order to take into account the relevant economies of scope. Also FWA active assets are calculated in the access network cost model.

The following figure shows the demarcation point between access and core networks (regulated and unregulated).

Figure 2 – Demarcation point
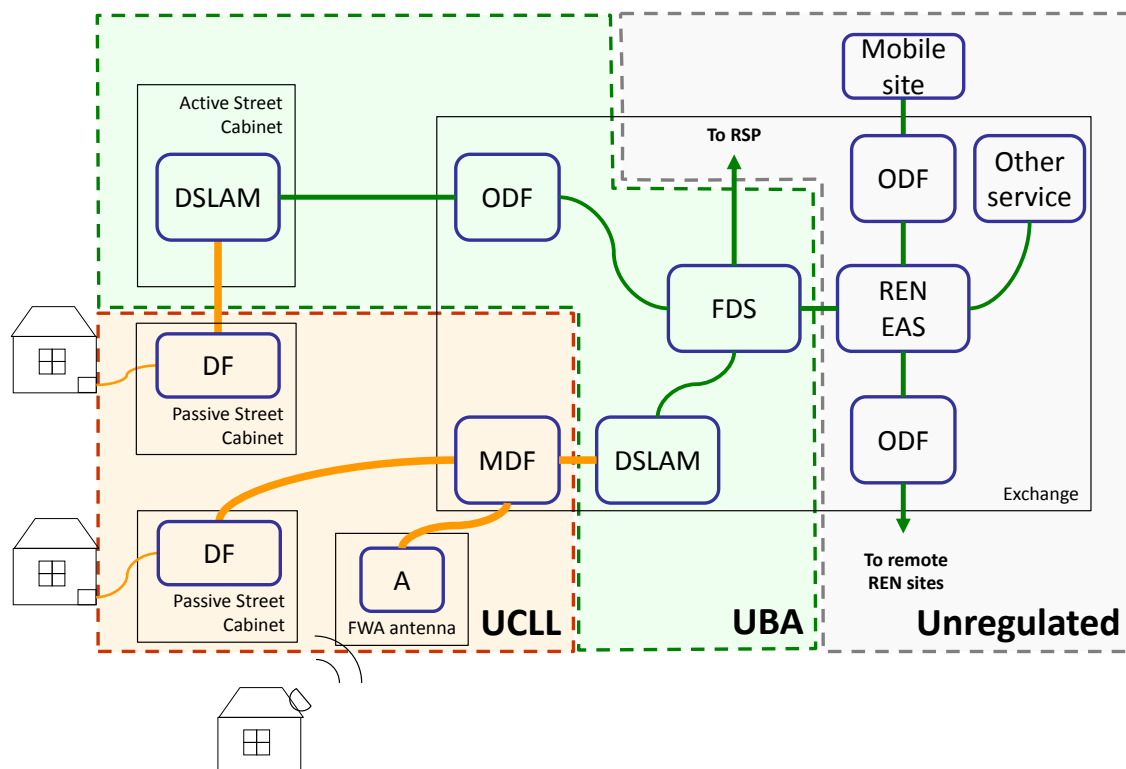
*Note that there is no cabinet in the fibre scenario, premises being directly distributed
from the exchange.*

Source: TERA Consultants

1.5 Access network modelling approach

1.5.1 Modelling approach

The access network modelling approach is based on the three following principles:

1. Fixed wired access networks are dimensioned based on all dwellings located in the areas covered (and not only on the basis of the current demand);
2. Fixed wired access networks follow streets and roads (like electricity distribution networks but unlike electricity transmission networks); and
3. The path followed by the cable connecting any dwelling to a network aggregation point is the shortest path (optimisation of the network length in order to ensure the best quality of service).

Fixed wired access network costs are mainly made of:

- Civil engineering assets (poles, ducts, trenches) cost, which depends on:
  - The length of streets/roads;
  - The unit costs which vary from country to country (mainly based on local wages); and
  - The number and size of telecommunications cables which they support.
- Cable cost which depends on:

o The length of streets/roads;

o The unit costs of laying cables which vary from country to country (mainly based on local wages);

o The unit cost of cables which is quite similar from one country to another; and

o The number of dwellings served by these cables.

This means three main types of data are needed:

- Roads length;
- Unit costs;
- Paths between dwellings and network points.

The access network modelling follows a 3-part and 8-step approach (see figure below):

- The network dimensioning phase derives the number of assets based on the total demand (steps 1 to 3);
- The network costing phase derives the yearly cost of the network based on the network dimensioning and on the unit costs (steps 4 to 7); and
- The network cost allocation phase derives the price of the different services (step 8).

Figure 3 - Access network modelling approach
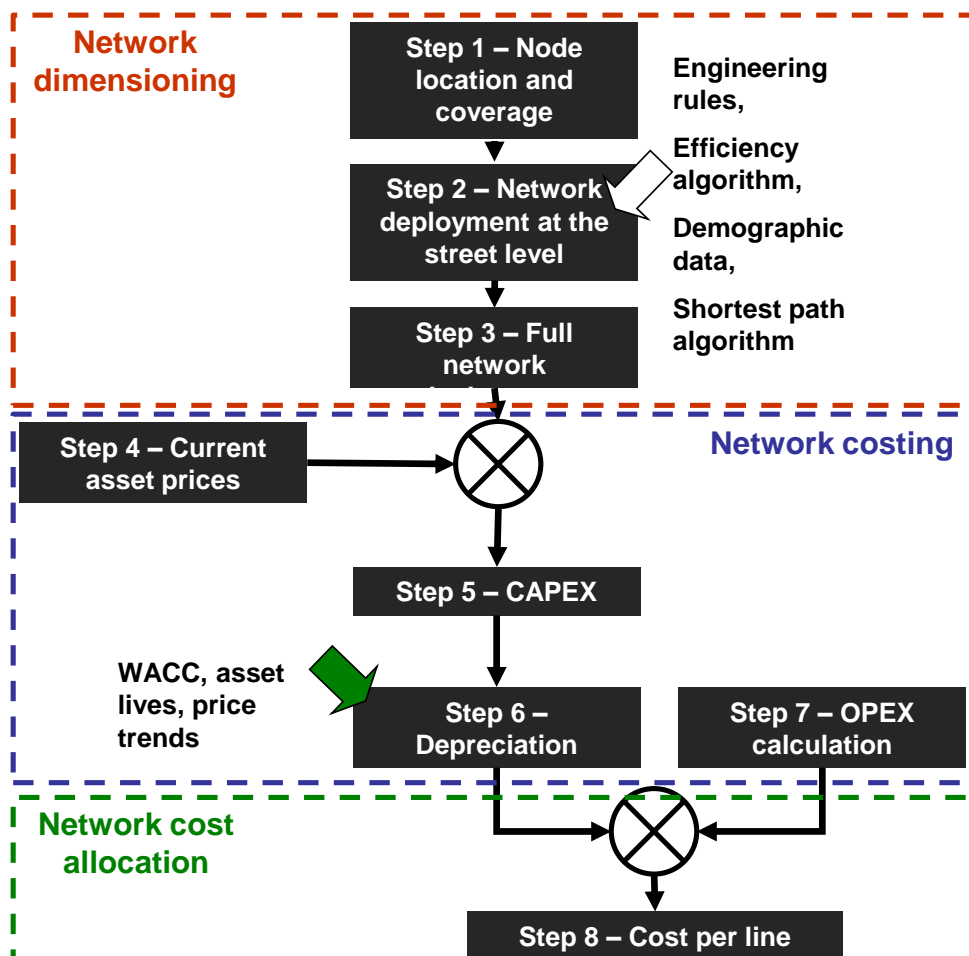
Source: TERA Consultants

1.5.2   Steps of the access network modelling

1.5.2.1   Node location and coverage

In line with criterion 23 of the Model Reference Paper, the starting point of the network dimensioning phase is the set of node locations and the set of coverage areas.

Following the optimisation approach, the model uses the nodes of Chorus copper network for:

- Identification of the MDF (exchange) positions; and

- Identification of the SC positions, in the copper network.

The identification of the MDF positions allows splitting the country into MDF areas (or exchange areas). All the end-users inside the same MDF area are connected to the same MDF.

In the copper network, the identification of SC positions allows splitting the MDF areas into SC coverage areas. All end-users inside the same SC area are connected to the same SC. As some end-users are directly connected to the MDF, the MDF is also considered as being a SC.

Figure 4 - MDF and SC coverage areas
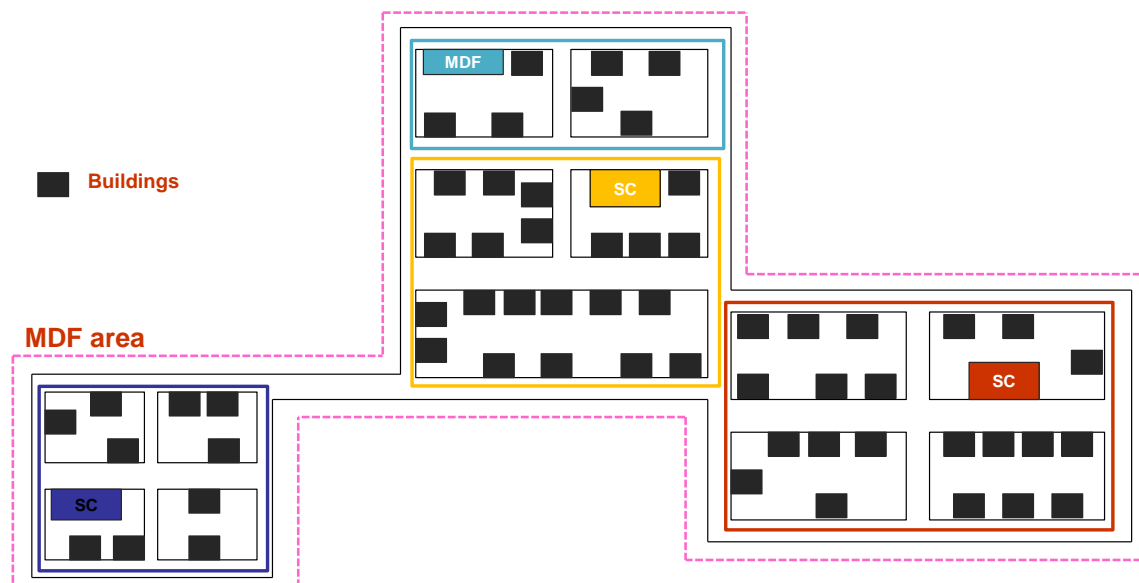
Source: TERA Consultants

In the fibre network, there are no SCs. All end-users are directly connected to the exchange (the ODF). However, intermediate flexibility points such as joints are modelled.

1.5.2.2   Network deployment at street level

Having determined the MDF and the SC coverage areas, it is possible to compute the cost efficient path connecting each end-user to a MDF. As described in the Model Reference Paper, this is based on the shortest path algorithm.

Two sets of paths therefore have to be computed to model the copper network:

- The shortest path from each building to its parent SC; and

- The shortest path from each SC to its parent MDF.

One set of paths has to be computed to model the fibre network which is the shortest path from each building to its parent ODF.

Figure 5 - Shortest path from SC to buildings
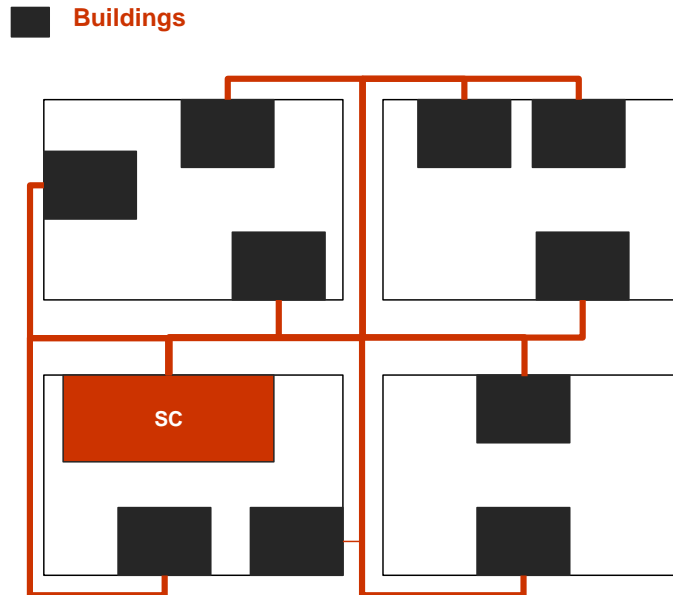
Source: TERA Consultants

Having computed all the shortest paths required, it is possible to compute the demand at the section level (a segment of road between two consecutive intersections).

The demand at the section level is made of:

- The demand of the current section, i.e. all the buildings located on this section; and

- The demand of the rear area of the section, i.e. all the buildings for which the shortest path to the SC or the MDF goes through the section.

Figure 6 - Computation of the local demand
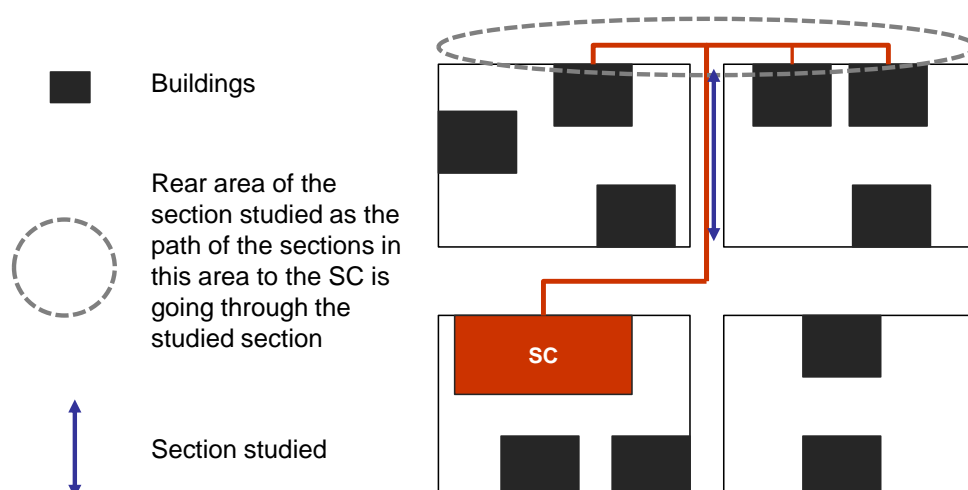
Source: TERA Consultants

In the above figure, the studied section has no local demand but has three buildings in its rear area: the distribution cable passing through this section must be dimensioned for those three buildings.

Furthermore, in the copper network, an additional feeder cable may be added if the connection between the SC and the MDF goes through the section.

The dimensioning of the access network at the section level consists of computing the number of assets required to meet the local demand, given engineering rules and a catalogue of assets.

1.5.3 Full network

The full network or the network at the exchange area level is dimensioned aggregating the number of assets computed at the section level. This allows the compilation of the network inventory.

This step ends the network dimensioning phase.

1.5.4 Current asset prices

The first step of the network costing is to derive the current unit cost, from all the unit costs applied, price trends and relevant mark-ups that capture all the required costs.

The current unit costs come in most cases from Chorus data collection or are otherwise inferred from benchmarks with other countries.

Trenching and ducting unit rates are inferred from Beca corridor analysis and geospatial data (soil type distribution).

1.5.5 Capex

The total investment is based on the inventory of assets and the assets' current unit costs. It is obtained by multiplying the network inventory by the current asset prices.

1.5.6 Depreciation

The network yearly cost is obtained by applying the asset-specific depreciation formula to the network capex, which depends on

- Asset lives;
- Prices trends;
- The tax depreciation rates;
- The corporate tax rate;
- The post-tax nominal weighted average cost of capital (WACC).

1.5.7 Opex calculation

The opex estimates are derived from the Opex model.

The total yearly cost is obtained by summing the network capex yearly cost, the opex, and the non-network costs.

This step ends the network costing phase.

1.5.8 Network cost allocation

The network cost allocation is used to build the different prices that are based on the access network cost model.

The cost per line is the result of dividing the UCLL yearly costs and specific costs (e.g. wholesale costs) by the total number of active lines.

1.6 Core network modelling approach

The UBA price is the sum of the UCLL price and of UBA additional costs. In this paper, the scope of the network corresponding to the UBA additional costs is called the "Core UBA".

In line with criterion 31 of the Model Reference Paper, the scope of the core network model covers the provision of the core (active) part of the UBA service and the dimensioning of all elements involved in this service as shown in the figure below. The passive part (local loop) is dimensioned and cost in the access network cost model.

Figure 7 - Core network model scope
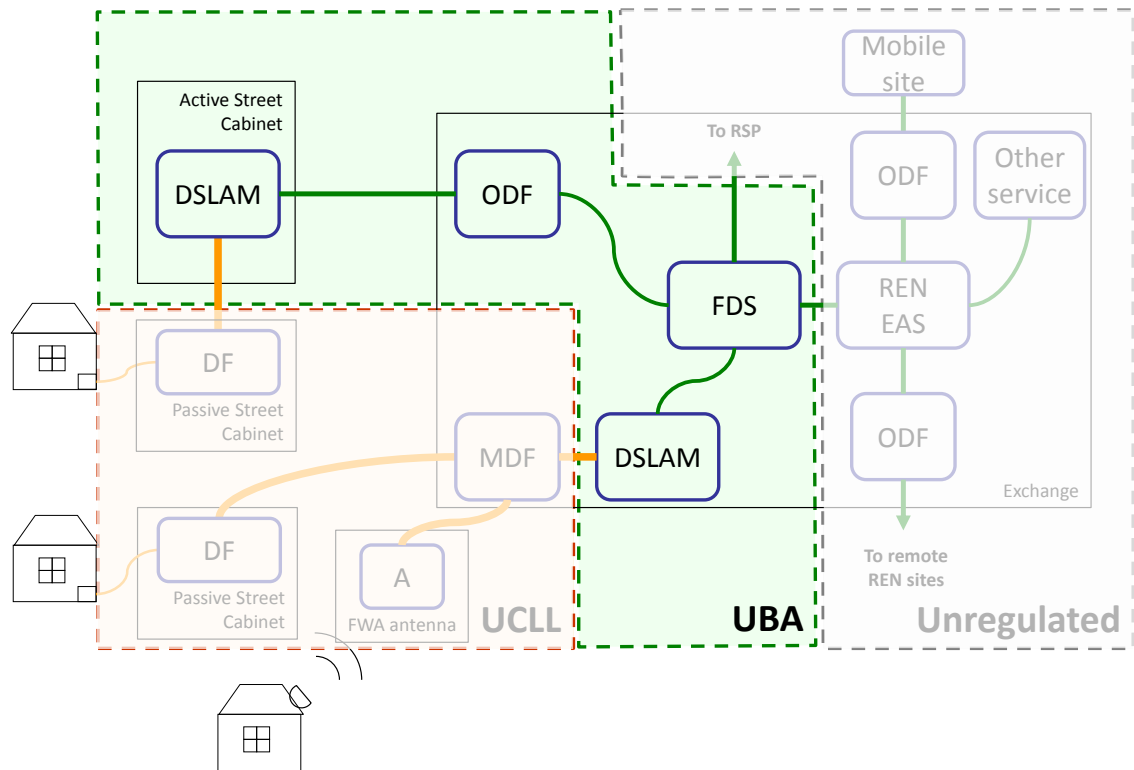
Source: TERA Consultants

The modelling is based on the optimisation approach described in §1.2. The demand is calculated at each existing node of the network. The network assets are dimensioned in order to fulfil this demand and provide the UBA service.

The UBA service consists of providing to RSPs (Retail Service Providers) a service starting from the network termination point (the ETP (external termination point) in the copper network) to an aggregation port located on a FDS (the port is not part of the monthly rental charge). It corresponds therefore to the combination of the UCLL service and the core UBA service as illustrated in the figure below:

Figure 8 - Core network model scope
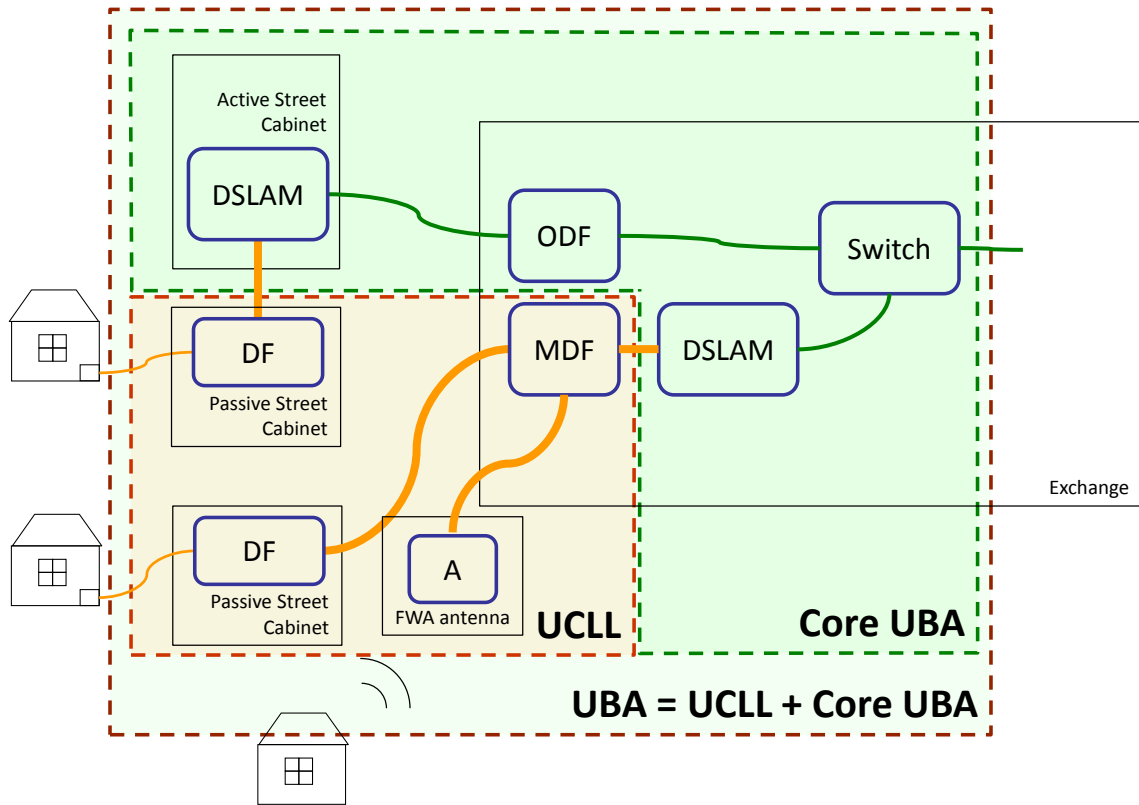
Source: TERA Consultants

However it has to be noted that the UCLL network may be used for other services than
UBA, and therefore the UCLL network has more active lines than UBA customers. The
economies of scale are therefore different between the two services.

2 Opex model

This section aims at describing the Opex cost model.

2.1 Opex data

In line with criterion 59 of the Model Reference Paper, the Opex model is based on Chorus' 2013/2014 accounts and on Vodafone data for 2014 regarding the FWA network. Opex not related to UBA or UCLL have been excluded (for example those relevant to non-recurring charges).

In order to forecast the opex for year 2015 and the subsequent years within the regulatory period, costs are divided into two main categories: labour related opex and non-labour related opex.

Labour related opex will evolve in the future with the wages. As a consequence, the labour related opex forecasts will be performed based on the labour cost index (LCI). The non-labour related opex are very difficult to forecast as they highly depend on the mix of expenditures (natural disaster recovery, preventive maintenance on active equipment…) that is performed for a given year. For these different types of activities, price evolution is very different so assessing whether non-labour related opex will go up or down is very complex. As consequence, non-labour related opex will be considered as constant in the years to come.

The price trends assumptions used to derive the "per MWh" energy charges and the "per square meter" floor space charges are based on the following indexes:

- Property fit outs (0% as the content of this category is probably heterogeneous),
- Buildings/Lands,
- Energy (set as the "energy assets" price trends even though it mainly consists of KWh consumption in the absence of better input).

2.2 Network expenses

2.2.1 Electricity and buildings expenses

All expenses related either to electricity or buildings costs are treated independently to derive a cost per kWh and a cost per m² that can be directly used in the TSLRIC models.

Hence, electricity and network building expenses are not included in the opex amount. These are assessed bottom-up in the Capex model as the demand (kWh requirement of each asset) is assessed in this model. Network building expenses aggregate together cost of rented sites, owned sites and associated property maintenance costs. These are assessed bottom-up in the Capex model as the demand (Floor space requirement of each asset) is assessed in this model.

2.2.2   Other expenses

Chorus' expenses are divided into several categories: labour costs, maintenance costs (mainly contractors' costs), IT costs, the cost of rents and taxes, the cost of electricity and buildings and some other costs. The different costs involved in network expenses are either related to specific equipment used for the UCLL and the UBA services or related to several assets at the same time. Therefore, each cost is allocated between the different equipment/services.

Allocation keys have to be consistent with the dimensioning driver in accordance with the capacity-based allocation approach (see criterion 55 of the Model Reference Paper). Thus, several allocation keys have to be computed. For example, maintenance costs related to air-conditioning have to be allocated to active equipment such as DSLAMs and the different levels of EAS (Ethernet Aggregation Switch). Some allocation keys are based on data from the network cost models (access network cost model and core network cost model). Others can be based on allocation of other costs: for example, labour costs related to maintenance costs are allocated with an allocation key based on the maintenance allocation.

Once all network costs are allocated to the different equipment or directly to UBA or UCLL, a total amount related to both services is calculated.

2.3 Non-network expenses

Non-network expenses include headquarters labour, building, IT and electricity costs, insurance, consultants and miscellaneous others costs.

2.3.1   Type of costs

Two types of costs are categorised as non-network costs: non-network expenses provided by Chorus and network expenses that cannot be distributed among the different assets or services (see Model Documentation for model details).

2.3.2   Approach

The non-network common costs incurred by the operator have to be considered.

Two approaches can be used:
*   building a "non-network cost mark-up";
*   using the non-network cost total amount in the model (after an allocation step).

The first approach consists in calculating the total amount of non-network costs from the accounting data and then dividing it by the total network cost from the account (annual capex + opex). It provides a non-network cost mark-up (%) that can be applied to the capex and opex calculated by the TSLRIC models. In Chorus' case, costs that are modelled are likely to be higher than accounting costs (e.g. as accounts include fully depreciated assets). Hence, if the mark-up is applied on this amount, it will lead to a higher non-network cost than the existing one.

The second approach is to use the total amount of non-network costs from the accounting data in absolute value. An allocation is then required to allocate this total value to the different services (UCLL, UBA, services that are note modelled in the TSLRIC exercise…). In line with the EPMU principle, this allocation should be based on accounting costs with the used of regulatory accounts. This breakdown of cost per service is not available in Chorus' annual report, but the revenue breakdown per service is available. Hence, this revenue data will be used as a proxy for the cost data required to apply EPMU to calculate the amount of non-network costs included and allocated to regulated services.

The second approach has been implemented, in line with criterion 56 of the Model Reference Paper.

2.4 Exclusion of Non-recurring charges related costs

To avoid any double counting with the costs assessed in non-recurring charges model, all costs that are specific to provisioning are identified and disregarded in the OPEX calculation.

The cost of service companies (contractors costs) is allocated between maintenance and provisioning. The share allocated to provisioning is disregarded in the OPEX calculation.

3   Geospatial

This section documents the geospatial network processes that have been undertaken and describes the geospatial data and the offline calculations that feed the access network cost model.

3.1 Reference files

There are two different types of geospatial inputs that are used:

- Data regarding New Zealand such as the road network and the location of the buildings.
- Network data allowing modelling of an optimised network such as the position of the exchanges, of the cabinets or the boundaries or the coverage areas of the exchanges.

The majority of the network build and analysis is based on the Terrabase road and address database from Corelogic.

The Corelogic dataset has been used because:

- It is the most comprehensive and complete database of the address and road network available for New Zealand.
- It is used widely in the telecommunications industry.
- Address points are generally positioned on the associated building compared with other datasets that position the address points near the road frontage or evenly distributed across the property. This is important for the estimation of the distance from the road frontage to the building used to estimate the lead-in distances.
- The road network includes road classification and number of lanes for each road segment which is important for estimating the physical width of the formed road.
- Information relating to the use classification of the address points is available. That is, whether the purpose that property is used for is residential, commercial, industrial, etc, purposes.

The files that have been used in the geospatial work are referenced in the following table:

<p align="center">Table 1 – Geospatial reference files</p>

File reference	Content	Usage
Corelogic Terrabase road and address database	Road and rail network, address points, and address categories.	The address points were used as an estimate of the location of buildings. The road network was used to derive the theoretical network to connect the buildings to

File reference	Content	Usage
		the exchange and street cabinets. The road classification and number of lanes was used to estimate the distance of an address from the road edge.
Landcare Research New Zealand Ltd, Land Resource Information System (LRIS) spatial data layers	Rock lithology	Input into trenching cost estimates.
Statistic NZ 2013 Census Data	2013 Meshblock and Census Data	Cross checks on Terrabase residential address coverage.
CERA – Red Zones	Areas zoned red where earthquake damaged land is unlikely it can be rebuilt on for a prolonged period. The data used was for the zones as at 4th December 2013.	Identification of properties to be removed from model, in line with criterion 6 of the Model Reference Paper.
Land Information New Zealand (LINZ) Survey Parcels	Survey Parcels, Legal Road Centerlines	Determine legal width (property boundary to property boundary) of roads. Determine distance of buildings to road frontage. Used to determine the location of network access points. .
Land Information New Zealand (LINZ) Certificate of Title dataset	Current title date of issue and relationship to LINZ Survey parcel	Determine buildings likely to be created post 2001. Also used to determine the location of shared NAP placement by identifying common access parcels.
Building footprints	Building footprints for Auckland City, Christchurch City, Kapiti	Used to determine the distance between a building and the road frontage. Used

File reference	Content	Usage
	District, Porirua City, Tauranga City, and Wellington City councils, The data was either downloaded directly or used via an open web service.	in conjunction with the Corelogic address database to estimate the distance from a building to the road frontage where the building footprint was not available.
Chorus Data	Exchange sites and boundaries, cabinet locations, cable paths	Used in coverage and shortest path calculations
Vodafone RBI Sites and Coverage	Name and coordinate of existing and proposed sites and coverage of final (2019) RBI coverage.	Used to determine FWA coverage
TSO Cluster Boundaries	Cluster Boundaries derived from 2001 residential connections	Used to determine which address points and road segments were within or outside of the TSO areas
Vodafone RBI 2019 final Coverage	Grid based file that shows the planned 2019 coverage for RBI	Used to determine which address points and road segments were within or outside of the RBI areas.

Source: The Commission

3.2 Processes and issues with the geospatial data

3.2.1 Road Network

There were very few issues encountered with the road network data from Corelogic NZ Ltd.

Initially some time was spent confirming the ownership of roads that were shown in the dataset as being privately owned when in fact it was clear that the road was public. Similarly many roads, particularly in rural areas, where shown as being public when they were actually a shared private access road. During the project it was decided to include all roads from the Corelogic dataset. This was because the Access model effectively ignores all road segments that do not contain any buildings when they do not form part of a shortest path from another road segment. The road ownership category was retained in order to apply a weighting for the shortest path calculations.

The Corelogic data defines the road segment status as being one of:

- In use

- Unsurveyed proposed
- Unformed surveyed
- Under construction
- Disused

The model used only those road segments with a status of 'In Use'. In addition, the Corelogic data classifies the road using the following criteria:

Table 2 – Corelogic road classification

Value	Notes
Access rural	Narrow roads including access roads to private dwellings and homesteads. These are less significant than minor roads. They differ from vehicle tracks because they are negotiable by 2WD vehicles
Access urban	Well formed narrow roads, navigable by 2WD vehicles, within parks and reserves, hospitals, universities, cemeteries, industrial complexes, private villages and other similar areas. Also includes access ways (vehicle), service lanes, and right of ways. Right of ways will be shown where they are named, or where it is required to walk/drive down the right of way to get access to the property
Arterial rural	Selected main roads in rural areas –predominantly sealed 2 lane roads, connecting two major roads, two towns (or populated places) or roads ending at a significant place (i.e. tourist destination).
Arterial urban	Selected main roads; sealed 2 lanes, in urban areas including numbered urban routes. NB. Numbered urban arterial routes are also a route_type
Ferry car	Car and passenger ferry route connecting to the road network
Ferry passenger	Passenger ferry route connecting to the road network
Foot path	Formed foot-path (not represented by parallel road segment). Mainly in urban locations
Foot track	Poorly formed walking track. May have either a rural or urban location
Major rural	Selected main roads that are predominantly sealed with 2 or more lanes. They are the primary routes between towns.
Major urban	Selected main roads that are sealed with 2 or more lanes. They are the primary routes between towns, urban villages and high density suburbs.

Value	Notes
Medium rural	Sealed or metalled 2 lane roads or narrow sealed roads that connect to other medium or higher class roads. These roads provide significant thoroughfare.
Medium urban	Sealed, 2 lane roads of less importance than major or arterial urban roads, but still connect to other roads. . These roads provide significant thoroughfare.
Minor rural	Narrow roads that are predominantly metalled or narrow sealed roads where entry/exit are the same or connect to other minor roads or tracks.
Minor urban	Roads of lesser importance than Medium roads. These can be thoroughfares or dead end roads They may run parallel to other higher class roads.
Motorway	Roads gazetted as having motorway status by NZTA These are always State Highway Routes. Includes on and off ramps. These roads are only for vehicles.
Vehicle track	Poorly formed reasonably permanent un-metalled road segment, generally negotiable by four wheel drive or farm vehicles. Minimum length 75m.
Water route	Centreline used for attaching addresses based on islands, centreline should be attached to the road network. Note not used.

Source: The Commission

The model removed Ferry car, Ferry passenger and Water routes as these are not applicable to a road network based model. In addition foot paths and foot tracks were removed unless they started and ended at a rural or urban road. This allowed for footpaths that interconnect the road network, for example as is often the case at the end of a cul-de-sac.

Two additional classifications were added to enable the model to connect to the exchange buildings and street cabinets and to add connection between a couple of islands. These additional classifications were:

- Lead: the connection between an Exchange building or a Street Cabinet and the nearest road segment

- Link: an arbitrary connection to link disparate networks within an MDF coverage area. Mostly connecting road networks on islands with the mainland.

Network leads were added by connecting the Exchange building and street cabinets to the nearest road segment and splitting the road segment at that point.

To avoid the creation of unnecessary cabinet coverage areas where a cabinet position was within 50m of the exchange position the cabinet has been deemed to reside in the

exchange and the location of the cabinet was adjusted to coincide with the exchange effectively removing the cabinet from the network calculations.

Street cabinets within the Christchurch Red Zone were removed from the model.

Figure 9 - Example of road sections with street cabinets
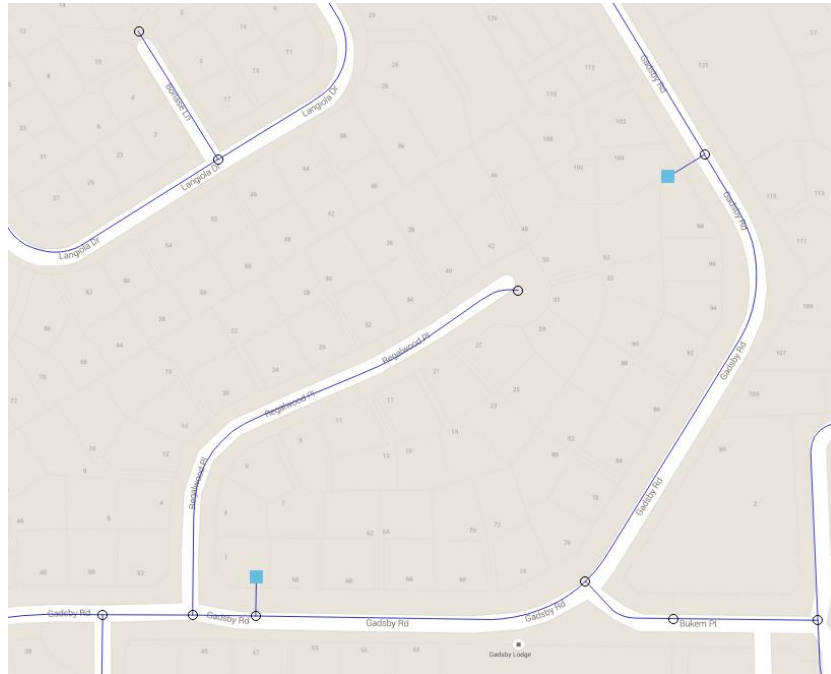
Source: geospatial data, the Commission

Start and end points of sections shown as circles. Street cabinets represented as squares.

To minimise the number of records in the Access Model SOURCE_SECTIONS table road segments were merged from intersection to intersection. For example if the original Corelogic road segment between two intersections was comprised of 3 segments these were merged into a single segment within the model.

3.2.2   Address points and buildings

The Corelogic address dataset was used as the basis for the population of the Access Model SOURCE_BUILDINGS table.

This dataset defines each address as having one of the following in use types:
1. Corner Alias
2. Park &/ Reserve
3. Range Alias
4. Renumber Alias
5. Unused
6. Unused Alias
7. Yes (Developed)

The model used only those address points with an in use type value of 'Yes (Developed)'.

Address points within the Christchurch red zone areas (as at 4th December 2013) were removed from the model.

The address points were grouped together where they were coincident or within 10 metres.

The Corelogic address data includes the ID of the associated road segment for the address. This value was used to connect the grouped address point to the nearest point on the associated road segment.

The location of the nearest point on the associated road segment was used to determine the HORIZONTAL_LENGTH and SIDE_OF_ROAD values in the SOURCE_BUILDINGS table using the direction of the road segment via the shortest path back the exchange point.

The RIGHT_SIDE value in the SOURCE_BUILDINGS table is set to true if the address location is on the predominate side of the road (it is equivalent to the major side, that is the side with the largest count of address points) or if neither side is predominate on the right hand side of the road segment direction via the shortest path back the exchange point.

Figure 10 – Address points on the major (circle) and the minor sides (triangle) of the road
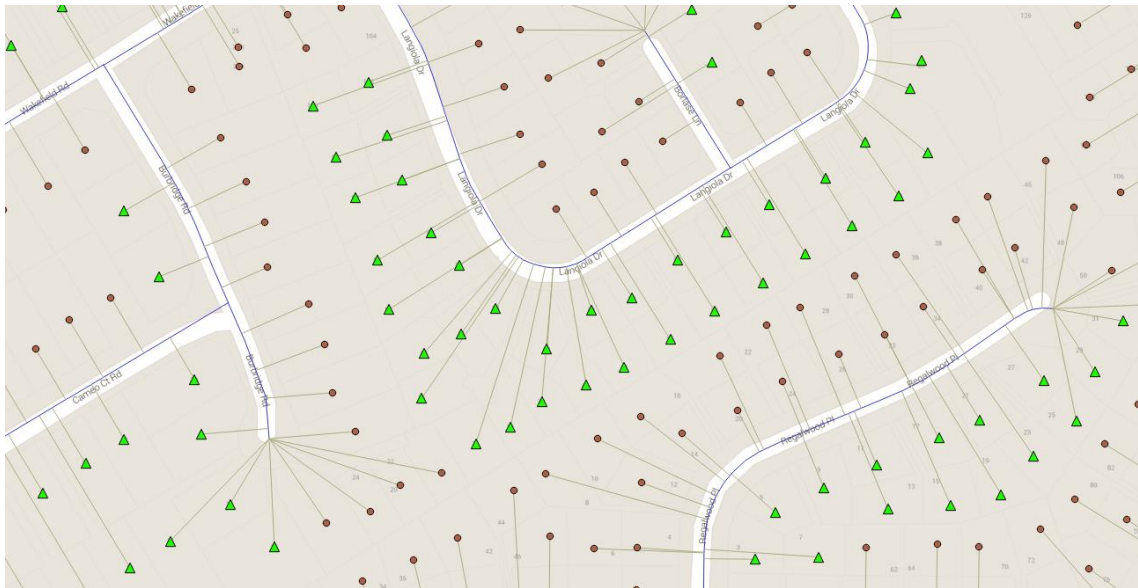
Source: geospatial data, the Commission

Data for the land use classification was supplied by Corelogic using the Quotable Value NZ rating data. This was matched to the address data and used to populate the NB_TOTAL, NB_RESIDENTIAL, NB_COMMERCIAL, NB_INDUSTRIAL and NB_OTHER fields in the SOURCE_BUILDINGS table of the Access Model. This data was also used to identify vacant land ie properties that do not have a building on them.

3.2.3 Building footprints

A total of 650,781 building footprints from Auckland, Tauranga City, Kapiti District, Porirua City and Welling City Councils were used for the calculations.

Building Footprint Data: The data was sourced from online datasets from the six
territorial authorities[4].

The legal road boundary data was downloaded from the Land Information New
Zealand website (https://data.linz.govt.nz/layer/796-nz-primary-road-parcels/).

Buildings with a footprint area of less than 50 square metres were deleted. Analysis
showed that use of a minimum floor area of 100 square metres was a reasonable
break point for distinguishing between dwellings and other buildings such as sheds and
garages.

A series of calculations were run to determine the minimum distance from the building
footprint to the nearest legal road boundary.

For urban areas the average distance from a building to the nearest legal road
boundary across New Zealand is 20.6 metres.

The average varies from 11.6 metres in Wellington City to 23.4 metres in Kapiti District.

The following table summarises the average distance and building count by territorial
authority.

Table 3 – Average distance and building count by territorial authority

Area	Average	Number of buildings
Auckland	21.9	365,742
Christchurch	20.2	118,099
Kapiti	23.4	15,794
Porirua	16.0	16,416
Tauranga	21.0	43,338
Wellington	11.6	50,031
Total	**20.6**	**609,420**

Source: geospatial data, the Commission

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[4] http://maps.aucklandcouncil.govt.nz/aucklandcouncilviewer/

http://cera.govt.nz/maps

http://apps.geocirrus.co.nz/?Viewer=KCDC

http://gis.pcc.govt.nz/HTML5/

http://gis.tauranga.govt.nz/maps/Viewer.html?Viewer=Mapi

http://wellington.govt.nz/about-wellington/maps/gis-data-terms-and-conditions/gis-data

**Figure 11 - Map showing sample distances from building footprints to legal road
boundary within Auckland Council.**

Source: geospatial data, the Commission

The building footprints that contained address points were then used to determine the
average offset distance from the address point to the edge of the building.

This was required because the capital contribution of the lead-in runs from the property
boundary to the ETP on the outside of the building. By assuming that the address
points are located in a consistent relationship to the actual building location and that
the building footprints are an accurate definition of the building extent then it is possible
to define an average offset from the address to the building. This offset can then be
applied to the address points that are in areas where the building footprints are not
available.

The average offset distance was determined to be 8.3m

The distance from the address point to the road frontage was calculated by joining the
address point with the nearest point on the associated road segment definition and
intersecting this line with the LINZ road parcels. There are many cases where no
intersection is possible due mainly to discrepancies between the CoreLogic and LINZ
data as well as many instances of road crossing private land or deviating out of the

legal road boundary definitions. There are also instances of privately owned land being used for roading but not vested (or yet to be vested) for roading purposes and therefore not shown on the LINZ dataset. In these instances an average distance to road value by road classification was calculated and applied to the records for which a value could not be derived.

The following table shows the average distance from an address point to the road frontage.

Table 4 – Average building footprint according to road classification

Classification	Average Distance
Access rural	58.4
Access urban	25.3
Arterial rural	95.5
Arterial urban	31.2
Foot path	13.8
Foot track	26.4
Major rural	87.3
Major urban	27.4
Medium rural	88.6
Medium urban	26.1
Minor rural	87.7
Minor urban	23.7
Vehicle track	60.3

Source: geospatial data, the Commission

3.2.4   Vacant buildings

Vacant address points (i.e. no building is likely to be present) have been removed from the building footprint using the land use categories within the Quotable Value NZ rating data e.g. Residential Vacant, Industrial Vacant etc

3.2.5   Calculation of legal width from Road Polygons

Legal width is the width from property boundary to property boundary, i.e. including footpath, berm and pavement.

The road polygon dataset was downloaded from Land Information New Zealand (www.data.linz.govt.nz).

The average width of the road polygon was calculated[5] as being 2*Area/Perimeter.

This was applied to each road segment that had more than 30% of its length within a LINZ road polygon by calculating the proportional average road width. Where there was a 30% or more overlap then the calculated value was applied.

The following table shows the average width by road classification for road sections that overlapped the legal road segment by 30% or more.

Table 5 – Average legal width according to road classification

Classification	Nb sections	Avg legal width
NULL	31,249	18.5
Access rural	859	23.1
Access urban	3,544	16.9
Arterial rural	3,100	23.5
Arterial urban	24,402	20.6
Foot path	*3,147*	*10.2*
Foot track	*31*	*20.6*
Major rural	6,934	27.2
Major urban	6,765	23.5
Medium rural	10,045	21.4
Medium urban	38,663	17.0
Minor rural	34,884	20.7
Minor urban	65,290	15.7
Motorway	308	52.3
Vehicle track	37	22.9

Source: geospatial data, the Commission

These averages were then applied to the road segments that had an overlap of less than 30%.

Foot paths and foot tracks which were set to a width of 3m.

3.2.6 Lead-ins

The length of the within property lead-in (being the distance from the road frontage to the building edge) was determined using the distance between the address point and the associated network access point and the legal road frontage data from Land

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[5] See calculation outlined at

http://gis.stackexchange.com/questions/20279/how-can-i-calculate-the-average-width-of-a-polygon

Information New Zealand. This distance was adjusted for the length within the building where known or the average address to building edge distance where no building footprints were available.

3.2.7 Shortest paths

Each road segment was assigned to the nearest exchange point using a weighted shortest path algorithm that used a weighting of 2 and 4 for private roads and motorways respectively.

All other road segments were given a weighting of 1 times the road segment length.

These paths were used to populate the SOURCE_MDF_BUILDING_PATHS and SOURCE_DETAILED_MDF_BUILD_PATHS table in the Access Model.

The road network model was also used to determine the shortest path from each street cabinet to the Exchange point. These paths were used to populate the SOURCE_MDF_SC_PATHS and SOURCE_DETAILED_MDF_SC_PATHS tables in the Access Model.

Similarly the road network model was used to determine the nearest street cabinet or exchange point for each road segment in the network. The derived paths were used to populate the SOURCE_SC_BUILDING_PATHS and SOURCE_DETAILED_SC_BUILDINGS_PATHS tables in the Access Model.

3.2.8 Identification of In-Fill since 2001

In order to determine the in-fill buildings, i.e. buildings built after 2001, it was necessary to have an approach that could compare the environment in 2001 with the current environment. Several options were considered for this, including the use of Census data, and we eventually decided to use the address points supplied by Telecom for the 2001 TSO determination as this was the most reliable and complete data set available and was also the dataset from which the TSO cluster polygons were derived.

The current building dataset is based on the Corelogic Street and Address dataset which has formed the basis for the TERA model. This dataset is more complete and spatially accurate than the 2001 TSO dataset due to the amount of effort that Corelogic has put into cleansing and updating the data over the last decade. This makes it significantly difficult to compare the two datasets to determine new subdivisions.

To mitigate errors associated with missing or incorrect data and to introduce the temporal element (that is, change since 2001) it was decided to utilise the Land Information New Zealand Certificate of Title database which, as well as containing the date that the title was issued, can be spatially defined using the relationship between the title and the Land Information New Zealand Survey Parcel.

This means that by filtering all the current titles that have been issued since 2001 it is possible to generate a map of the gross infill.

Titles can apply to multiple parcels within the same ownership and include reference to easements and shared parcels. To ensure no duplication only those parcels that contain buildings were included in the In-Fill calculations.

3.2.9   Process

The process was divided into the following steps:

1. For each TSO address point determine which Survey Parcel it is within.

2. For each Certificate of Title extract those created since 2001 and determine which Survey Parcel it is within.

3. For each building point determine which Survey Parcel it is within.

4. Identify those Survey Parcels that contain at least one Certificate of Title (step 2) and one building point (step 3).

5. From the Survey Parcels from step 4 identify those that have a larger number of Certificate of Titles than TSO Address Points or that have no TSO Address Points.

6. Flag the data model of building points that are within any of the survey parcels from step 5 as being 'in-fill'.

Figure 12 - Survey Parcels and the 2001 TSO Address Points
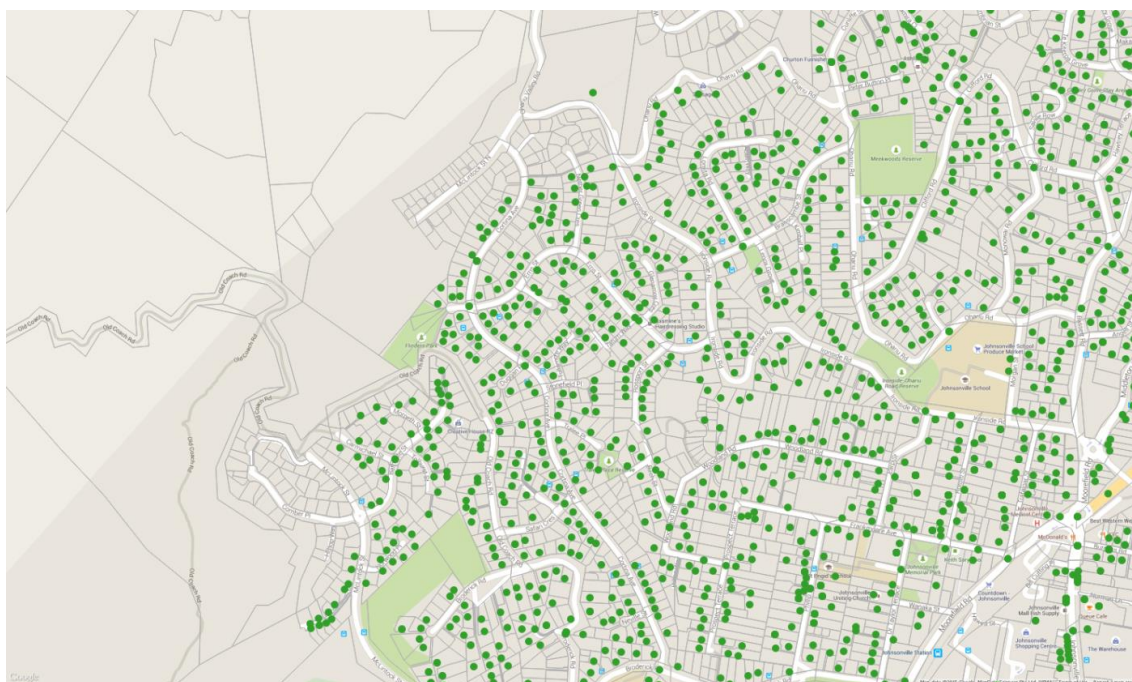
Source: geospatial data, the Commission

The figure above shows the TSO 2001 address points represented as green filled circles in relation to the LINZ Parcel boundaries.

Figure 13 - Survey Parcels and the location of Certificate of Titles Issued since 2001
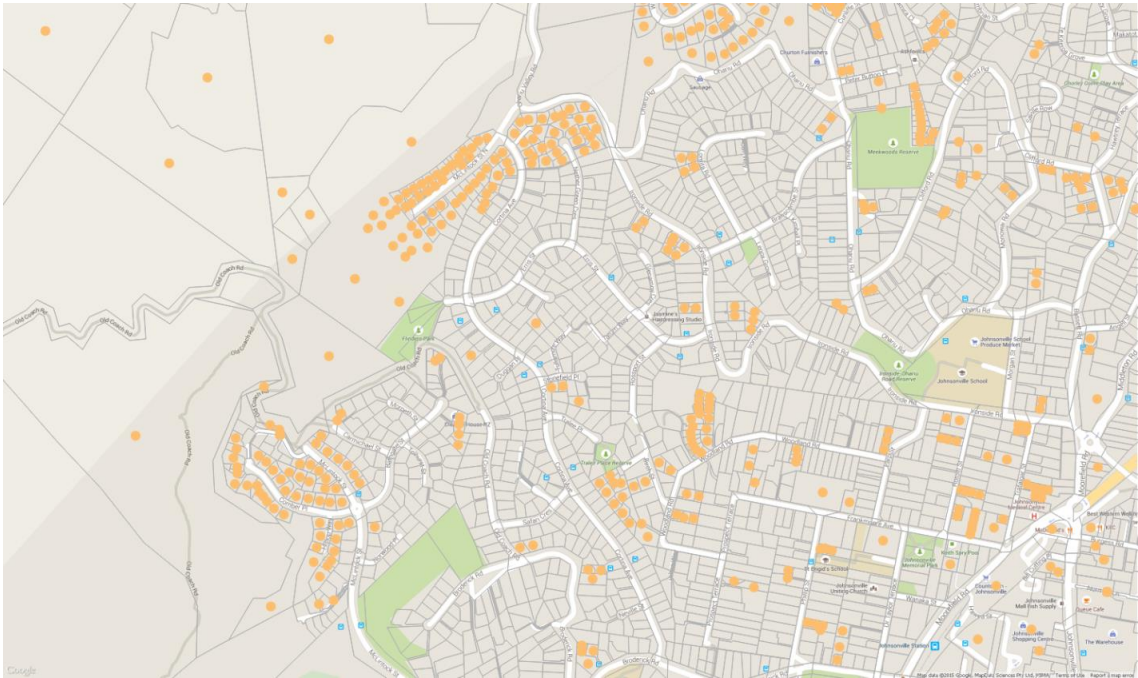
Source: geospatial data, the Commission

The figure above shows the location of titles issues since 2001 represented as orange filled circles in relation to the LINZ Parcel boundaries.

Figure 14 - Land Base and location of Certificate of Titles Issued since 2001 and 2001 TSO Address Points
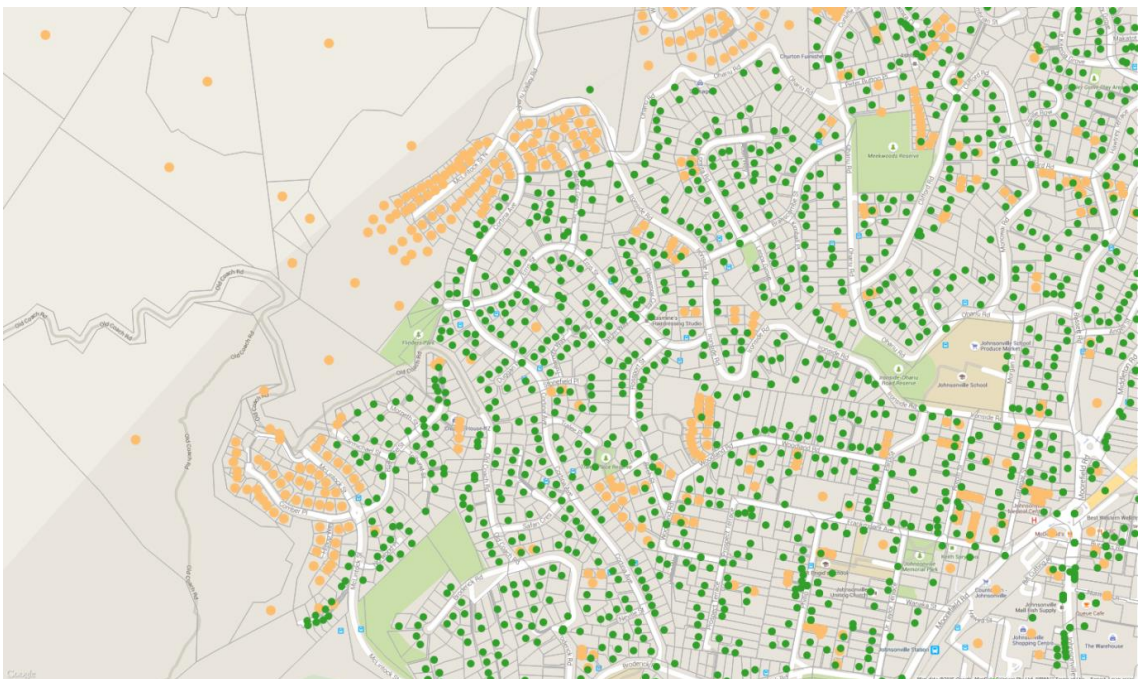
Source: geospatial data, the Commission

The figure above shows the location of titles issues since 2001 represented as orange filled circles and the TSO 2001 address point represented as filled green circles, in relation to the LINZ Parcel boundaries.

Figure 15 - location of calculated 'In-Fill' buildings in relation to Certificate of Titles issued since 2001 and 2001 TSO Address points
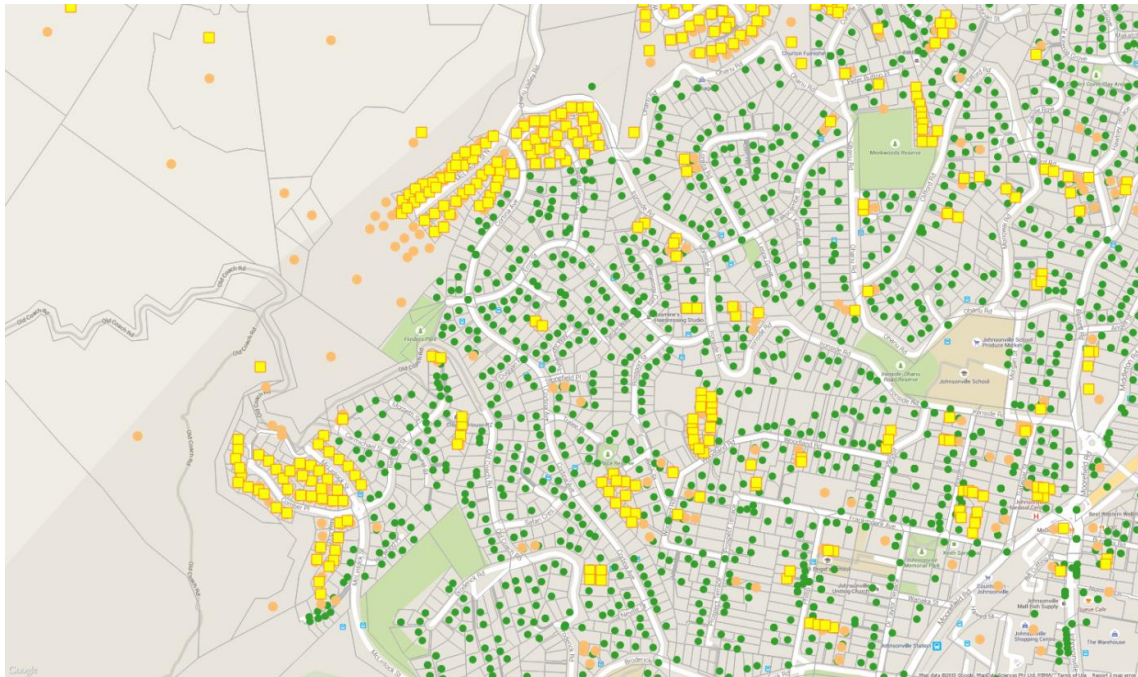
Source: geospatial data, the Commission

The figure above shows the location of buildings determined to be 'in-fill using the process described above, in relation to titles issues since 2001 and the TSO 2001 address point.

The ratio between the number of infill buildings and the total number of buildings on each road segment was determined using the relationship between the building and the road segment.

Where this ratio was over 75% it was deemed that the entire road segment is in-fill.

The following figures shows an example of this calculation in the Hamilton area where the infill buildings are shown as yellow squares and the infill road segments as green lines.

3.2.10 TSO boundary

Sections crossing the TSO boundary are split in two, in order to avoid edge effects when determining the network demand in the TSO areas and outside the TSO areas. As a consequence, the number of sections has been increased compared to the initial database.

3.2.11 Determining Location of Network Access Point (NAP)

The approach for the determination of the NAP location was as follows:

1. The Land Information New Zealand (LINZ) parcel and road data was used to determine:
   a. The parcel that contains the address point,
   b. The legal road segment that contains the Corelogic road segment,
2. Using 1.a and 1.b we determined the road frontage boundary for the parcel (being the intersection of the parcel and the road segment),
3. For parcels that did not intersect the road polygons the LINZ title information was used to determine which adjoining parcels provided either right of ways or shared access to the road frontages,
4. Once the road frontages were determine the location of adjoining road frontages was determined to find the point on the road frontage that is common for adjacent parcels (shown as red dots on the following diagram),
5. For private roads with multiple address points within a single parcel (e.g. rest homes etc.) a similar approach was used but the road width was determined by the number of lanes attribute. The location of the NAP along the line was set as the point half way between adjoining address points.

In all cases, the first and last locations on each segment have been placed to minimise the trench length of the minor side.

The relationship between the address point and the road segment (i.e. which road segment the address is attached to) was based on the Corelogic address and road database which contains for each address point the identifier of the associated road segment.

It was possible to use this approach for about 99.5% of the address points. For the balance of the other locations (0.5%) the approach used in the previous model was maintained ie the location of the lateral was determined by using the location on the road segment that was nearest to the address point. These tended to be in rural areas where the parcels are large with the address points that are a significant distance from the road segment.

There were several issues that needed to be accounted for when undertaking this work including:

- Road segments that crossed multiple legal road polygons,
- Adjoining legal road polygons that did not contain road segments (usually the result of road widening),
- Corelogic road segments not following the legal road polygon (common in rural areas where the physical road is not within the legal road).

In each case these were identified as they were encountered and either handled as exceptions or ignored (i.e. formed part of the 0.5% of roads)

Note also that these calculations were done after the vacant land address points were removed which means that the vacant land sites were not used or taken into account when determining the optimum lateral position.

Figure 17 – Network Access Point placement

Source: geospatial data, the Commission

The above figure shows the results of modelling the Network Access Point location for a typical urban area. The building locations are represented by the green triangles and the NAP's by the red circles. The diagram shows the property and road data from LINZ with the legal road areas shaded grey and the vacant sites shaded light yellow. The buildings served by individual NAP's are shown as a light grey line that connects the two feature types.

3.3 Exchange areas

In the selected approach, nodes are located at their actual location while their coverage is optimised in order to reflect a cost-efficient network.

Optimisation is based on the Voronoï method (using a shortest road network path), which determines for each point in the country what is the closest exchange following the road network from the premises to the exchanges (direct paths, i.e. without passing through street cabinets).

3.4 Copper network

As described in §4.2, the copper network is made of three parts:

- The "feeder" which is the link between the exchanges and the SC (active or passive);
- The link between the SC (active or passive) and the customers (exchanges are considered as a SC for the customers directly connected to the exchange). This link is made of the two following parts:
    - The "distribution" which is the part of the network between the SC and the CCT; and
    - The "lead-in" which is the part of the network between the CCT and the ETP.

The modelling of lead-in does not require deriving a set of paths as the dwellings are connected to a distribution point located on the same section. Two sets of paths are therefore required to connect all the dwellings.

Please note that the definition of the lead-in used in modelling includes the lateral. However, the lateral inventory and costs have been included as they are not within the property boundary and are therefore outside of the scope of costs removed for capital contributions.

Each path follows the road network and is the output of the shortest path algorithm restrained to an area:

- Restrained to the SC coverage area for the link between the SC and the customers; and
- Restrained to the MDF area for the feeder.

The computation of the shortest path algorithm is in line with the length-based optimisation as described in the Model Reference Paper.

3.4.1 SC coverage areas

The location of the exchanges and the location of the SC are known (data collected from Chorus).

MDF and SC coverage areas are inferred from MDF and SC locations.

Figure 16 – Starting point

MDF Area

● **MDF**

● **SC**

All the customers have to be connected to a SC or to the exchange. The MDF associated with an exchange or SC therefore has its own coverage area. Each road segment is connected to the closest SC (or exchange for customers directly connected to the exchange). The distance between the road segment and the closest MDF, SC or Exchange, is the road distance and not the straight-line distance as the network follows the road network

The SC coverage areas have been determined by using the modified Voronoï's polygons:

* The boundary of each polygon is computed so that the distance between any point[6] inside any polygon and its centre is shorter than the distance to the centres of all other polygons;
* The distance used is the distance following the road network instead of the straightline distance.

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[6] Calculations are made at the section level: a section is assigned entirely to a cabinet or exchange area. When points of a section could be assigned to a cabinet while other points of the same section could be assigned to another cabinet, all the points of the section are assigned to the same cabinet: the one which minimizes the section-average distance to the cabinet.

Figure 17 – SC coverage areas

MDF Area

End users located on
sections within the
area are connected
to the same cabinet

● MDF

● SC

5 cabinet + 1 MDF = 6 "SCcoverage areas"

Source: TERA Consultants
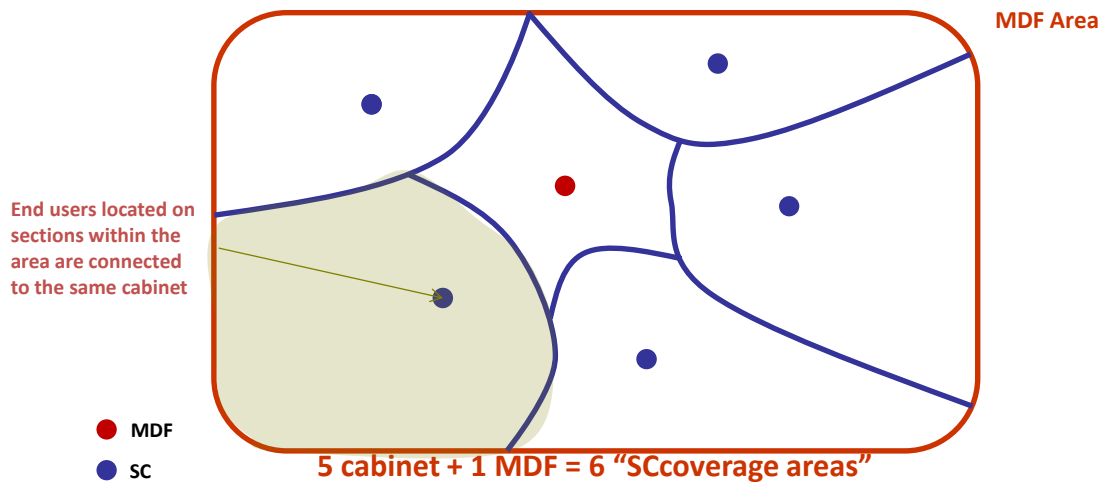
All the customers located within the same SC coverage area are therefore connected
to the same SC (or exchange).

3.4.2   Distribution

The second step is to derive the distribution, i.e. the paths linking each customer to its
parent SC.

Figure 18 – Distribution

MDF Area

End users located in
road section 'a' will
be connected to the
SC located on section
'd' via sections 'b'
and 'c'

d

a

c

b

● MDF

● SC

Source: TERA Consultants
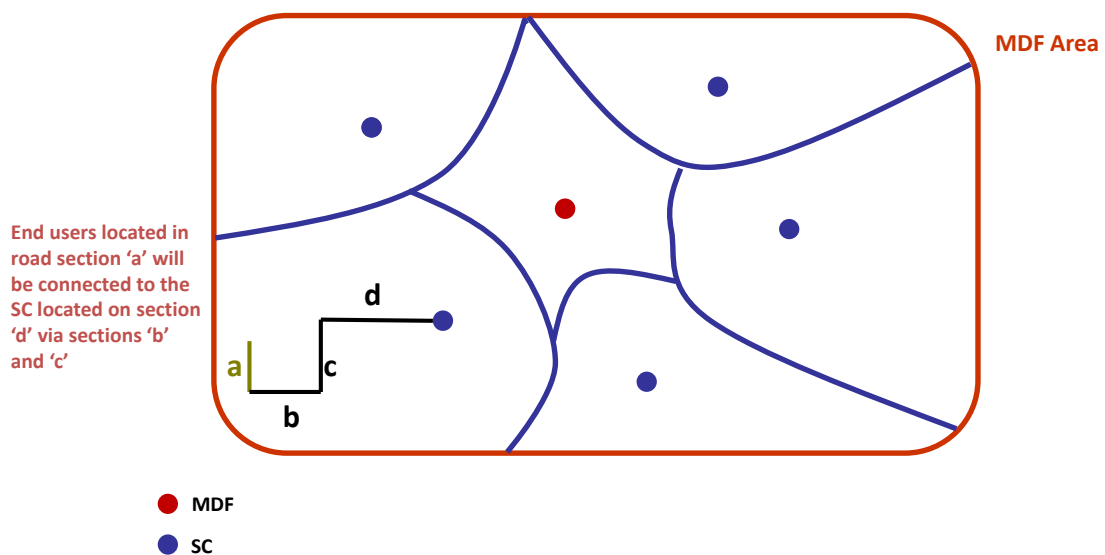
The shortest path algorithm is applied to determine for each road its route linking it to
its parent SC.

3.4.3   Feeder

The third step is to derive the feeder, i.e. the paths linking each SC to its closest
exchange (defined as parent exchange).

Figure 19 – Feeder

● MDF

● SC

The shortest path algorithm is applied to determine for each SC its route linking it to its parent exchange.

3.5 Fibre network

As described in §5.2, the fibre network is made of solely two parts

- The distribution which is the links between the exchanges and the FAT; and
- The lead-in which is the links FAT and the ETP.

Similarly to the modelling of the copper network, no set of paths is needed for the modelling of the lead-in. Only one set of paths is thus required to connect all customers to their parent exchange.

Exchange coverage areas are determined by using the Voronoï's polygons approach set above for street cabinet areas.

The shortest path algorithm is applied to determine for each customer its route linking it to its parent exchange.

3.6 Lead-in

For each building, the geospatial data provides two vertical lengths:

- Vertical length from the network access point – located at the property boundary – to the ETP;
- Network access point location on section, resulting from sharing among two or three buildings.

It should be noted however that dedicated lead-in trenches are not taken into account in the network costing (within-property trenches, from the network access point to the ETP, cf. section 4.3.4.4.1).

Aerial lead-ins (poles) are not shared among buildings, at the exception of

- the first pole bearing the distribution; and
- the opposite pole on the minor pole.

Which are shared among the buildings distributed through the same distribution point.

3.7 TSO areas

The geospatial analysis provides for each road section whether it is located inside the TSO or outside the TSO.

As non-TSO areas benefit from subsidies for network deployment, network modelling follows two distinct approaches:

- Inside the TSO area, the network is dimensioned according to the total demand, i.e. according the local demand and all the lines of the rear area, including those outside the TSO;
- Outside the TSO area, the network is dimensioned according to the TSO demand, i.e. for the sole TSO lines in rear area.

This is in line with criterion 17 of the Model Reference Paper

3.8 Inter-exchanges links

The inter-exchange links are the fibre cables that are connecting exchanges together. There are two different types of links:

- The links between exchanges that both contain at least one Ethernet switch. These links are not part of the scope of the core model. However, they have to be modelled in order to capture the relevant economies of scope; and
- The links between exchanges with at least one that does not contain an Ethernet switch. These links are part of the UBA service and should be included in the modelling

For each link, the starting point and the end point have been identified. The shortest path algorithm is applied to determine the path of the link.

The computation of the shortest path algorithm is in line with the cable length-based optimisation as described in criterion 25 and 26 in the Model Reference Paper.

3.9 DWDM links

In line with criterion 47 in the Model Reference Paper, the core network may contain DWDM links due to long distance. These long distance links have been identified from the full list of DWDM links provided by Chorus.

For each link, the starting point and the end point have been collected. The shortest path algorithm is applied to determine the path of the link.

3.10 Submarine links

In line with criterion 47 in the Model Reference Paper, the core network may contain submarine links connecting an island to the main land.

For each link, the starting point and the end point have been collected. The length of the link is its actual link length.

3.11 Access part of the fibre leased lines[7]

The fibre leased lines[8] are made of two parts:

- The core part that is shared with other services;
- The access part that is made of dedicated fibre cables.

The access part of the leased lines is interconnecting either:

- two sites together; or
- one site to a node of the network.

The cables used in the access part are sharing the same infrastructure (trenches, chambers, etc.) as the access network or the core network. There are therefore economies of scope that should be captured: the leased lines should bear a part of the infrastructure costs according to the space used.

If Chorus had provided geospatial information on where the access part of fibre leased lines are located, it could have been possible to identify the road sections where they are deployed and match these road sections with the road sections where the access and core networks are deployed. Chorus has not been able to provide such information. In order to overcome this absence of data, a macro-parameter has been created that defines the level of cost that is allocated to the leased lines. This macro-parameter indicates the percentage of the length of access network which is shared with the access part of fibre leased lines. The value of this macro-parameter has been set so that the share of costs borne by the leased lines is consistent with what has been observed by TERA in other countries, where operators have provided detailed geospatial information on the access part of leased lines and therefore where it has been able to precisely assess the percentage of the access network which uses the same infrastructure as the access part of fibre leased lines.

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[7] Copper leased lines are not provided using dedicated copper cables and therefore they are not discussed in here

[8] Leased means any point to point link with a dedicated capacity regardless of the type of link (e.g. copper or fibre). It includes leased lines, fibre circuits, managed services etc.

3.12 Fixed wireless access

The fibre network scenario is a combination of a wired network (the fibre network) and
a wireless (FWA) network (the model can also calculate the costs of a full fibre
network).

3.12.1 Determining the cost of FWA sites

3.12.1.1 FWA base stations

The locations of Vodafone's sites are used as a starting point to model the FWA
network, in line with criterion 13 of the Model Reference Paper. The set of Vodafones'
sites is narrowed to sites located in exchange areas unlikely to be unbundled. 268
FWA RBI sites are selected.

3.12.1.2 Connection of the FWA sites

In line with criterion 14 in the Model Reference Paper, each FWA site is connected to
the closest exchange by a fibre cable. The sections located on the paths from an
exchange to a FWA site are connected by the fibre cable.

As described in §3.5, the fibre network is based on direct links between customers and
the exchanges using the shortest path algorithm. There is thus no need to derive any
extra path for linking the FWA sites to their covered premises.

3.12.1.3 Determining the cost of the FWA network

The total capital cost of the FWA network is then comprised of the cost of the following:

- base stations
- spectrum;
- backhaul from base stations to exchanges; and
- share of ODF costs at exchange.

3.12.2 Determining the coverage of the FWA network

When a premise is served by FWA, it is removed from the FTTH demand. Premises
served by FWA are likely to be the costliest premises in an FTTH network, within each
exchange area.

FWA coverage is determined by:

- RBI FWA sites theoretical coverage;
- Site capacity;
- Throughput demand per premise (based on copper line speed equivalence).
- Whether it is served by an MDF that is unlikely to be unbundled.

Premises furthest from the exchange are served first, up to the point at which FWA site
capacity is exhausted. The premises which are located along the FWA backhaul are
excluded from FWA coverage (and served by fibre instead).

3.12.2.1 RBI sites coverage

Sites locations are based on Vodafone's RBI FWA sites. Sites located within exchanges that are unlikely to be unbundled are selected for the base case scenario. Other RBI sites are excluded from modeling.

RBI FWA sites coverage is provided by Vodafone. It can cross exchange area boundaries which means that premises located in an exchange area can be connected by a RBI FWA site present in another exchange area.

3.12.2.2 Site capacity

Site capacity is set to 66 Mbps per site, in line with criterion 15 of the Model Reference Paper.

3.12.2.3 Throughput demand per premise

Throughput demand per premise is based on ADSL 2+ quality of service, in line with criterion 16 of the Model Reference Paper.

Throughput served to premises is determined by what they would have received in a copper network, this is based on distance to the nearest non-RBI active cabinet or MDF.

Premises further 7 km are voice only customers, and are being offered 150 kbps throughput.

Premises below 4.4 km are broadband customers and are being offered 1.9 Mbps throughput.

Premises between 4.4 km and 7 km are being offered intermediate throughputs based on the document New Zealand copper local loop preliminary interference management plan, part 2, spectral compatibility determination process, November 2007.

3.12.2.4 Premises excluded from FWA coverage

Premises along the fibre backhaul of the FWA sites are removed from FWA coverage, as they can already be covered by FTTH at a small incremental cost.

Plus, non-TSO and sections in post-2001 subdivisions (i.e. sections deemed as post-2001, in which 75% or more buildings have been built after 2001) are excluded from FWA coverage.

3.12.2.5 Premise selection

Premises with the greatest distance to the MDF are selected first to fill the FWA site. They are also likely to be the most expensive.

3.12.3 Alternative FWA scenarios

Three alternative FWA sub-scenarios are tested in the FTTH+FWA scenario:

- FWA covering the full areas where unbundling is unlikely to occur,

- FWA covering long lines in areas where unbundling is unlikely to occur and covered by RBI or extrapolated when not covered by RBI,
- Absence of FWA i.e. full FTTH.

In the first two scenarios, the location of sites is based on RBI sites in the base case scenario, and extrapolated thanks to the total FWA throughput in the network.

In the third FWA network, there is no FWA site needed.

4   Equipping the copper access network

4.1 Demand for the copper access network

4.1.1   Actual demand

As described in the Model Reference Paper, the copper access network is dimensioned according to all dwellings. Indeed, in line with other TSLRIC models developed in other jurisdictions and in line with the approach followed by network designers, fixed wired access networks are dimensioned for the number of dwellings and not for the actual demand. The reason for that is that dimensioning a network for the number of dwellings is much more efficient in the long run since it prevents having to redeploy cables, redig trenches or redeploy poles when actual demand increases and therefore enables significant cost savings. This is why any fixed wired access network dimensioning would consider the number of dwellings of a given area since all these dwellings represent a potential demand in the long run.

In order to derive the cost per line, the demand considered for the copper access network is Chorus' actual copper demand plus the LFC demand and the Chorus UFB demand. The modelled network is fully loaded since it includes the maximum number of customers a HEO could get today and is assumed to receive revenues from all these customers.

4.1.2   Forecast demand

In line with criterion 22 in the Model Reference Paper, the demand is assumed to be constant.

4.2 Copper network

The architecture of the modelled local access copper network (see Figure 20 below) includes 3 levels of nodes:

- MDF;
- SC; and
- CCT.

CCTs are always located on the section of the lead-in building.

Figure 20 – Architecture of the local access copper network
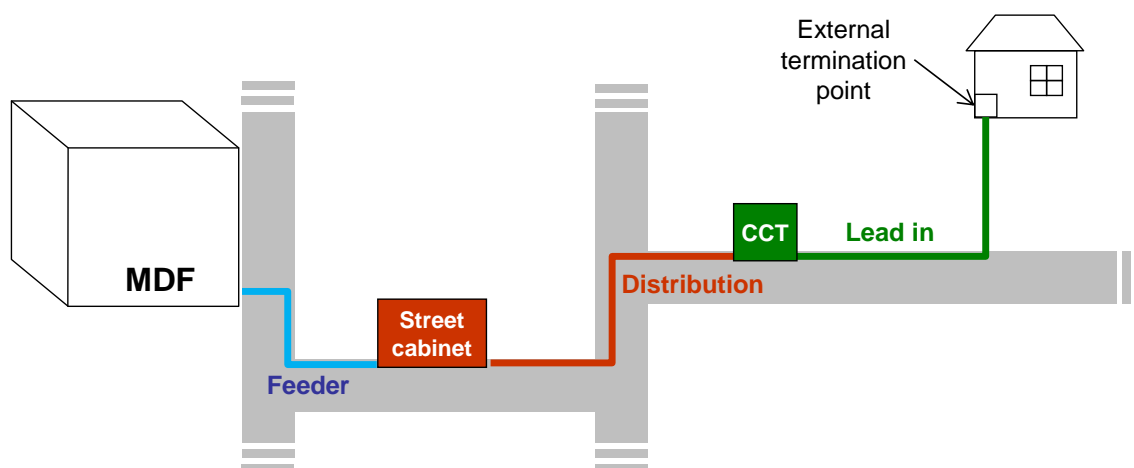
Source: TERA Consultants

Hence, there are three levels of networks:

- Feeder: from the Exchange to the street cabinet;
- Distribution: from the street cabinet or exchange to the CCT;
- Lead-in: from the CCT to the ETP at the foot of the building. It is important to note that the Network Access Point, which is located at the boundaries of properties, is part of the lead-in.

The feeder, distribution and lead-in cables are copper cables.

The MDF and street cabinets coverage areas are an input of the Microsoft Access component of the access network cost model, and the paths between MDF and street cabinets, as well as the path between exchanges and street cabinets and sections, are based on the shortest path algorithm.

When the street cabinet contains active equipment, then the link between the MDF and the street cabinet is a fibre cable used to provide the SLU backhaul.

In such a case, there is no feeder in the local access network.

Figure 21 – Architecture of the local access network when the street cabinet is active
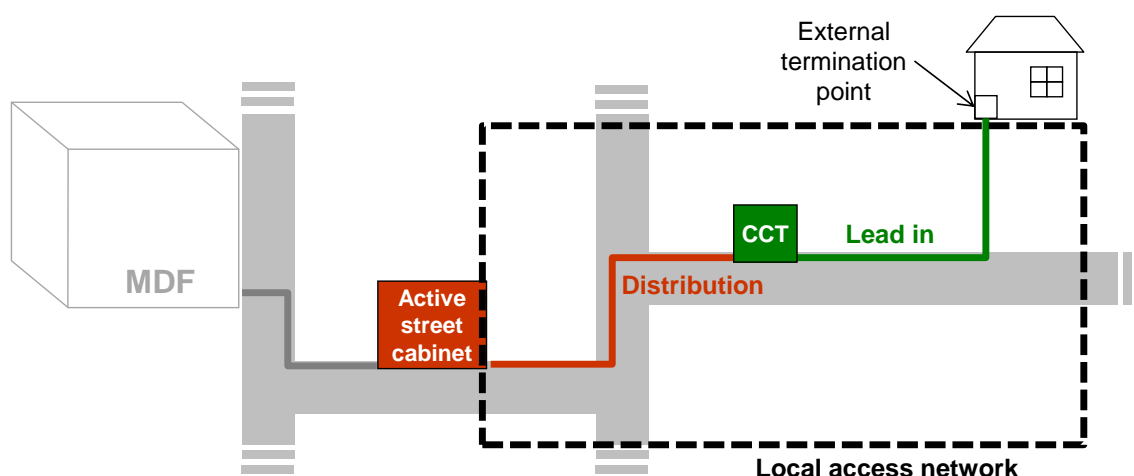
Source: TERA Consultants

As the CCT are located on the section of the buildings they serve, most of the "Lead-in" assets can be computed at the building level.

Furthermore, it should be noted that Chorus charges the end-user for all or part of the lead-in installation as part of the connection fee.

Therefore, the following rule is applied:

- For all buildings the following lead-in assets are taken into account in the modelling:
    - Cables;
    - Overhead infrastructures.
- Dedicated underground infrastructures (dedicated ducts, trenches from the NAP to the building) are not taken into account in the modelling (for all premises inside the TSO boundary, including those in post-2001 subdivisions).
- Laterals are taken into account except for subdvisions where laterals are assumed to be covered by capital contributions. Similarly, underground infrastructures along the road are dimensioned according to pre-2001 subdivisions demand.

The dimensioning of the local access network is then made in two steps:

- Dimensioning at the building level;
- Dimensioning at the section level.

4.3 Network dimensioning

4.3.1 Section configuration

The side of the section with the majority of buildings is called the "major side", and the opposite side the "minor side".

When the access network is underground, the section can be trenched on the major side or on both sides of the section, according to the number of buildings on the minor side and the distance between buildings on the minor side.

The section is trenched on both sides when it is cost effective, i.e. when:

- Trenching the cross road at each building exceeds the length of a trench along the minor side plus a crossroad trench.

Figure 22 – Section configuration

Source : TERA Consultants
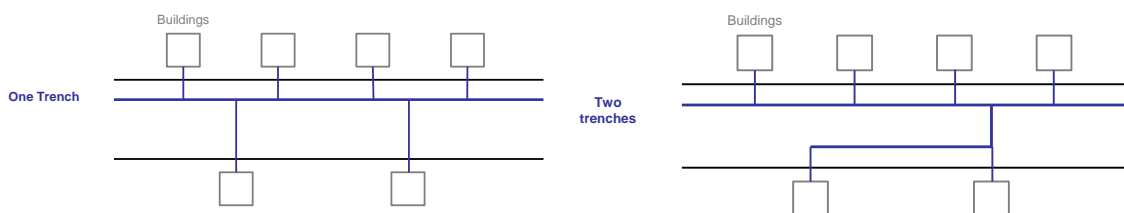
When the section is overhead, the cables and equipment are deployed only on the major side of the section.

4.3.2   Cables

4.3.2.1   Lead-in

TERA have used copper pairs' allocation rules. Following Chorus lead-in copper pairs' allocation rules, and based on the smallest copper cable available is a [   ]**CNZCI**, the lead-in copper cables are:

- [   ]**CNZCI** pairs aerial copper cables when the lead-in level is overhead;
- [   ]**CNZCI** pairs underground copper cables when the lead-in level is underground.

The lead-in copper cable is deployed from the CCT to the ETP on the building.

When underground, the lead-in cable follows the section to the building's network access point (that can be shared with other buildings) onto the road, then go to the building.

A mark-up is applied to the length of the cable from the network access point to the building to reflect the non-linearity of the path.

When overhead, the lead-in cable goes in a straight line from the CCT to the building. When the building is on the minor side, the cable goes from the CCT to the minor side pole, then from the minor side pole to the building.

Figure 23 – Length of the lead-in cable

(a) Overhead configuration   (b) Underground configuration
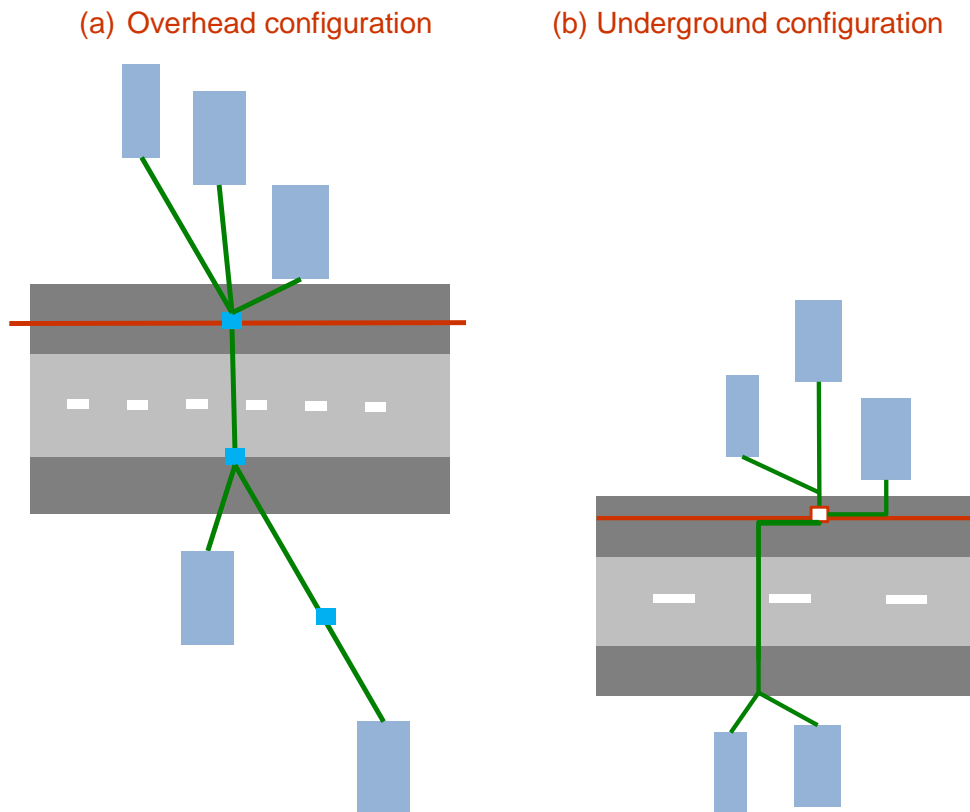
Source: TERA Consultants

The CCT are located on the road according to three engineering rules:

- Maximum number of buildings lead-in per CCT;
- Maximum length between the building and the CCT;
- No more than one CCT per building.

The CCT are located uniformly along the section, on the segment from the first to the last building.

When the section is trenched twice, i.e. on each side of the street/road (as described in §4.3.1), the CCT are located on each side of the section and dimensioned on each side of the section.

The lead-in cable in (b) above includes the lateral. The architecture of the laterals is detailed below:

Figure 24 – Underground lead in architecture
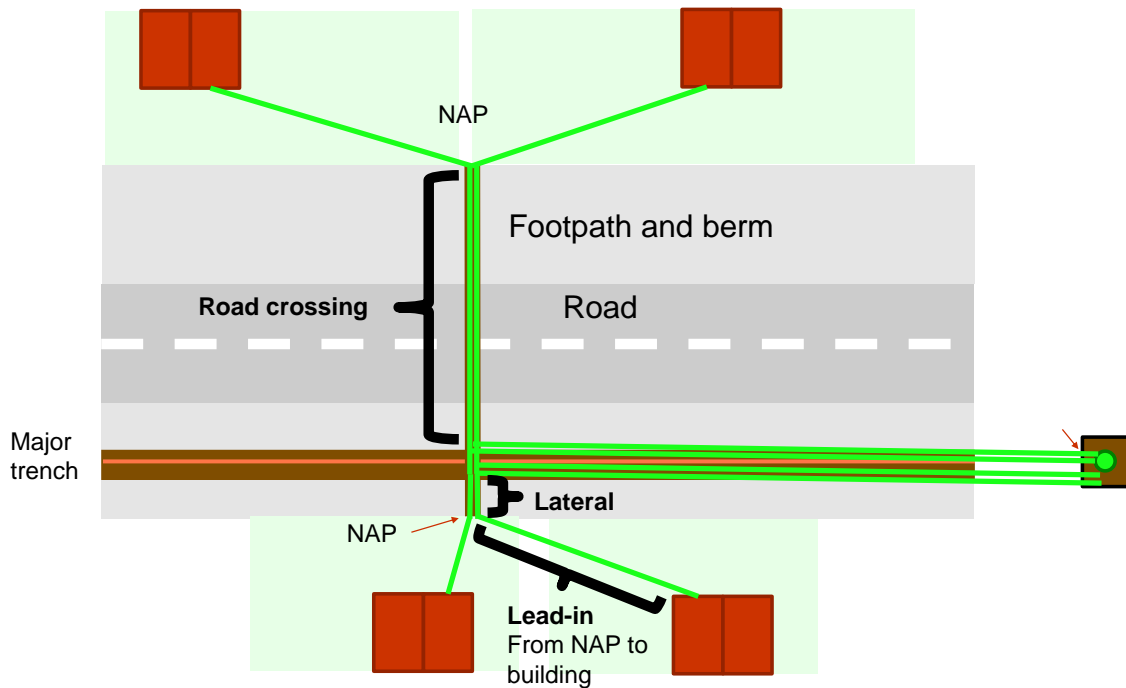
Source: TERA Consultants

4.3.2.2   Distribution

The distribution cable is a copper cable dimensioned to fit the local distribution demand, i.e. to distribute:

- The dwellings on the minor side;
- The dwellings on the major side;
- The dwellings on the rear area of the section.

The distribution cable dimensioning is made following copper pairs allocation rules.

The rules may differ for single dwelling units and multi dwelling units, as well as for urban and rural dwellings.

Spare capacity is added at the distribution level.

Following roll-outs best practices, when the distribution demand exceeds the largest cable available (2,000 pairs in underground, 50 pairs in overhead), multiple 2,000-pairs (respectively 50 pairs) cables are deployed to meet the demand.

The distribution cable is deployed all along the section when the section has a distribution rear area, or only until the last building of the section when the section has no distribution rear area.

When the section is trenched twice, a distribution cable is deployed on the minor side to fit the minor side distribution demand.

4.3.2.3 Feeder

The feeder cable is the copper cable linking the MDF to the passive street cabinet. For each section, the feeder cable is dimensioned to feed the street cabinets whose path to the MDF goes through the section.

The feeder cable dimensioning is made following copper pairs allocation rules.

No spare capacity is added at the feeder level.

When the feeder demand exceeds the largest cable available (2000 pairs in underground, 50 pairs in overhead), multiple 2000-pairs (respectively 50 pairs) cables are deployed to meet the demand.

The feeder cable is deployed all along the section.

4.3.3 Joints

4.3.3.1 Lead-in

There are no joints at the lead-in level.

4.3.3.2 Distribution

On the major side, joints are used according to the standard drum length of the copper cable used. When there is already equipment along the cable, joints are not necessary as the existing equipment can be also used as joints.

On the major side, joints can be replaced by the CCT, street cabinets and MDF.

On the minor side, joints can by replaced by the CCT.

If the section has a distribution rear area, then there is at least one joint at the intersection with the rear area section(s) (see below).

When there is a minor side trench, there is at least one joint at the intersection with major side (see below).

Figure 25 – Joints on the major and minor sides
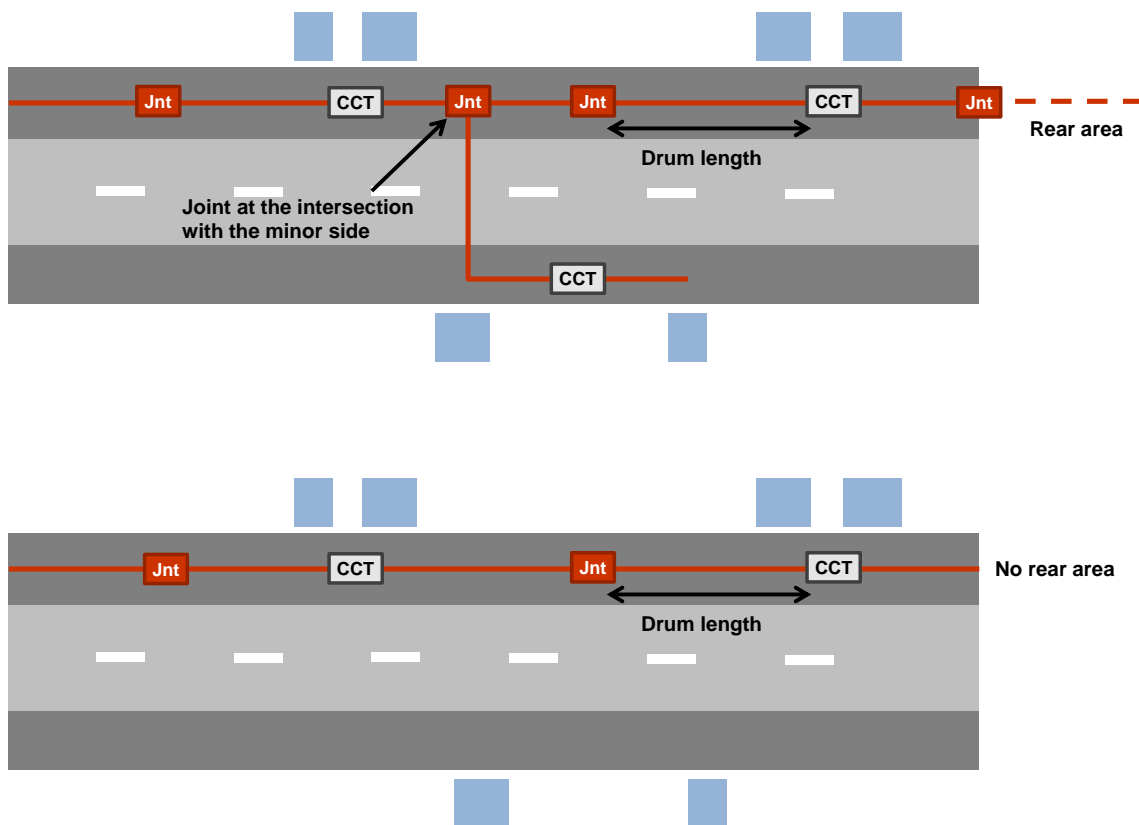
Source: TERA Consultants

4.3.3.3 Feeder

Joints are used according to the standard drum length of the copper cable used. Joints can be replaced by the existing equipment on the section, i.e. streets cabinets and MDF.

If the section has a feeder rear area, then there is at least one joint at the intersection with the rear area section(s).

4.3.4 Civil engineering

4.3.4.1 Aerial versus underground

The copper network is modelled twice: as an underground network, and as an overhead network.

The two resulting networks are then combined according to the underground/overhead mix in each exchange area: combined inventory is a weighted average of underground and overhead inventories:

- at the lead-in level, the weight for overhead network is 46%;
- at the distribution and feeder level, the weight for overhead network is 47%.

The underground network is fully underground.

The overhead network contains underground sections, when trenches are already dug for the core network. In such case, the lead-in level stays overhead and the distribution and feeder level are buried and follow the underground dimensioning rules (dimensioning of ducts, trenches, choice of cables).

4.3.4.2 Poles

In the overhead network, poles are located on the major and minor sides of the section. Poles height is determined by road clearance requirements.

4.3.4.2.1 On the major side

The number of poles on the major side is set according to the following rules:

- Maximum distance between poles ➔ m_1;
- Overhead equipment (CCT, joints), that must be deployed on poles ➔ m_2.

The number of poles set by m_2 for the distribution and feeder levels is estimated by the maximum equipment per cable for each level.

The number of poles on the major side is then:

$$\frac{(m_1 + m_2) + \max(m_1, m_2)}{2}$$

Indeed, $\max(m_1, m_2)$ is the required number of poles when CCTs and joints are evenly distributed along the section. A greater number of poles is chosen to reflect the heterogeneous distribution of dwellings along the sections.

Figure 26 – Location of poles
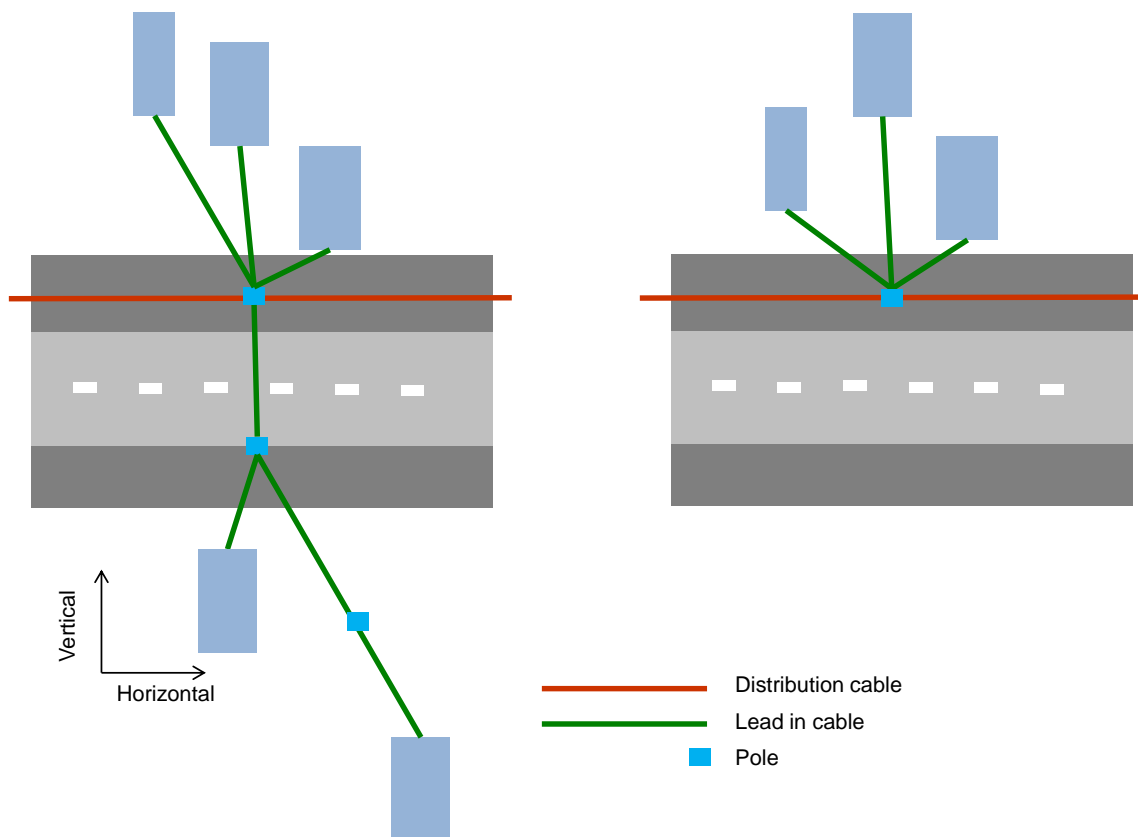
Source: TERA Consultants

Along the major side, the access network reuses the power utility poles by paying a rental cost to the power utility company and the capital cost for poles that need to be replaced.

4.3.4.2.2 On the minor side

When buildings are located on the minor side, poles that support CCTs are dimensioned for buildings on the minor side.

On the minor side, poles are installed for the access network (no sharing with utilities).

4.3.4.2.3 On the vertical part of the section

Poles are also deployed on the vertical part of the section, when the lead-in cable exceeds the maximum distance between poles.

On the vertical part of the section, poles are installed for the access network (no sharing with utilities).

4.3.4.3 Ducts

In the underground network, ducts run over the full length of cable of the section, from the lead-in cables to the core cables.

When the length of cables differ, e.g. when the distribution cable goes to the last building and the feeder cable goes to end of the section, the ducts run along the longer length of cable.

The cut surface of ducts provides an estimate of the size of the trench.

4.3.4.3.1 Lead-in

Each building has a dedicated 50 mm duct, which is deployed on the vertical part and on the horizontal part, from the building to the distribution point.

Ducts within the property boundary are not taken into account in the modelling as they are considered to be the responsibility of the property owner. However, ducts in the lateral part (i.e. outside the property boundary) are taken into account.

On the horizontal part, the duct is shared with distribution and feeder.

4.3.4.3.2 Distribution and feeder

Distribution and feeder share a 110 mm duct. When the cable surfaces exceed the duct useful surface, multiple ducts have to be used. The ducts are allocated following a capacity-based approach. As the number and size of cables is the driver of the duct dimensioning, ducts are allocated on the basis of cable surfaces.

4.3.4.3.3 Backhaul and core network

Each of the backhaul and core cables is protected within a sub-duct.

The core DSLAM-to-Exchange (backhaul), core Exchange-to-FDS and inter-FDS networks share one or more 110 mm ducts, on the basis of the surface of sub-ducts.

There are no FWA links modelled in the copper network.

4.3.4.4 Trenches

4.3.4.4.1 Vertical trenches

Each building has a vertical dedicated trench (see diagram above for the definition of a vertical trench), whose size is measured by the number of 50 mm ducts along the trench, i.e. the number of 50 mm ducts dedicated to the building.

This within-property lead-in trench is not taken into account in the modelling as they are considered to be the responsibility of the property owner. Note however, the trench in the lateral part (i.e. outside the property boundary) is taken into account, except for post-2001 subdivisions.

The trench from the network access point to the horizontal trench ("lateral") is however taken into account in the cost modelling.

4.3.4.4.2 Horizontal trenches

When the section is trenched twice (as described in §4.3.1), there are three portions of trench with different sizes:

- The minor side trench;
- The road cross trench;
- The major side trench.

Figure 27 – Horizontal trenches
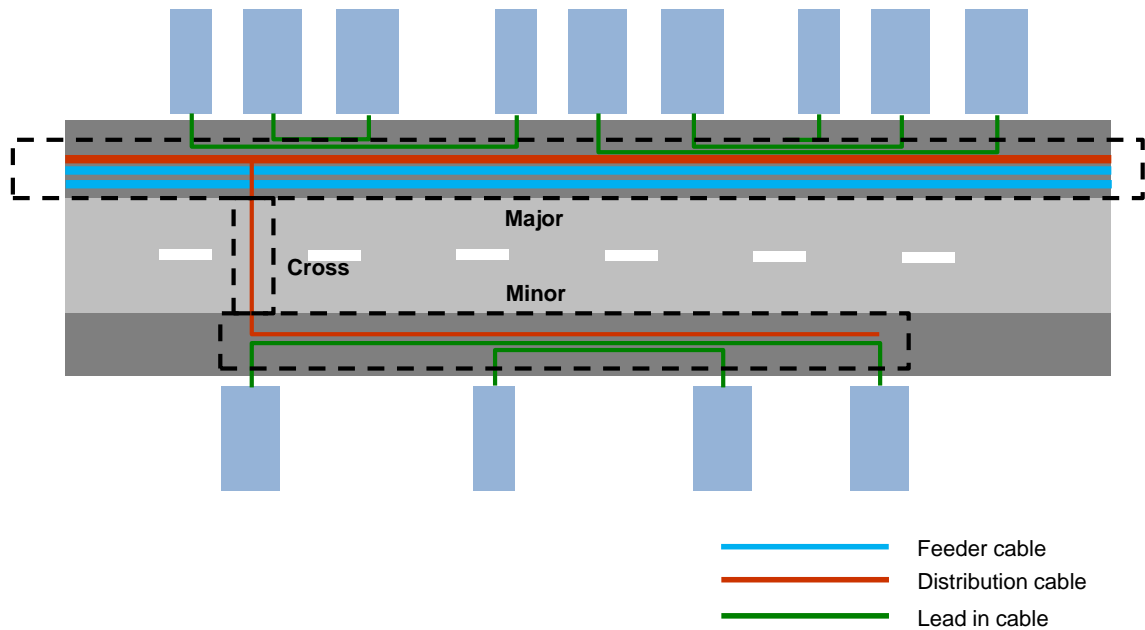
*In the illustrative figure above, road crossing is represented in a simplified manner.
Road crossing is from trench to trench, i.e. as long as width from boundary to boundary
minus twice laterals.*

Source: TERA Consultants

The minor side trench runs along the buildings of the minor side. The minor side trench
size is determined by the number of ducts shared by distribution and lead-in on the
minor side. The need for ducts for lead-in is computed through an average.

The crossroad trench runs across the width of the road. The crossroad trench size is
determined by the ducts needed for the distribution cables on the minor side.

The major side trench runs along the section or until the last building (as described in
§4.3.4.3). Its size is determined by:

- The number of ducts for the access network (lead-in, distribution and feeder);
- The number of ducts for core;

Trench costs are allocated following a capacity-based allocation approach. As the
capacity of a trench is driven by the number of ducts buried, the trenches are allocated
on the basis of the surface of ducts. For instance, the allocation key for distribution is
the composed ratio:

$$\frac{Surface_{cable}^{distr}}{Surface_{cable}^{lead\ in} + Surface_{cable}^{distr} + Surface_{cable}^{feeder}} * \frac{Surface_{ducts}^{access}}{Surface_{ducts}^{access} + Surface_{ducts}^{core}}$$

The need of ducts for lead-in is computed using the average number of dwellings per
building over the section.

The costing of trenches is based on their size and the terrain and soil types.

4.3.4.5 Chambers

A chamber is either a manhole, a handhole or a pithole. It is an underground box where joints are installed and can be easily accessed.

The number of chambers is determined on the basis of the following rules:

- The maximum distance between chambers, due to pulling in tension limits;
- The number of underground equipment that should be freely accessible (joints, CCT).

The chambers are allocated following the same allocation keys as the trenches.

4.3.4.6 Post-2001 subdivisions

In post-2001 subdivisions, identified as sections where at least 75% of buildings were built after 2001, trenches outside the property boundary (along the road and laterals) are not included, unless they serve pre 2001 buildings in their rear area.

Other assets (including cables, joints, aerial infrastructures, distribution points) are dimensioned according to the full network, i.e. pre and post 2001.

The same rule applies in the fibre network.

4.3.4.7 Critical trenches

The trenches serving more than [   ]**CNZCI** customers are deemed critical and are duplicated on both sides of the street.

4.4 Civil engineering sharing

4.4.1 Civil engineering sharing with the core network

Underground infrastructures are shared with the core network. The access network cost model provides as an output the allocated assets for each network level, including for the core network (see above).

4.4.2 Civil engineering sharing with the access part of leased lines

As explained in §3.11, the underground infrastructure is shared with the leased lines network, resulting in cost reduction. This cost reduction is implemented through a macro-parameter applying to underground infrastructure investment.

4.4.3 Civil engineering sharing with utilities

Underground and overhead infrastructures might be shared or rented to, or from utility networks, leading to cost reduction, according to data sourced by the Commission. Ducts are not shared.

Such infrastructure sharing is performed through four parameters when assessing the local access network investment:

Table 6 – Parameters setting the percentage of shared underground infrastructure (trenches and chambers but not ducts)

Asset	Amount shared	Benefits of sharing	Net benefits
Underground infrastructure	5%	50%	2.5%

Source: TERA Consultants

Table 7 – Parameters setting the percentage of shared aerial infrastructure (trenches and chambers but not ducts)

Asset	Amount shared	Capital cost paid by the HEO
Shared poles (on the major side)	100%	10%
Shared poles (on the minor side and on lead in)	100%	100%

Source: TERA Consultants

On the major side, the HEO reuses power utility poles and incurs 10% of the capital costs related to the power poles (transformed into a rental charge), plus an additional management fee.

On the minor side and on lead-in, poles are dedicated to the HEO's network.

5% of trenches are shared with other network or utilities, leading to a 2.5% cost reduction.

5 Equipping the fibre access network

The fibre access network dimensioning follows similar rules, if not identical rules, to the copper access network dimensioning.

Thus, many references are made to §4.

5.1 Demand for the fibre access network

5.1.1 Current demand

In line with criterion 19 and 21 in the Model Reference Paper, the demand for the access network is Chorus' actual copper demand plus the LFC demand and the Chorus UFB demand. The modelled network is fully loaded since it includes the maximum number of customers a HEO could get today and is assumed to receive revenues from all these customers. In terms of buildings served, fibre demand is the same as copper demand.

The network is dimensioned according to all dwellings. Indeed, in line with other TSLRIC models developed in other jurisdictions and in line with the approach followed by network designers, fixed wired access networks are dimensioned for the number of dwellings and not for the actual demand. The reason for that is that dimensioning a network for the number of dwellings is much more efficient in the long run since it prevents having to redeploy cables, re-dig trenches or redeploy poles when actual demand increases and therefore enables significant cost savings. This is why any fixed wired access network dimensioning would consider the number of dwellings of a given area since all these dwellings represent a potential demand in the long run.

5.1.2 Forecast demand

In line with criterion 22 in the Model Reference Paper, the demand is assumed to be constant.

5.2 Fibre network

In line with criterion 8 in the Model Reference Paper, the access fibre network is a point-to-point fibre network (see Figure 28) and includes 2 levels of nodes:

- ODF; and
- FAT.

FATs are always located on the section of the led in building.

Figure 28 – Architecture of the local access fibre network
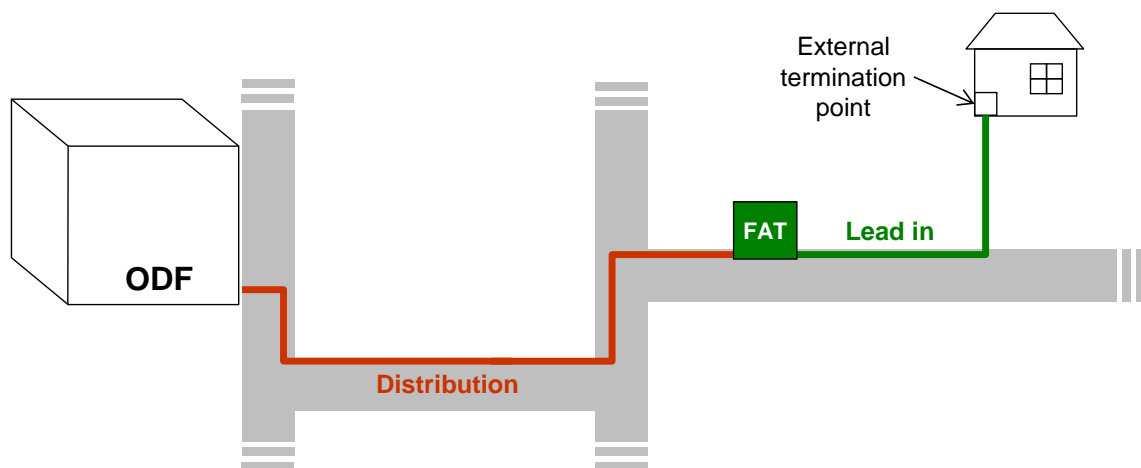
Source: TERA Consultants

Hence two levels of networks:

- Distribution: from the Exchange to the FAT
- Lead-in: from the FAT to the ETP, through the network access point, at the foot of the building.

The distribution and lead-in cables are fibre cables.

The MDF coverage areas are an input of the Microsoft Access component of the access network cost model, and the paths between MDF and sections are determined based on the shortest path algorithm.

As the FAT are located on the section of the buildings they lead-in, most of the lead-in assets can be computed at the building level.

When a section is covered by FWA, the section is then not served by the fibre access network.

The dimensioning of the local access network is then made in two steps:

- Dimensioning at the building level;
- Dimensioning at the section level.

5.3 Network dimensioning

5.3.1   Section configuration

The section configuration follows the same rule in the fibre and copper networks (see §4.3.1).

5.3.2   Cables

5.3.2.1 Lead-in

Following lead-in fibre allocation rules and the fibre catalogue, the lead-in fibre cables are:

- [ ]**CNZCI** fibres aerial cables when the lead-in level is overhead;
- [ ]**CNZCI** fibres underground cables when the lead-in level is underground.

The lead-in fibre cable is deployed from the FAT to the ETP in the same way the lead-in copper cable is deployed from the CCT to the ETP, i.e.:

- Along the road trench from the FAT to projection of the network access point;
- On the lateral trench to network access point;
- From the network access point to the ETP.

The dimensioning and location of FAT follows similar rules to CCT, possibly with different parameters in some instances.

5.3.2.2   Distribution

As in the copper network, the distribution cable is a fibre cable dimensioned to fit the local distribution demand: dwellings on the minor and major sides and on the rear area of the section.

The distribution cable dimensioning is made following fibre allocation rules, which are identical for all dwellings, single dwelling units and multi dwelling units, urban and rural dwellings: one fibre per dwelling at the distribution level, in accordance with observed best practices (Chorus has not provided any engineering rule for this).

When the distribution demand exceeds the largest cable available (624F for underground and overhead), multiple 624F cables are deployed to fit the demand.

As in the copper network, the distribution cable is deployed all along the section when the section has a distribution rear area, or only until the last building of the section when the section has no distribution rear area.

When the section is trenched twice, a distribution cable is deployed on the minor side to fit the minor side distribution demand.

5.3.3   Joints

5.3.3.1   Lead-in

As in the copper network, there are no joints at the lead-in level.

5.3.3.2   Distribution

The dimensioning of joints follows the same rules in the copper and fibre networks (see §4.3.3.2), replacing CCT by FAT and using fibre cable drums, which are significantly longer than copper cable drums.

5.3.4   Civil engineering

5.3.4.1   Aerial versus underground

As for the copper network, the fibre network is modelled twice; as an underground network, and as an overhead network. Underground/overhead combination and

overhead design rules when core network shares the section are identical in the copper and the fibre networks (cf. 4.3.4.1).

5.3.4.2   Poles

Pole dimensioning and allocation follow the same rules as for the copper network (see §4.3.4.2).

5.3.4.3   Ducts

Duct length and dimensioning follow the same rules in the copper and in the fibre networks (see §4.3.4.3), differing slightly on:

- Duct dimensioning and allocations are always based on cable surface for distribution and lead in cables
- FWA backhaul and core cables are protected within sub-ducts;
    - As those fibre cables are protected in sub-ducts, the access network cost model also dimensions the length of sub-ducts for each network level;
- There is no feeder level in the fibre network, hence one set of ducts is dedicated to distribution instead of being shared among distribution and feeder.

5.3.4.4   Sub-ducts

According to fibre cable diameter, two types of sub-ducts can be used:

- 10/14mm diameter (inner/outer)
- 20/25mm diameter.

When cable diameter exceeds 8.5 mm, a 25 mm diameter sub-duct is used instead of a 14 mm diameter sub-duct.

Sub-ducts are used solely for FWA sites' backhaul, backhaul and core cables, but not for access fibre cables. This is because they are more critical than access cables. They aggregate more customers than a single fibre cable in general.

5.3.4.5   Trenches

Trench configuration, dimensioning and allocation follow the same rules in the copper and in the fibre networks (see §4.3.4.4), with the slight difference that there is neither feeder level nor core DSLAM-to-Exchange in the fibre network, hence no share of trench is allocated to these levels.

5.3.4.6   Chambers

Chamber dimensioning and allocation follow the same rules in the copper and in the fibre networks (cf. 4.3.4.5).

5.4 Civil engineering sharing

Sharing with other infrastructures and asset re-use follow the same rules in the copper and fibre networks (see §4.4).

6 Equipping the fixed wireless access network

6.1 Demand for the fixed wireless access network

6.1.1 Current demand

The actual FWA coverage is based on the FWA RBI coverage. FWA is used only in areas unlikely to be unbundled and as explained in section 3.12.2.4 premises along the fibre backhaul of the FWA sites are not connected to FWA and non-TSO and post-2001 premises are excluded from FWA coverage.

The throughput demand is based on distance to active nodes (non-RBI active cabinets or MDF) criteria (cf. section 3.12.2.3) and ADSL 2+ quality of service. Throughput is stable over the regulatory period.

6.1.2 Forecast demand

In line with criterion 22 in the Model Reference Paper, it is assumed the demand is constant.

6.2 Fixed wireless access network

The fixed wireless access network consists of FWA base stations covering dwellings within their coverage areas, and fibre cables linking the FWA base stations to their nearest ODF.

FWA base stations consist each of three sectors. As with any mobile base station, FWA base stations have a limited capacity.

The FWA network dimensioning is performed according to RBI base stations (cf. section 3.12):

The dimensioning of the FWA network cables and infrastructures is performed jointly with the local access network dimensioning.

6.3 Network dimensioning

6.3.1 Base stations

There is one LTE base station with 3 sectors at each FWA site, with the FWA site shared among three operators.

Only passive assets are shared among operators.

6.3.2 Cables

FWA sites are fed through 12F fibre cables from the nearest ODF, following the shortest path algorithm (see section 7.4.1.1).

6.3.3   Joints

On sections crossed by a FWA cable, joints are used following the same rules as for the distribution fibre cables (see section 5.3.3.2).

Joints are located whenever the cable length on the section exceeds the drum length of the cable.

There is at least one joint per cable on sections crossed by a FWA cable.

6.3.4   Civil engineering

FWA cables are buried and protected within sub-ducts. The dimensioning of the civil engineering assets allocated to the FWA network is detailed in §4.3.4 and §5.3.4.

6.4 Civil engineering sharing

Sharing with other infrastructures follow the same rules in the copper and fibre networks (see §4.4).

6.5 FWA scenarios tested

In addition to modelling FWA constrained by RBI coverage and throughput, we have also tested three alternative FWA scenarios:

- No FWA, i.e. FTTH only;
- Full FWA coverage in exchange areas that are unlikely to be unbundled;
- FWA based on RBI sites and capacity and extrapolated out to exchange areas that are unlikely to be unbundled based on the proportion of coverage within RBI areas.

The less expensive scenario among the four scenarios tested (base case plus alternative scenarios) is considered as the base case scenario.

6.5.1   Full FTTH

In the full FTTH scenario, there are no FWA sites, nor backhaul to such sites.

All areas are covered by fibre.

6.5.2   Full FWA in exchange areas that are unlikely to be unbundled

In this scenario, areas to be unbundled are fully covered by FWA, except for lines along the backhaul.

The costs of sites (including ODF and backhaul) are based on the base case scenario and extrapolated through the throughput ratio:

- Total throughput to be provided to cover the full areas unlikely to be unbundled, divided by
- Total throughput provided in the base case scenario.

Indeed, the capacity is the key driver of FWA costs, rather than the geographical constraints (this assumption has been verified by comparing the capacity of RBI FWA sites and the calculated throughput supported by each RBI site and by comparing densities and line lengths of areas not covered by RBI FWA to make sure they have similar features).

6.5.3 Partial extrapolation scenario

In the third scenario, it is assumed that in non-RBI areas unlikely to be unbundle (i.e. areas unlikely to be unbundle with less than 50% RBI theoretical coverage), the same share of lines as in areas unlikely to be unbundled and covered by RBI FWA (lines in the base case) is to be covered by FWA.

For each area unlikely to be unbundled and not covered by RBI FWA, a given share of lines is to be covered by FWA: the lines furthest from the exchange are served first, at the exception of lines along the backhaul.

At total, the FWA coverage comprises of:

- The coverage of the base case, plus
- The most remote lines in the areas unlikely to be unbundled and not covered by RBI FWA.

In the same way as for the second scenario, the costs of FWA are extrapolated from the base case scenario, using the same throughput ratio.

7   Equipping the core network

This section describes the core network cost modelling approach.

7.1 Structure of the network

Due to history, Chorus' network is made of several networks. An ATM network is partly used to provide some DSL services, and other data or voice services. However, in line with criterion 34 of the Model Reference Paper, the MEA for the UBA service is based on a NGN Ethernet network. Therefore the other networks are disregarded and are not modelled. The modelled NGN Ethernet network assigns the ATM DSL customers to the NGN Ethernet network.

The modelled core network used to provide DSL is made of more than 6,000 nodes (more than 700 exchanges and 5,496 active cabinets) at which DSLAMs are installed. These sites do not reconcile entirely with the access network, however a best match has been used to reconcile Chorus' data. These DSLAMs are aggregated by FDS. These FDS are located on around 90 sites, collocated with exchanges. These FDS are also referred as EAS in Chorus' Network. The modelled NGN Ethernet network is therefore based on these 6,286 sites.

Chorus' NGN Ethernet network consists of [   ]**CNZCI** Regional Ethernet Network (REN) covering the country linking the switches together. These REN carry the Ethernet traffic, except the traffic of the new fibre services (UFB).

Each REN is made of several open rings aggregating all switches sites.

<p align="center">Figure 29 – Example of a REN</p>

<p align="center">[   ]CNZCI</p>

<p align="right">Source: Chorus</p>

These rings are however not used for the UBA service, and are therefore not modelled in the core network. However the fibre rings are modelled as part of the passive network (modelled in the access network cost model) in order to take into account economies of scope because the fibre cables of these rings use the same trenches as other parts of the network relevant for UCLL and UBA.

The UBA service stops at the FDS, and is therefore a local service. It can however be extended by subscribing to either a service called Tail Extension Service (TES) or regulated UBA backhaul service. This TES service is not modelled in the Core model as it is an unregulated service.

Figure 30 – Description of the UBA in the STD for Chorus UBA
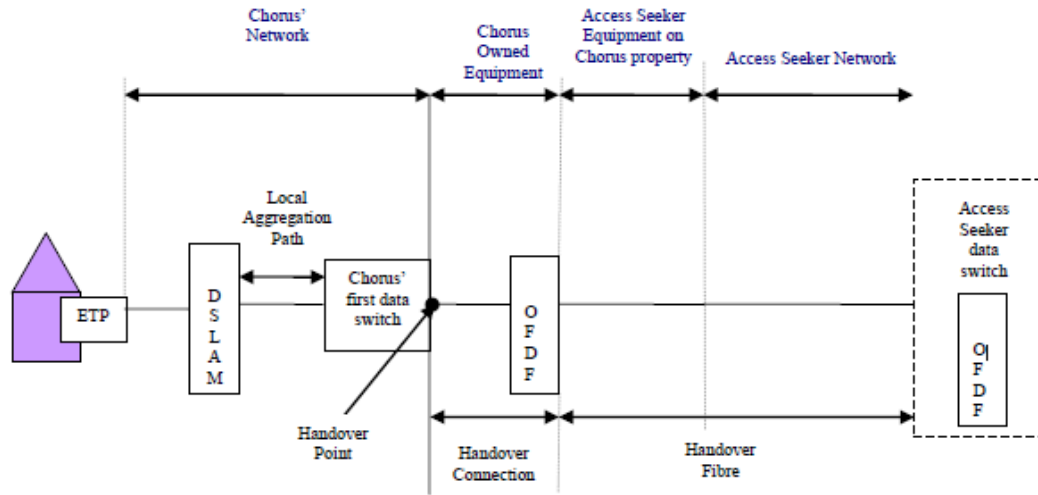
*Source: STD FOR CHORUS' UNBUNDLED BITSTREAM ACCESS SERVICE
SCHEDULE 1 UBA SERVICE DESCRIPTION*

Figure 31 – Scope of the core modelling
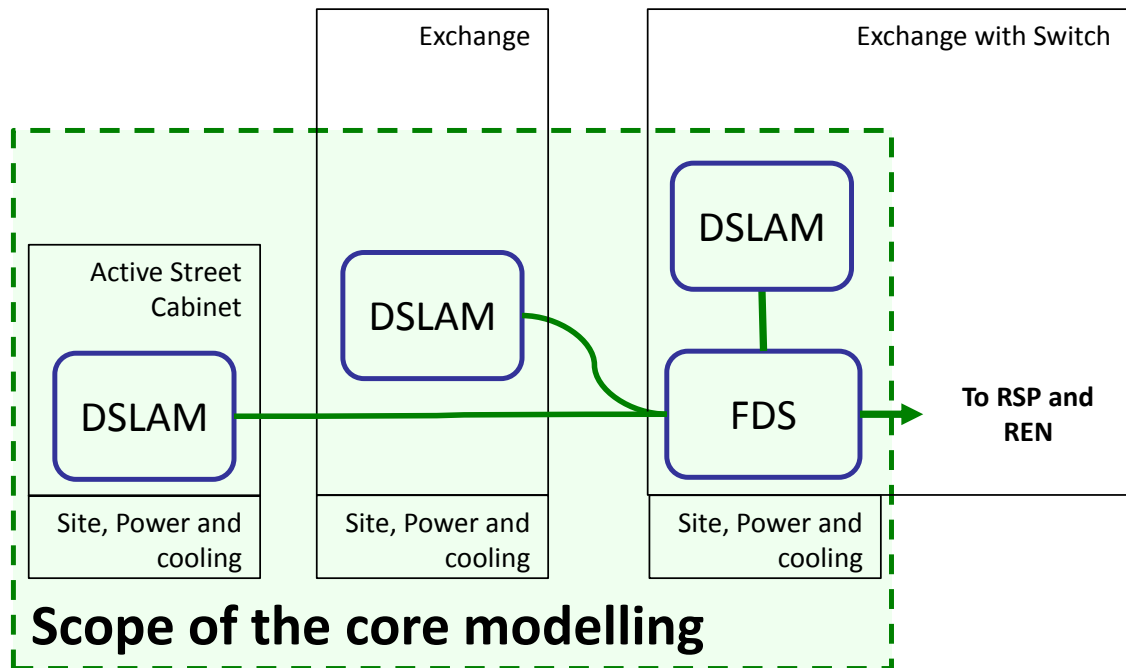
Source: TERA Consultants

7.2 Number of subscribers

The number of connections for UBA is lower than the number of connections for UCLL because some customers are voice only customers. Also, UCLL demand includes LFC

while UBA does not include this. The HEO UBA network is fully loaded because it includes the full UBA demand faced by Chorus.

The number of subscribers has been provided by Chorus for 2014 for all UBA services. In line with the Model Reference Paper, the demand consists of solely the actual UBA demand. The HEO UBA network is fully loaded because it includes the full UBA demand faced by Chorus, in line with criteria 41 and 42 of the Model Reference Paper. The number of connections for UBA is lower than the number of connections for UCLL because some customers are voice only customers. Also, UCLL demand includes LFC while UBA does not include this. The HEO UBA network is fully loaded because it includes the full UBA demand faced by Chorus.

At the DSLAM level, the number of subscribers modelled includes the three following categories of customers using regulated and commercial offers:

- UBA customers (BUBA and EUBA, about 1.1 million connections in 2013);
- VDSL customers (about 80,000 customers); and
- SHDSL customers (about 20,000 customers).

The copper network accounts for about 1.8 million connections in 2013. It offers several services, including all UBA, VDSL and SHDSL customers, plus some additional customer services or unbundled lines. These additional services account for approximatively 600,000 lines.

It has to be noted that the figures provided come from different sources in Chorus, and may have been measured at different times. The total number of copper connections observed by Chorus may therefore slightly differ (about 3%) from the total provided in the model.

Customers such as PSTN customers and other services using legacy equipment or an independent network (e.g. fibres used to feed mobile stations) are not considered in the modelling. However as they may use the same fibre cables (but different fibres), cables used to provide the UBA service are considered to be shared with these services. Therefore only a share of the total costs of these cables is allocated to the UBA service (see §8.7.2.2).

7.3 Engineering rules of active assets

Several different network active pieces of equipment are modelled:

- DSLAM at Cabinet;
- DSLAM at Exchange; and
- First Data Switch.

Their engineering rules have been provided by Chorus. These reflect standard rules used by constructors that are publicly available. These engineering rules are described successively below.

7.3.1 DSLAMs

The DSLAMs are made of three different assets:

- The line card, where the customer copper line is terminated;
- The subrack holding the line cards and processing the traffic; and
- The rack holding the subracks.

The DSLAMs at the cabinet and at the exchange are made of the same types of assets. However their capacity is different.

7.3.1.1 DSLAMs at cabinet

The dimensioning rules are presented in the figure below:

Figure 32 – DSLAMs dimensioning
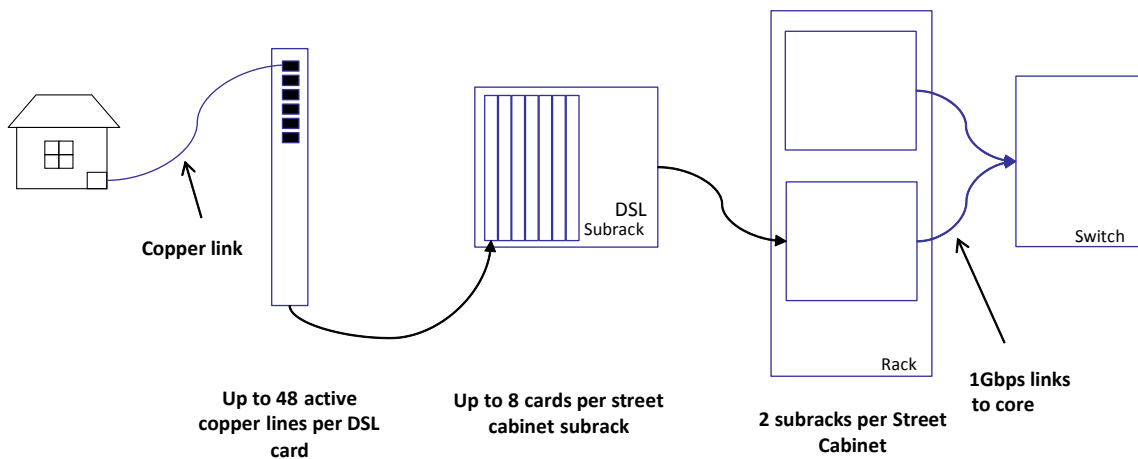
Source: TERA Consultants

The dimensioning rules for cards are the following:

- 48 copper lines per DSL card (1 port per active line); and
- 24 copper lines per SHDSL card (1 port per active line).

The dimensioning rules for subracks are the following:

- Up to 8 cards per street cabinet subrack.
- A subrack is linked to the FDS by one 1Gbps fibre link (or 2 links if the traffic requires it).

A rack can hold up to two subracks.

Given the dimensioning rules, a subrack can serve up to 384 (=48*8) DSL customers. The 1Gbps fibre link between the subrack and the FDS grants more than 2.6 Mbps of throughput at busy hour per customer.

7.3.1.2 DSLAMs at Exchange

The dimensioning rules are presented in the figure below:

Figure 33 – DSLAMs dimensioning
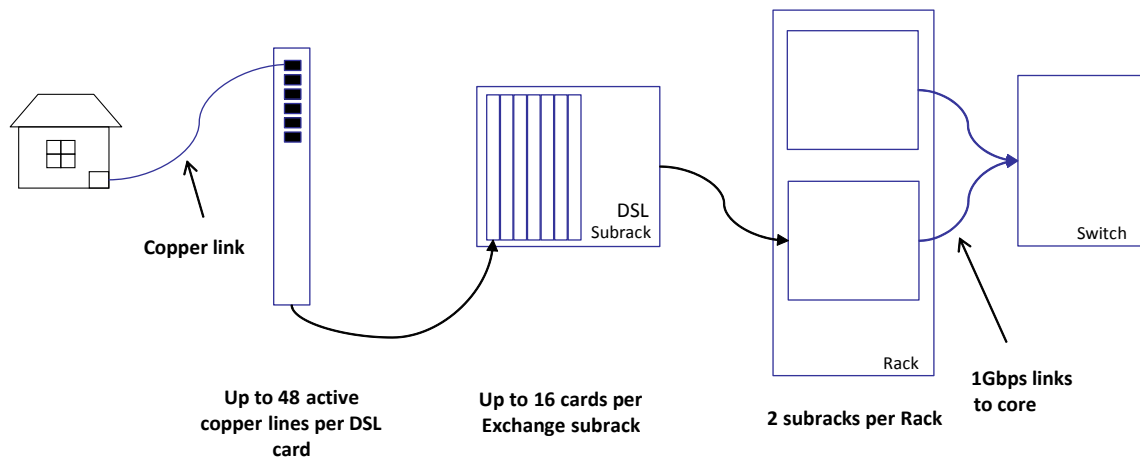
Source: TERA Consultants

The dimensioning rules for cards are the following:

- 48 copper lines per DSL card (1 port per active line); and
- 24 copper lines per SHDSL card (1 port per active line).

The dimensioning rules for subracks are the following:

- Up to 16 cards per exchange subrack.
- A subrack is linked to the FDS by a 1Gbps fibre link (or 2 links if the traffic requires it).

A rack can hold up to two subracks.

7.3.2   FDS

The FDS is made of five assets:

- The Small Form factor Pluggable (SFP) transceiver;
- A MDA line card;
- An IOM card (holds MDA cards);
- A subrack; and
- A rack.

The dimensioning rules of these 5 assets are presented in the figure below:

Figure 34 – FDS dimensioning
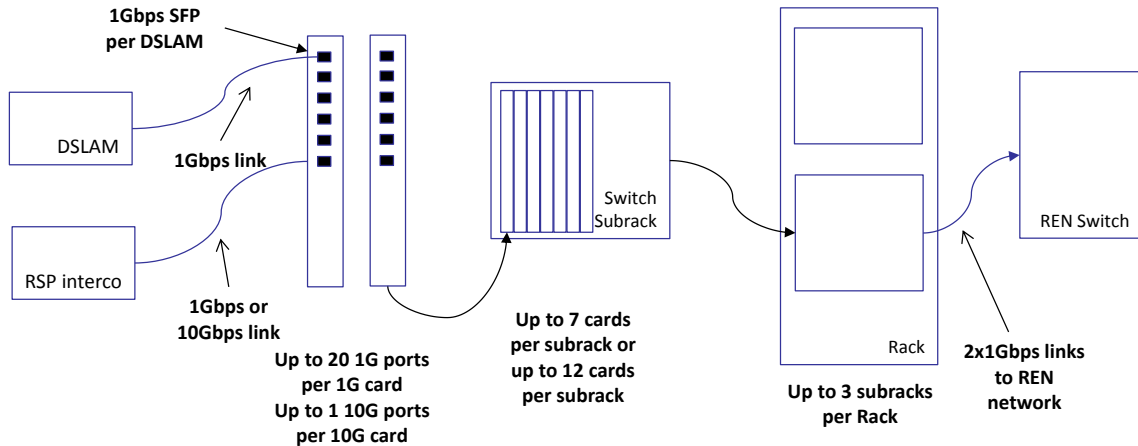
Source: TERA Consultants

One SFP is required per active port to connect the fibre (1 SFP per DSLAM subrack connected to the switch and 1 SFP per fibre link between the switch and another switch).

The dimensioning rules for cards are the following:

- 20x1Gbps ports per 1G-MDA card;
- 1x10Gbps ports per 10G-MDA card; and
- 1 IOM for 2 MDA cards.

The dimensioning rules for subracks are the following:

- Up to 10 MDA-cards per subrack 7 (capacity of 5 IOM); or
- Up to 20 MDA-cards per subrack 12 (capacity of 10 IOM).

A rack can hold up to three subracks.

The choice between the subrack 7 and the subrack 12 is based on the following rules:

- The number of subrack 12 is calculated by the formula: $Floor(\frac{number\ of\ MDA-cards}{20})$, where 20 is the capacity of the subrack 12; and
- The remaining MDA-cards are installed in either a subrack 7 if there are less than 10 remaining cards or in a subrack 12 if there are between 11 and 20 cards.

7.4 Civil engineering

7.4.1 Trenches, ducts and cables

7.4.1.1 Cables

The DSLAM-to-Exchange and FWA links use shared 12F underground fibre cables. The DSLAM-to-Exchange links follow the shortest path algorithm.

When multiple DSLAM-to-Exchange (or multiple FWA links) share a route, one or more 12F cable is used.

Note that there is no FWA in the copper network, and conversely no SLU backhaul in the fibre network.

The other core network levels (Exchange-to-FDS and inter-EAS) use separate 24F underground fibre cables, one cable per core route. For instance, if multiple core links from one switch to other switches use the same section, there are as many 24 F cables as links.

This size of cable is standard in other countries for this type of usage and therefore has been based on international best practices in the absence of information provided by Chorus.

Figure 35 – DSLAM-FDS fibre cables
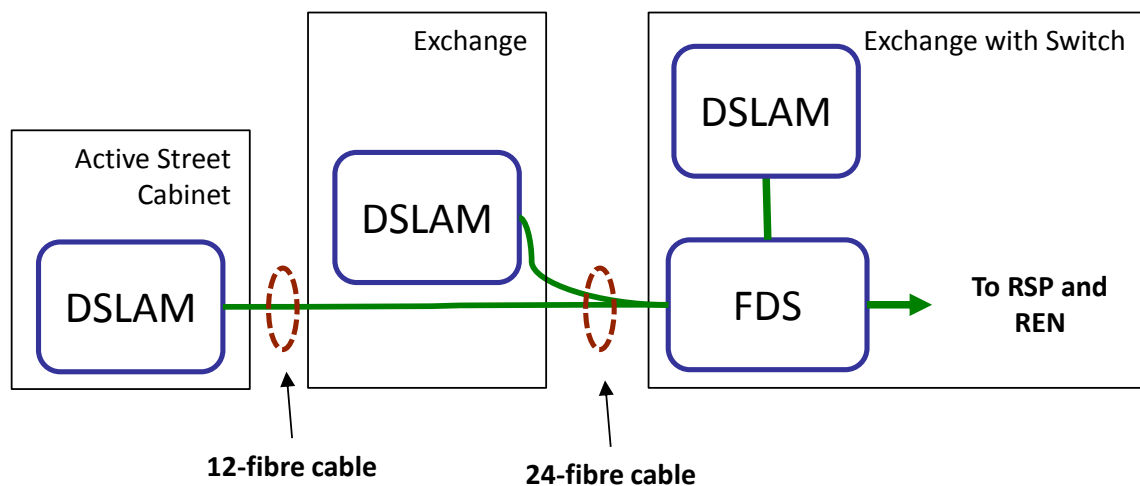
Source : TERA Consultants

7.4.1.2   Trenches, ducts and manholes

The dimensioning and allocation of trenches, ducts and manholes follow the same rules as in the copper and fibre access networks (§4.3.4 and 5.3.4).

As mentioned in §4.3.4.3.3, FWA, backhaul and core cables are protected within sub-ducts.

7.4.2   Other links

As described in the Model Reference Paper, the core network can use alternative types of fibre links:

- Submarine links;
- DWDM links.

The core network uses a submarine links to link islands. In such case, there is a submarine cable. Whenever stated by Chorus, a landing station is installed.

When the core network uses a DWDM link on a section, there is a fibre along the section. At both ends of each DWDM link, a DWDM platform is installed.

7.5 Fibre UBA scenarios tested

The model also enables to calculate fibre UBA costs. In this case, there is no active equipment at cabinets. Two scenarios are considered:

- One scenario where fibre cables of the access network are connected to FTTH P2P ports in the OLT.
- One scenario where fibre cables of the access network are first aggregated through a splitter and then connected to a PON port in the OLT. This scenario enables to save ports in the OLT which can be expensive.

In these scenarios, the following assets are needed:

- Switch,
- Subrack,
- Port cards,
- SFP,
- Splitters in the 2nd scenario.

The rest of the core network is supposed to be identical.

The figure below enables to compare the fibre UBA configurations and the copper UBA configurations:

Figure 36 – Components at the exchange and at the cabinet for copper UBA and fibre UBA
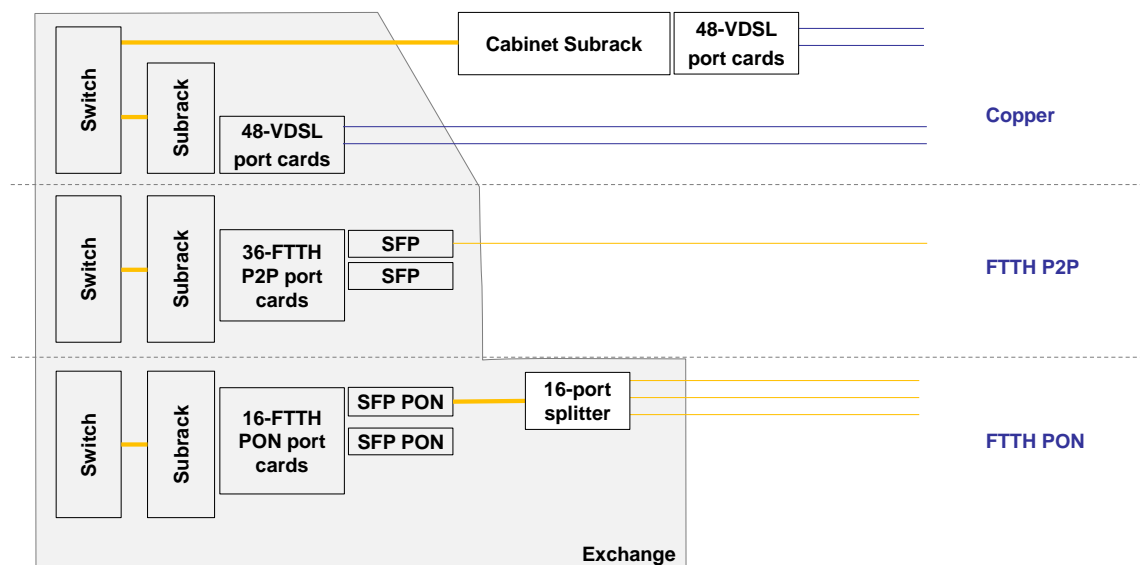
Source : TERA Consultants

8   Network and services costing

8.1 Unit costs input

8.1.1   Unit costs

The starting point to set the unit costs is to use the data provided by Chorus during the data collection.

The unit costs of each asset are made of:

- Material;
- Labour;
- Design, project management;
- Service company overheads.

Service company overheads have been applied according to Chorus' asset classification: i.e. for some assets, the service company overhead is applied and for other it is (depending on whether the asset is consigned or not). This was reviewed for each type of asset. Project management and design costs have been extracted from Chorus accounts. The cost categories showing cost of Chorus staff responsible for project management and design have been calculated in the OPEX model. For those assets where Chorus does not conduct design activities (such as trenches), design costs have been added separately. As part of the information gathering process we asked Chorus about the scope of costs to ensure that they were not over or under counted.

The unit costs of some assets such as the active assets of the core network are quite uniform across the world as there is an international market for these assets.

The unit costs of the material of some passive assets such as the cost of ducts or the cost of cables are also quite uniform as these assets are standard (however the installation costs of these latter assets may vary a lot from one country to another). Such passive assets include, but are not limited to:

- Cables;
- Joints;
- Distribution points;
- Street cabinets;
- MDF/ODF; and
- FWA base stations, submarine landing stations.

The unit costs of these assets have therefore been benchmarked in order to assess whether the unit costs provided by Chorus are in line with what has been observed in other jurisdictions or not. When the unit costs seem unrealistic, the benchmarked unit costs have been used.

Where relevant, unit costs stemming from the model developed by Chorus are used.

Unit costs from Vodafone are used for the FWA network.

For assets for which Chorus did not provide unit costs, such as MDF/ODF, costs are inferred from benchmarks with other countries.

The unit cost of other assets such as trenches can vary from one country to another as it depends on local parameters such as the local wages.

8.1.2 Copper cable unit costs

Copper cable unit costs are based on the model developed by Chorus.

8.1.3 Trenching and ducting unit costs

One of the main cost categories of a fixed network is the cost of trenching which is difficult to benchmark as it depends on the following:

- local labour costs;
- type of soils and the trenching technology;
- trenching rules.

Specific attention has therefore been given to the trenching costs.

The model uses the NZRI 66 soil classification which includes 5,147 different types of soil. For each of these types of soil, the cost efficient trenching technology has been identified among the following ones:

- Chain digger;
- Mole ploughing;
- Hydro trenching;
- Open trench 400 mm wide;
- Open trench 600 mm wide;
- Directional drilling;
- Rock saw 600 mm deep; and
- Thrust boring.

Selection of trenching technique is based on the lowest cost technique when the soil type is known, and is based on a weighted average of available techniques when the soil type is unknown, i.e. when the road is labelled "town" without information on the underlying soil type. Some trenching methods, such as chain digging or mole ploughing, are not applied in urban areas.

Weights are estimated by Beca and reflect the actual distribution of techniques used in the network.

The scope of the trenching cost includes the following tasks:

- Excavation;
- Duct installation and accessory material supply (e.g. glue) ;
- Backfill;
- Surface reinstatement for laterals;
- Consenting;
- Traffic management; and

- Design costs
  ([   ]**CNZCI**).

For each of these tasks, the efficient unit cost has been assessed by independent consultants, Beca (except for design costs which have been assessed and added separately).

MDF-specific costs are inferred from the model developed by Beca as weighted averages of soil-specific cost efficient trenching technologies and intra-MDF soil type distribution. The soil type blend within each MDF is performed with the geomarketing data, limited to TSO areas and corresponding to FTTH footprint.

The labour component of ducts' unit cost (ducting, i.e. inserting ducts into trenches) is also deduced from the model developed by Beca.

8.1.4 Chambers

A chamber is either a manhole, a handhole or a pithole.

The unit cost of a chamber is the weighted average of manhole, handhole and pithole unit costs, according to the following weights:

- Manholes are dug when two or more joints are buried.
- Handholes are dug when one joint is buried.
- Pitholes are dug when no joint is buried (pithole digging is then driven by length limit).

8.2 Spectrum costs for FWA

The spectrum costs should be included in the valuation of the FWA costs. Spectrum costs have been assessed at the reserve value of the latest auction for the 700 MHz band.

As such costs derive from a national coverage, spectrum costs used in the model are discounted by the share of FTTH lines (inside and outside the TSO):

$$Spectrum_{FWA\ areas} = Spectrum_{National} * \frac{FWA\ customers}{FWA\ and\ FTTH\ customers}$$

FWA and FTTH customers being all address points.

8.3 Price trends

Due to the separation between Spark (Telecom) and Chorus, setting price trends based on historical Chorus procurement data has not been possible.

As a consequence, several approaches have been envisaged to derive price trends for the different assets and opex categories:

1. **Cost escalation**: Identifying the relevant index or set of indices the asset category cost is supposed to evolve with (corresponding figures have been provided by NZIER). These are chosen among:

   - The consumer price index (CPI): Applied to miscellaneous material parts.
   - The labour cost index (LCI): Applied to installation parts of assets and labour related opex.
   - The fabricated steel index: Applied to the material part of ODF/MDF costs.
   - The copper index: applied to the copper part of copper cable material cost.
   - The fibre optic cabling index: applied to the material part of optical fibre cables.

2. **The 'default' approach**: When no better data is available, it is proposed to use international benchmark for active equipment, the CPI for passive equipment and the LCI for labour related opex.

3. **International benchmark**: Average price trends assumptions within publicly available TSLRIC models (Australia, Denmark, Sweden, France, Norway).

4. **NZIER estimates**: The experts have provided estimates for trenches price trends in the NZ context.

It should be noted that all indices inputs used in these calculations have been corrected for purchasing power parities differences.

Then, the "preferred approach" among the four available has been selected with the following rules:

- The Escalation approach (#1) is chosen for passive equipment (except ducts and trenches) if a relevant index or set of indexes can be found. If not, the CPI is used (#2).
- NZIER estimates (#4) are used for ducts and trenches as these price trends are closely related to the NZ context.
- Active equipment price trends are derived from international benchmarks (#3) as the market for active equipment is international.
- Labour related opex evolves with the LCI (#1).
- Non-labour related opex evolution is very hard to forecast so those costs are assumed to remain stable.

Note that passive FWA assets have a different price trend applied than active FWA assets (as in the table below).

The selected price trends assumptions are listed in the table below:

Figure 37 – Selected price trends for the different assets / opex categories

	Escalation	'default' approach	International benchmark	NZIER estimates	Preferred approach	Selected price trend
	1	2	3	4		
Copper cables	2,6%	2,0%	X	X	**1**	**2,6%**
Copper joints	2,0%	2,0%	X	X	**1**	**2,0%**
Copper Distribution points	2,0%	2,0%	X	X	**1**	**2,0%**
Fibre Distribution points	2,0%	2,0%	X	X	**1**	**2,0%**
Fibre cables	-0,3%	2,0%	X	X	**1**	**-0,3%**
Fibre joints	2,0%	2,0%	X	X	**1**	**2,0%**
Ducts	2,0%	2,0%	X	3,3%	**4**	**3,3%**
Trenches	2,0%	2,0%	X	3,3%	**4**	**3,3%**
Poles	2,0%	2,0%	X	X	**1**	**2,0%**
Chambers/Manholes/Jointholes	2,0%	2,0%	X	X	**1**	**2,0%**
MDF/ODF	2,8%	2,0%	X	X	**1**	**2,8%**
FWA base stations – Active	2,0%	-5,0%	-5,0%	X	**3**	**-5,0%**
FWA base stations – Passive	2,0%	2,0%	X	X	**2**	**2,0%**
Submarine links (cables/landing stations)	2,0%	2,0%	X	X	**2**	**2,0%**
Microwave links	2,0%	2,0%	X	X	**2**	**2,0%**
DWDM links (active part)	2,0%	-5,0%	-5,0%	X	**3**	**-5,0%**
DSLAM (card/subrack/rack)	2,0%	-5,0%	-5,0%	X	**3**	**-5,0%**
Switches/routers (card/subrack/rack/SFP)	2,0%	-6,2%	-6,2%	X	**3**	**-6,2%**
Building/Land	1,9%	2,0%	X	X	**1**	**1,9%**
Power equipment	2,0%	2,0%	2,0%	X	**3**	**2,0%**
Air-conditioning equipment	2,0%	0,0%	0,0%	X	**3**	**0,0%**
Site equipment (e.g. security equipment)	2,0%	2,0%	X	X	**2**	**2,0%**
Opex – labour related	2,0%	2,0%	X	X	**1**	**2,00%**
Opex – Non-labour related	0,0%	0,0%	X	X	**1**	**0,0%**
Spectrum	0.0%				**1**	**0.0%**

Source: TERA Consultants

8.4 Asset lives

TERA have used the following list of asset lives.

[   ]**CNZCI**. When the asset lives provided seem out of line with what has been observed in other jurisdictions or were not provided, benchmarks have been used to adjust asset lives. The asset lives benchmarked come from decisions (publicly available or not) made by other national regulatory authorities mainly located in Europe. TERA has also considered confidential information from jurisdictions where the decisions are confidential and confirmed that these are not significantly out of line with the asset lives we have selected.

8.4.1   Asset lives for the TERA Access Network

Table 7 – Assets life for the TERA Access Network

Asset category	Asset life	Source
Copper cables, joints and distribution points underground	20	[ ]**CNZCI**
Copper cables, joints and distribution points overhead	14	[ ] **CNZCI**
Fibre cables, joints and distribution points	20	[ ] **CNZCI**
Underground infrastructure	50	[ ] **CNZCI**
Overhead infrastructure	20	[ ] **CNZCI**
Street cabinets	14	[ ] **CNZCI**
—MDF/ODF	20	[ ] **CNZCI**
FWA base stations and MW sites	14	[ ] **CNZCI**
Submarine links	20	[ ] **CNZCI**
DWDM sites	10	[ ] **CNZCI**
FWA spectrum	17	[ ] **CNZCI**

Source: TERA Consultants

8.4.2 Asset lives for the TERA Core Network

Table 8 – Assets life for the TERA core network

Asset category	Asset life	Source
DSLAM	7	[ ] **CNZCI**
FDS	5	[ ] **CNZCI**
Power	15	[ ] **CNZCI**
Cooling	15	[ ] **CNZCI**
Site	18	[ ] **CNZCI**

Source: TERA Consultants

8.5 Cost of capital

For the costs that are valued bottom-up, the cost of capital is embedded in the annuity calculated. The nominal pre-tax WACC is used to feed the depreciation factor (see §8.6).

For the costs that are assessed top-down based on Chorus' accounts, the cost of capital is assessed by multiplying the net book value by the nominal pre-tax WACC. The depreciation cost as provided by the accounts is not including the cost of capital. It therefore has to be included. The nominal pre-tax WACC is derived from the nominal post-tax WACC using the following formula:

$$WACC_{Pre-Tax} = \frac{WACC_{Post-Tax}}{(1 - Legal\ Corporate\ Tax\ rate)}$$

where the legal corporate tax rate is 28%.

8.6 Annuity calculations

The annuity calculation is based on the tilted annuity formula. In line with criterion 60 of the Model Reference Paper, a tax adjusted annuity is used.

8.6.1 Time to build

In line with criterion 61 of the Model Reference Paper, the time to build has been set to 6 months.

8.6.2 Tax depreciation rates

The first step of this approach is to define for each asset class a tax depreciation rate that reflects the tax shield.

Table 9 – Tax depreciation rate

Asset class	Tax depreciation rate
Copper cables	13%
Copper joints	13%
Copper Distribution points	13%
Fibre Distribution points	13%
Fibre cables	13%
Fibre joints	13%
Ducts	4%
Trenches	4%
Poles	10%
Chambers/Manholes/Joint-holes/Pits	4%
MDF/ODF	16%
Switches/routers	20%
FWA base stations	8%
FWA spectrum	20%
Submarine links (cables/landing stations)	8%
Microwave links	12%
DWDM links	13%
DSLAM (card/subrack/rack)	16%
Switches/routers (card/subrack/rack/SFP)	16%
Building/Land[9]	3%
Power equipment	8%
Air-conditioning equipment	16%
Site equipment (e.g. security equipment)	20%

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[9] Tax depreciation rate refer to the tax shields specific to each asset.

It is important to note that land is not being depreciated, i.e. has an infinite asset life. Cost of capital is however incurred for lands.

Source: The Commission based on IRD's general depreciation rates

These values are in line with the values described in the Commission's Attachment G of the final determination for UBA and Attachment G for UCLL.

8.6.3 Adjustment to pre-tax annuity

The prices that are derived in the model are pre-tax prices. It is therefore required to adjust the post-tax annuity in order to take into account the level of tax paid. This adjustment is based on the tax depreciation rate defined in the previous section using the following formula:

$$Adjustment\ to\ Pre\ Tax\ annuity = \frac{1 - \dfrac{Corporate\ Tax\ Rate * Tax\ Depreciation\ Rate}{Tax\ Depreciation\ Rate + WACC_{Post-Tax\ nominal}}}{1 - Corporate\ Tax\ Rate}$$

8.6.4 Post-tax real WACC

The third step is to derive a post-tax real WACC based on the post-tax nominal WACC. This is achieved by using the following formula:

$$Post\ Tax\ real\ WACC = \frac{1 + WACC_{Post-Tax\ nominal}}{1 + Price\ Trend} - 1$$

8.6.5 Annuity

The final step is to determine the annuity. It is obtained by computing the annuity of the total investment using:

- The interest rate as defined by the post-tax real WACC;
- The asset life; and
- The annuity is corrected by the adjustment to pre-tax annuity.

The Excel formula used is therefore the following one:

$$Annuity = Investment\ in\ current\ year * Depreciation\ factor$$

Where the depreciation factor is:

$$Depreciation\ factor$$
$$= Adjustment\ to\ pretax\ annuity * PMT(Post\ tax\ real\ WACC, asset\ life)$$

And the investment in current year is the investment in the first year, with price trends applied onto it.

8.7 Cost allocation

In line with criterion 55 in the Model Reference Paper, the capacity-based allocation approach is used for the infrastructure and equipment costs allocation in UCLL and UBA.

8.7.1   Capacity-based allocation for UCLL

The different infrastructure assets involved in the local access network may be shared with other network levels (FWA, core network, and SLU backhaul). The cost of each asset has to be allocated between the different network levels.

For each asset, the allocation key is computed at the dimensioning step, following the capacity-based approach, consistent with the dimensioning driver.

- The costs of trenches and manholes are allocated on the basis of the ducts in the trench (see §4.3.4.4.2).
- The costs of ducts are allocated on the basis of the cables surfaces, when copper, and on the basis of the cable or sub-duct surface, when fibre (see §4.3.4.3.)
- The costs of poles are allocated on the basis of the equipment carried by the poles, i.e. the number of joints (see §4.3.4.2.). E.g. if a pole is carrying three joints, 2 used by feeder and one by the distribution, then 2/3 of the cost of the pole is allocated to the feeder and 1/3 to the distribution.

8.7.2   Capacity-based allocation for UBA

8.7.2.1   Active assets

The different active assets involved in the UBA service provision may be shared with other services, such as Chorus' SHDSL-based high speed network service. The cost of each asset therefore has to be allocated between the different services.

The allocation key should be consistent with the dimensioning driver (capacity-based allocation approach). Thus, for each asset, a dedicated allocation key has to be computed. As all active assets of the core network are dimensioned based on the number of customers, the allocation keys will be the relevant number of customers. E.g. for a DSLAM located in a cabinet, the costs of the rack and the subracks will be allocated based on customers connected to the cabinet, a xDSL card will be fully allocated to the xDSL service and a SHDSL card will be fully allocated to the SHDSL service.

The FDS are also used for the REN interconnection for RSP who are interested in buying a TES. This means that a small part of the FDS costs have to be allocated to interconnection links. Therefore FDS costs are allocated partly to interconnection links, based on the number of ports used:

- To connect the FDS to the REN (allocated to other services);
- To connect the RSP (allocated to other services); and
- To connect the DSLAMs (allocated to UBA).

It should be noted that, in other jurisdictions, the key generally used to allocate the cost of the active assets is the traffic. However, the definition of the core UBA network in other jurisdictions is much broader as it includes not only the exchange to FDS link but also inter-FDS link, national backbone, etc. And because in these other parts of the core network, traffic is the driver, traffic is often used as a driver for the whole core

network. However in New Zealand, the scope of the core network used to provide UBA is limited to the part between the exchange and the FDS. And this part of the core network is not dimensioned based on the traffic as the true dimensioning factor is the number of customers. Therefore the allocation key that has to be used in New Zealand is different from what is generally used in other jurisdictions.

8.7.2.2 Passive assets

The access network cost model provides the cost of the fibre links between the cabinets and the exchanges, and between the exchanges and the FDS. These links are not dedicated to the provision of UBA, but are shared with other services such as leased lines, legacy services, UFB or dark fibre services. The cost of these links has therefore to be allocated to each service. The cost of the link between the exchanges and their parent FDS have been allocated based on the share of revenue of the corresponding segment. The share of revenue allocated to bitstream services has been evaluated at a level of 36% of the total revenues.

The cost of the link between the cabinets and their parent exchange is 100% allocated to the SLU backhaul service.

The costs allocated to bitstream services (regulated and unregulated) are then split based on the number of customers[10].

8.8 Indirect capex costs

Some costs are modelled neither in the access network cost model nor in the core network cost model and have to be taken into account.

There are named "Indirect Capex" and have to be allocated to the different services in the core network cost model.

In line with the criterion 55 in the Model Reference Paper and the methodology traditionally used by NRAs, the EPMU approach has been implemented.

Two types of indirect capex are included:

- IT costs indirect capex; and
- Miscellaneous indirect capex.

The IT costs include hardware and software costs related to network, billing platforms, network management platforms, Information system platforms, etc.

The Miscellaneous indirect capex include costs related to office equipment, furniture, tools and plants, and motor vehicles.

These costs are derived in the Opex model.

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[10] These parameters are available in the model 'Parameters' spreadsheet, section 'Share of civil engineering allocated to UBA'.

8.9 Services costing

8.9.1 Costing of the UBA

UBA (UCLL + UBA additional costs) is a service based on the copper local loop. The UBA additional costs should therefore be computed with the copper roll-out scenario. The UBA cost is obtained with the following formula:

$$UBA = UCLL_{Copper\ based} + UBA\ additional\ costs$$

Where the UBA additional costs includes:

- The cost of the link between the different exchanges and their parent exchanges where their FDS is located;
- The cost of the DSLAM; and
- The cost of the FDS.

8.9.2 Costing of the UCLL and the SLU

8.9.2.1 Lowest cost roll-out scenario

The costing of the UCLL is based on the cheapest roll-out scenario among the fibre access network costing (including FWA) and on the copper access network costing:

The choice of the cheapest configuration can be either performed at:

- The MDF level;
- National level.

In line with the criterion 10 of the Model Reference Paper, the choice of the cheapest configuration is performed at the national level.

8.9.2.2 Double recovery between UCLL and UBA

The scope of the copper network is different from the scope of the fibre network. The fibre network is using the same exchange nodes and the same exchange coverage areas as the copper network. However the copper network uses active street cabinets. The demarcation point between the access network and the core network is therefore not the same between the copper network and the fibre network.

Figure 38 – Demarcation point of the copper and of the fibre networks
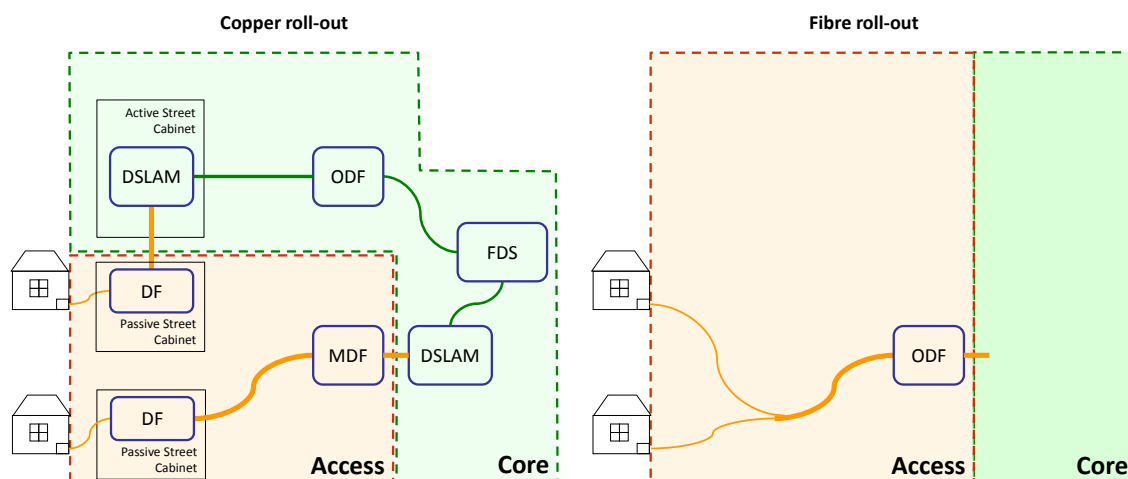
The core network starts at the active street cabinets for the lines that are aggregated on active street cabinets and at the exchange for the lines aggregated at the exchange whereas the core network always starts at the exchange for the fibre network. It is therefore important to ensure that no cost is recovered twice and that all costs are recovered.

8.9.2.2.1 Copper is the lowest cost configuration

If copper is the cheapest configuration in a MDF, then there is no double recovery between UBA and UCLL as the UBA is always based on a copper local loop.

8.9.2.2.2 Fibre is the lowest cost configuration

As the fibre network modelled uses the exact same exchanges as the copper network modelled, there is no double recovery possible for the part between the exchange and the FDS.

The fibre network aggregates all customers at the exchange whereas to aggregate all customers at the exchange for the copper network, a combination of the local loop plus the SLUBH is needed.

If fibre is the lowest cost configuration in a MDF, then there is an overlap between the costs recovered by the UBA and the costs recovered by the UCLL:

- The fibre loop allows recovering the cost of aggregating all customers at the exchange, i.e. the SLUBH is included in the scope of the fibre loop.

If fibre is the cheapest configuration, then an adjustment is required to prevent the SLUBH being recovered twice. The cost of the SLUBH should therefore be excluded from the cost of the fibre loop.

8.9.2.3 Selecting the cheapest configuration

UCLL is the cost of the access network either based on a copper loop or on a combination between a fibre loop and the FWA technology. In line with the criterion 10, the cheapest configuration should be selected. In order to compare networks with the

same scope and therefore to have comparable configurations the cost of the copper local loop is compared with the cost of the fibre local loop (+FWA) minus the cost of the SLUBH.

If the cost of the copper configuration is the cheapest, then the UCLL is based on the copper configuration.

If the cost of the fibre configuration minus the cost of the SLUBH is the cheapest, then the UCLL is based on the fibre (+FWA) configuration minus the cost of the SLUBH.

8.9.2.4 Costing the UCLL and the SLU

Having selected the cheapest configuration, the sum over all MDF provides the total cost of the loop (the cost of ULL), i.e. the total cost of the sub-loop for the lines aggregated at an active cabinet plus the total cost of the loop for the lines aggregated directly at an exchange (going through or not a passive cabinet).

The cost of the SLUBH is an output of the model as it is a direct result of the capacity-based allocation.

The following notation is used:

#ULL = Number of active lines

#SLU = Number of active lines connected to an active cabinet

#SLUBH = Number of active customers using the SLUBH

It is assumed that #SLU= #SLUBH, i.e. that there is no unbundling at the cabinet.

C_{ULL} = cost of the ULL

C_{SLUBH} = cost of the SLUBH

P_{UCLL} = unit price of the UCLL

P_{SLUBH} = unit price of the SLUBH

P_{SLU} = unit price of the SLU

The cost of connecting all customers to an exchange is given by $C_{ULL}+ C_{SLUBH}$

The average cost per line is therefore $\frac{C_{ULL}+C_{SLUBH}}{\#ULL}$

The cost per line should be the same whether the line is cabinetised or not:

$P_{UCLL} = P_{SLUBH} + P_{SLU} = \frac{C_{ULL}+C_{SLUBH}}{\#ULL}$

Therefore the unit price of the three access services are given by the following formulas:

$P_{UCLL} = \frac{C_{ULL}+C_{SLUBH}}{\#ULL}$

$P_{SLUBH} = \frac{C_{SLUBH}}{\#SLUBH}$

$P_{SLU} = \frac{C_{ULL}+C_{SLUBH}}{\#ULL} - \frac{C_{SLUBH}}{\#SLUBH}$

9 Verifications

9.1 Introduction

In line with the approaches we have followed for other regulatory authorities for similar projects and in line with best practices, TERA Consultants has performed different types of tests and verifications which are described in this section (but also in the following section with sensitivity analyses).These tests ensure that models use the correct data, perform the correct calculations and are consistent with the Commission's decisions.

Telecommunications network bottom-up cost models are logical tools which aim at reflecting the engineering rules used in the dimensioning and deployment of fixed and mobile networks so as to produce reliable information on the costs associated with the provision of a given service. They build also upon sometimes fairly complex accounting rules (cost allocation, depreciation). Throughout its track-record of cost modelling, TERA Consultants have defined and systematically followed quality assurance arrangements in order to minimise the risk of errors/mistakes as well as in order to increase acceptance of the cost model results by stakeholders (operators, regulators). TERA Consultants has applied several types of quality assurance arrangements during the project:

- Sensitivity analysis. If the outputs of the model vary in a non-intuitive way when one of input is modified, then it is possible to identify errors/mistakes. TERA Consultants has therefore conducted a large number of sensitivity analyses over the project. The results of some of these sensitivity analyses are provided in section 10.5.
- Comparison with existing network. It is useful to compare the number of assets of the operators with the number of assets determined by its models both at the national and the local levels in order to assess whether the results remain realistic. A bottom-up cost model will never reflect the top-down information or the existing network inventory because the latter two are based on networks which have been deployed over a long time. However, this can be useful to identify reasons for large differences.
- Audits. Several people (managers, directors, Commerce Commission staffs) have conducted audits of the model. This is described in section 9.5. Two more specific audit works have been conducted:
  - o Audit of the aggregation formula used (see section 9.2)
  - o Audit of the Microsoft Access part by comparing manual calculations for samples and model calculations (se section 9.3).
- Benchmark with publicly available information on similar cost modelling exercises for consistency checks purposes. Especially, this has been conducted for unit prices. This is described in section 9.6.
- Model validation in interaction with relevant operators. While the level of transparency of national regulatory authorities varies from a country to another,

the models have been made fully available to the relevant operators and their consultants. The high level of transparency of the models has allowed operators to review and comment the model. This has enabled mistakes to be identified or improvements to be made to the models.

- Formulas checked
    - o Access network
    - o Aggregation formula and cost recovery

9.2 Cost recovery

The formula used to calculate the unit price of the SLU, the SLUBH and the UCLL derived in §8.9.2.4 allows recovering the cost of the network.

The revenues generated are the unit price of each service multiplied by their demand:

$$Revenues = \#UCLL * P_{UCLL} + \#SLUBH * P_{SLUBH} + \#SLU * P_{SLU}$$

The unit price of the different access services are the following ones:

$P_{UCLL} = \frac{C_{ULL} + C_{SLUBH}}{\#ULL}$

$P_{SLUBH} = \frac{C_{SLUBH}}{\#SLUBH}$

$P_{SLU} = \frac{C_{ULL} + C_{SLUBH}}{\#ULL} - \frac{C_{SLUBH}}{\#SLUBH}$

The unit prices in the revenues formula can be replaced:

$$Revenues = \#UCLL * \frac{C_{ULL} + C_{SLUBH}}{\#ULL} + \#SLUBH * \frac{C_{SLUBH}}{\#SLUBH} + \#SLU * (\frac{C_{ULL} + C_{SLUBH}}{\#ULL} - \frac{C_{SLUBH}}{\#SLUBH})$$

Given that:

#SLU= #SLUBH

#ULL = #UCLL + #ULL

The revenues formula can be simplified:

$$Revenues = C_{ULL} + C_{SLUBH} = Cost\ of\ the\ network$$

The cost of the network is therefore recovered with the unit prices defined with the formulas set in §8.9.2.4.

9.3 Access network calculation verifications

The results of the Microsoft Access component of the access network cost model are checked on representative sections using an Excel replica of the access network dimensioning model. This allows easing the cross-checks and offers more transparency to the industry.

Thirteen representative sections – and their buildings – have been chosen to perform the cross-check analysis onto the Dimensioning at the section level and Dimensioning at the building level algorithms:

1. A section with no network;
2. A section with only FWA or core network, underground;
3. A section with only FWA or core network, overhead;
4. A section with distribution only, underground, with one trench;
5. A section with distribution only, underground, with two trenches;
6. A section with distribution only, overhead;
7. A section with distribution and feeder, underground;
8. A section with distribution and feeder, overhead;
9. A section with distribution and core, underground;
10. A section with distribution and core, overhead;
11. A section with distribution, feeder and core, underground, with one trench;
12. A section with distribution, feeder and core, underground, with two trenches; and
13. A section with distribution, feeder and core, overhead.

These 13 case studies represent all the possible situations.

All the input parameters of the Microsoft Access component of the access network cost model are compiled in the Excel cross-check file.

Figure 39 - Screenshot of the Access network cross-check: input parameters[

]CNZCI

Source: TERA Consultants

For each section, the section and its buildings inputs are retrieved from the Microsoft Access component of the access network cost model, i.e. the section-specific and building-specific data, as well as the local demand.

Figure 40 - Screenshot of the Access network cross-check: inputs

Source: TERA Consultants

Then, for each section and each building of the section, the outputs of the "Dimensioning at the section level" and of "Dimensioning at the building level" are

computed within the Microsoft Excel file, using, if necessary interim, computations. The
dimensioning is made following the exact same rules as described in this document
and in the model documentation.

Figure 41 - Screenshot of the Access network cross-check: computations
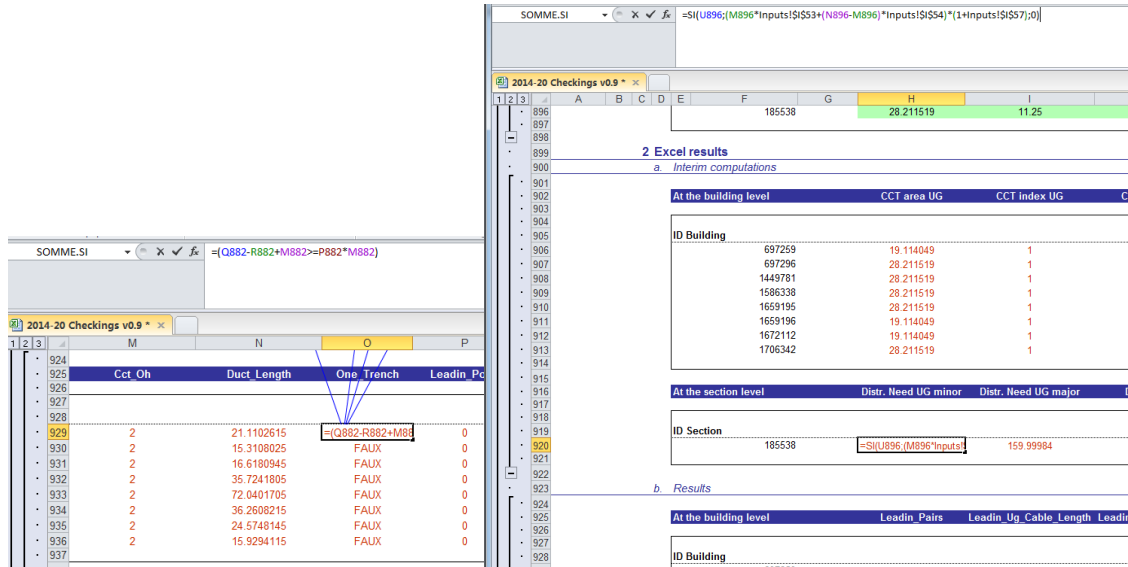
Source: TERA Consultants

Ultimately, the results of the Microsoft Access component of the network access cost
model are retrieved into the Excel file and compared to the results of the Excel
computations.

**Figure 42 - Screenshot of the Access network cross-check: comparison between Access
and Excel**
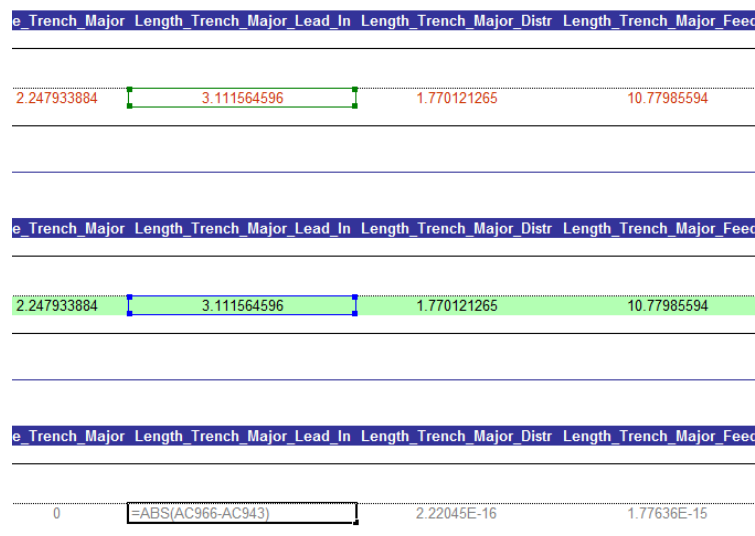
Source: TERA Consultants

If the difference between the Microsoft Excel and the Microsoft Access computation is
lower than a given margin of error ($\varepsilon = 10^{-12}$), then the test is conclusive.

Otherwise, the Microsoft Access component of the access network cost model is adjusted to meet the desired result.

9.4 Comparison with Chorus' inventory

9.4.1 Access network

The outputs of the copper model have been compared to the inventory of the model developed by Analysys Mason for Chorus which itself is based on Chorus' network inventory.

The Chorus model is compared to the model developed by TERA for a national footprint, i.e. including non-TSO areas and post-2001 subdivisions, and excluding lead ins.

Inventories from both models are in line. Specific differences are further explained in the audit document "Analysis of Chorus bottom up model" published in February 2015.

For most of assets, inventories are in the same order of magnitude.

The following changes have been made to the Commission inventory:

- The network coverage includes non-TSO areas and post-2001 subdivisions;

- the final drop assets (infrastructures and cables) are excluded;

- the ducts allocated to distribution are excluded, in order to reflect Chorus assumption to bury directly distribution cables;

- the share of aerial network has been set to 20%;

- the number of poles have been increased to reflect divergences in inter-poles average distance.

- Subducts have been removed in the fibre backhaul.

Table 10 – Comparison of the inventories

Asset	Unit	Inventory		Comparison
		Chorus	The Commission (copper)	
Copper joints	#	[ ]CNZCI	264,560	[ ] CNZCI
Distribution points	#	[ ] CNZCI	396,044	[ ] CNZCI
Lead-in	#	[ ] CNZCI	1,814,433	[ ] CNZCI
Poles	#	[ ] CNZCI	448,580	[ ] CNZCI
Manholes	#	[ ] CNZCI	930,193	[ ] CNZCI
Trenches	km	[ ] CNZCI	65,246	[ ] CNZCI
Copper cables	km	[ ] CNZCI	96,219	[ ] CNZCI
UG		[ ] CNZCI	81,334	[ ] CNZCI
OH		[ ] CNZCI	15,585	[ ] CNZCI
Ducts	km	[ ] CNZCI	51,151	[ ] CNZCI

Cabinets	#			10,488	
SLUBH fibre	km	[ ] **CNZCI**		24,293	**[ ] CNZCI**

Source: TERA Consultants

9.4.2 Core model

In order to validate the core model, the inventory derived by the modelling is compared to Chorus' actual inventory.

Table 11 – Comparison of the inventories

Asset	Modelled inventory	Chorus' inventory
DSLAM subrack located in cabinets	[ ] **CNZCI**	[ ] **CNZCI**
DSLAM subrack located in exchanges	[ ] **CNZCI**	[ ] **CNZCI**
FDS subrack 7	[ ] **CNZCI**	[ ] **CNZCI**
FDS subrack 12	[ ] **CNZCI**	[ ] **CNZCI**

Source: TERA Consultants

As the scope of the core model has been calibrated to model the UBA service, it is expected that the number of assets modelled is lower than the number of assets contained in Chorus' inventory.

9.5 Audits

In addition to the aforementioned cross-checks, all the models developed by TERA – including the inputs of the model – have been audited by the Commission and by a consultant from TERA external to the project, in order to check for modelling errors.

Plus, each time a model is updated, its results – inventories, costs, etc. – are audited, in order to check for expected differences with former versions of the model.

9.6 Unit cost benchmarks

Unit costs used in the cost models should generally be based on inputs provided by national operators in New Zealand and mainly Chorus. This is because the HEO would have similar bargaining power and suppliers as operators in New Zealand. Relying on unit costs from different countries would not enable to take into account the specificities of New Zealand (Chorus was formally separated from Spark (ex-Telecom), size of the country, geographic differences, level of wages, etc.).

However, most of unit costs have been benchmarked in order to check for efficiency and reasonableness. Data has been extracted from several models developed in different countries, some of which are public, some of which are not public. Therefore for confidentiality reasons, names of countries have been hidden.

Cable costs are in line with international benchmarks. Jointing costs are more expensive than international benchmarks. When differences were observed with benchmarked data, further questions were asked to Chorus to understand why such differences were observed and where we determined that costs were unjustifiably high, for instance where there was double counting, an adjustment was made to unit costs.

Figure 43 – International benchmark of unit costs
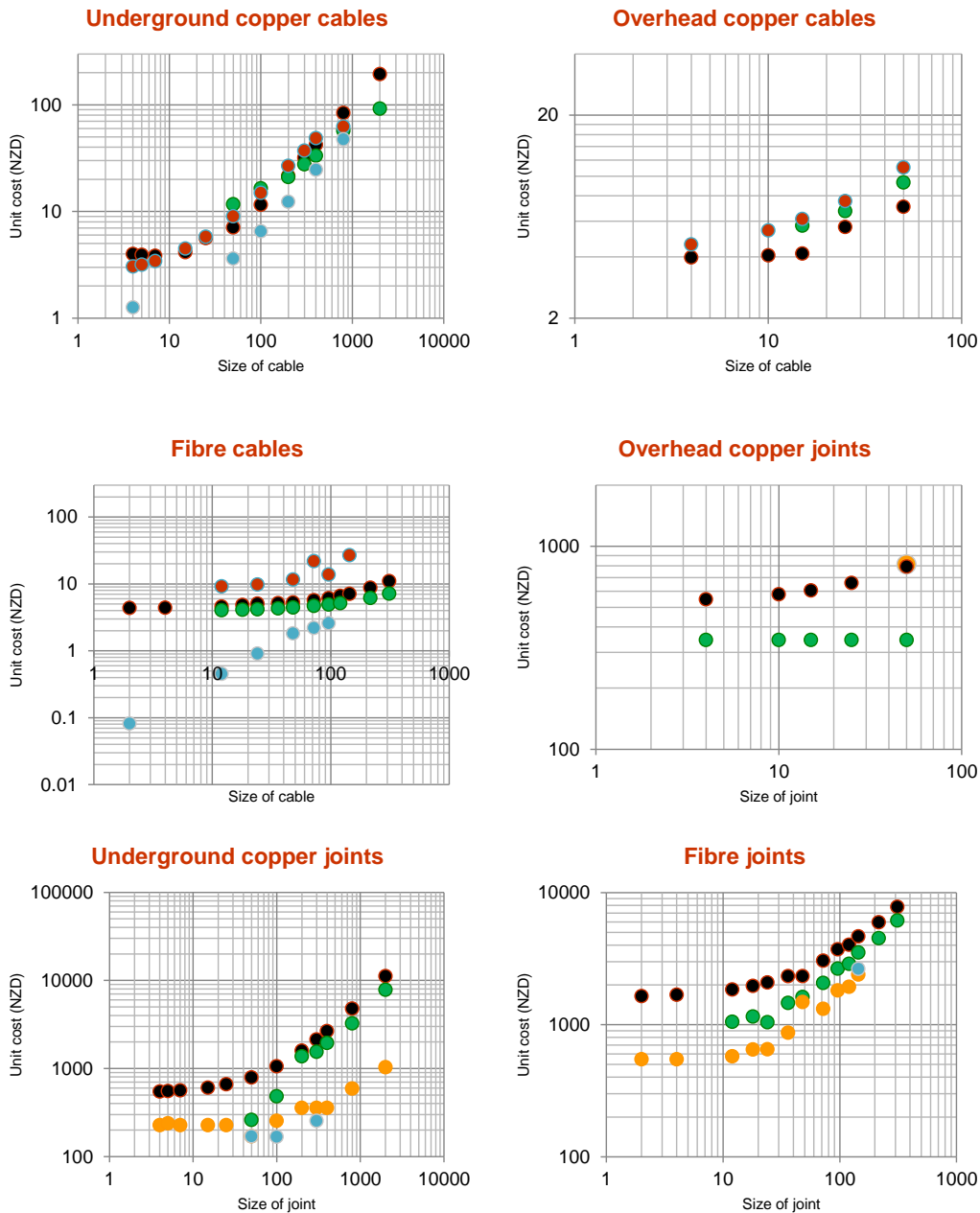
New Zealand costs are represented in black. Other selected countries are represented in blue, green, red and orange. They are not labelled for confidentiality issues.

Source: TERA Consultants

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10 Prices

10.1 Price control period

The price control period is the 2016-2020 period.

10.2 Prices over the price control period

For each service, a unique price is set over the price control period.

As the unit cost of the network assets are changing each year as all price trends are not null (see §8.3), the yearly prices will change every year. In order to set a stable price over the price control period, the yearly prices should be smoothed.

Given that the demand is assumed to be stable, the following smoothing formula will ensure both stable prices over the price control period and cost recovery:

$$Price = \frac{\sum_{i=1}^{5} \frac{Price_i}{(1 + WACC_{post_{tax}})^i}}{\sum_{i=1}^{5} \frac{1}{(1 + WACC_{post_{tax}})^i}}$$

This smoothing feature is not used in the base case scenario: the model provides different prices for each year.

10.3 Gradients

Given the different products that are modelled, the dimensioning of the core network is independent of the traffic (this is consistent with the engineering rules described in §7.3). The cost of providing the different UBA services is therefore the same. However, the unit price of the different UBA services should be different and reflect the different added value of each service.

In order to ensure cost recovery and price differentiation, a gradient approach has been used. The mark-up of the different UBA services is based on a benchmark:

Table 12 – Gradient mark-ups

Service	Mark-up
BUBA	0%
EUBA 40	21.32%
EUBA 90	26.57%
EUBA 180	36.02%

Source: TERA Consultants

10.4 Results

The TSLRIC model for UBA and UCLL have been constructed by following the principles and specifications described in the Model Reference Paper and in the present document. The results of the TSLRIC model are given in the table below, in NZD/month/line, first in 2015, then from 2015 to 2020:

Table 13 – Results of the TSLRIC model for UCLL and BUBA in 2015

Chorus product	Price /customer/month in 2015 (NZD)
UCLL	29.29
BUBA	40.96

Source: TERA Consultants

Table 14 – Results of the TSLRIC model for UCLL and BUBA from 2016 to 2020

Chorus product	Leveled price	2016	2017	2018	2019	2020
UCLL	30.63	29.75	30.22	30.70	31.19	31.68
BUBA	41.69	41.19	41.44	41.71	42.02	42.35

Source: TERA Consultants

Table 15 – Results of the TSLRIC model for UCLL and BUBA from 2016 to 2020

Chorus product	2016	2017	2018	2019	2020
Remote tie cable service space rental charge	11.06	11.37	11.69	12.01	12.35
Subloop tie cable service space rental charge	2.72	2.80	2.87	2.95	3.04
Handover Fibre space rental charge	11.06	11.37	11.69	12.01	12.35

Source: TERA Consultants

10.5 Sensitivity analysis

In this section, the results of sensitivity analyses are provided.

For each sensitivity analysis, the prices of the following services are provided:

- UBA additional costs;

- SLU;
- UCLL.

In addition, the total annuities (depreciated capex for 2016) of the following network scopes are provided:

- UBA additional costs;
- SLU backhaul;
- Copper network;
- Fibre network.

The annuity of the fibre network has been adjusted to take into account the geographical scope difference with copper, i.e. the figure shown is the fibre network annuity minus the SLUBH annuity.

10.5.1 Sensitivity to the geographic scope: TSO-derived boundary and post 2001 subdivisions

In the base case scenario, only the areas inside the TSO-derived boundary are taken into account to calculate the results. Also, only pre-2001 subdivisions are fully taken into account to calculate the results. FWA coverage is based on the areas inside the TSO-derived boundary and within pre-2001 subdivisions.

The scope of the cost modelling can be extended to a national scope, i.e. to the areas outside the TSO-derived boundary and to the post-2001 subdivisions. In such a scenario, the FWA coverage areas remain based on the TSO-derived boundary and pre-2001 subdivisions.

This scope extension leads to an increase in UCLL and SLU prices as capital contributions for such areas (outside of TSO, post 2001 subdivisions) are no longer taken into account. It has of course a small impact on UBA.

Table 16 – Sensitivity to the TSO-derived boundary[11]

Scenario	Annuity (mNZD)			
	UBA	SLUBH	Copper network	Fibre network
Base case scenario	108.02	83.45	377.88	347.86
Including areas outside the TSO-derived boundary	107.34	77.36	478.02	444.87

UCLL price	2016	2017	2018	2019	2020
Base case	29.75	30.22	30.70	31.19	31.68

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[11] The TSO-derived boundary is based on the area defined in the TSLRIC model used for TSO. Each segment within the road network model was tagged with a TSO value of 'True' if 50% or more of its spatial definition fell within one or more of the convex polygons we calculated based on (December 2001) data about the extent of Telecom's network, otherwise the segment's TSO value was set at false. The convex polygons were derived from the historic customer locations for each exchange area which were grouped into clusters.

National network	34.27	34.83	35.39	35.97	36.56

SLU price	2016	2017	2018	2019	2020
Base case	15.52	15.70	15.89	16.07	16.26
National network	21.70	22.00	22.30	22.61	22.92

UBA price	2016	2017	2018	2019	2020
Base case	11.44	11.22	11.01	10.83	10.67
National network	11.07	10.85	10.65	10.47	10.31

Source: TERA Consultants

10.5.2 Sensitivity to the share of overhead network

In the base case scenario, the share of overhead network at the distribution levels is estimated at 47%.

A sensitivity analysis is run onto the model to assess the impact of changes to the share of overhead network.

When the share of overhead network increases

- Capital costs decrease as aerial routes are less expensive than trenches;
- Opex slightly increase, as LFI increases with share of overhead.

At total, UCLL and SLU prices decrease.

The UBA price is slightly increasing because of the reallocation of common costs.

Table 17 – Sensitivity to the share of overhead network

Scenario	Annuity (mNZD)			
	UBA	SLUBH	Copper network	Fibre network
Base case (47%)	108.02	83.45	377.88	347.86
Overhead 36%	108.02	83.45	387.62	354.38
Overhead 58%	108.02	83.45	368.14	341.34

UCLL price	2016	2017	2018	2019	2020
Base case (47%)	29.75	30.22	30.70	31.19	31.68
Overhead 36%	30.01	30.49	30.98	31.48	31.99
Overhead 58%	29.48	29.94	30.41	30.88	31.37

SLU price	2016	2017	2018	2019	2020
Base case (47%)	15.52	15.70	15.89	16.07	16.26
Overhead 36%	15.90	16.10	16.29	16.49	16.69
Overhead 58%	15.11	15.28	15.45	15.62	15.80

UBA price	2016	2017	2018	2019	2020
Base case (47%)	11.44	11.22	11.01	10.83	10.67
Overhead 36%	11.42	11.20	10.99	10.81	10.65
Overhead 58%	11.46	11.24	11.04	10.85	10.69

Source: TERA Consultants

10.5.3 Sensitivity to the cost of capital

In the base case scenario, the post-tax nominal WACC is equal to 5.56% and price control period lengths five years and starts December 16th 2015.

Alternative WACC and price control periods are tested:

- WACC at 5.52% and four year control period starting December 1st 2014;
- WACC at 6.14% and one year control period starting December 1st 2015;

The cost of UCLL is highly sensitive to changes in WACC, as many UCLL assets have long asset lives. The cost of UBA is also sensitive to the WACC, to a lesser degree, since asset lives of active assets are usually shorter than for infrastructures.

Table 18 - Sensitivity to the WACC

Scenario	Annuity (mNZD)			
	UBA	**SLUBH**	**Copper network**	**Fibre network**
Base case (5.56%)	108.02	83.45	377.88	347.86
WACC at 5.52%	107.71	82.84	375.77	346.16
WACC at 6.14%	112.50	92.45	409.19	372.92

UCLL price	Leveled price	2014	2015	2016	2017	2018	2019	2020
Base case (5.56%)	**30.63**		29.29	29.75	30.22	30.70	31.19	31.68
WACC at 5.52%	**30.27**		29.18	29.64	30.10	30.58	31.07	
WACC at 6.14%	**30.90**	30.46	30.94					

SLU price	Leveled price	2014	2015	2016	2017	2018	2019	2020
Base case (5.56%)	**15.86**		15.34	15.52	15.70	15.89	16.07	16.26
WACC at 5.52%	**15.73**		15.31	15.49	15.67	15.85	16.04	
WACC at 6.14%	**15.82**	15.66	15.84					

UBA price	Leveled price	2014	2015	2016	2017	2018	2019	2020
Base case (5.56%)	11.06		11.67	11.44	11.22	11.01	10.83	10.67
WACC at 5.52%	11.14		11.65	11.42	11.20	11.00	10.81	
WACC at 6.14%	11.96	12.19	11.94					

Source: TERA Consultants

10.5.4 Sensitivity to price trends

As explained in §8.3, there are several sources for the price trends:

- The base case scenario corresponds to the most reasonable values identified among all sources.
- The low price trend scenario corresponds to the minimum price trends.
- The high price trend scenario corresponds to the maximum price trends.

As the price trends increase, the prices of the services decrease.

Low sensitivity to price trends reflects narrow ranges for price trends. For instance, price trends for underground infrastructures range from 2% to 3.3%, with base case scenario equal to 3.3%.

Table 19 – Sensitivity to price trends

Scenario	Annuity (mNZD)			
	UBA	SLUBH	Copper network	Fibre network
Base case	108.02	83.45	377.88	347.86
Lower price trends	110.05	96.11	410.13	359.43
Higher price trends	100.63	81.86	377.88	337.54

UCLL price	2016	2017	2018	2019	2020
Base case	29.75	30.22	30.70	31.19	31.68
Lower price trends	30.94	31.37	31.81	32.25	32.70
Higher price trends	29.23	29.75	30.27	30.81	31.36

SLU price	2016	2017	2018	2019	2020
Base case	15.52	15.70	15.89	16.07	16.26
Lower price trends	14.96	15.15	15.35	15.56	15.76
Higher price trends	15.23	15.44	15.65	15.86	16.08

UBA price	2016	2017	2018	2019	2020
Base case	11.44	11.22	11.01	10.83	10.67
Lower price trends	11.52	11.30	11.10	10.91	10.75
Higher price trends	10.85	10.97	11.09	11.22	11.37

Source: TERA Consultants

10.5.5 Sensitivity to the capital contribution for RBI DSLAM

In the base case scenario, the investment of RBI DSLAM is removed.

Including the investment for RBI DSLAM increases the UBA price.

This leads to a reallocation of common costs and therefore leads to a decrease in the price of access products (SLU, UCLL).

Table 20 – Sensitivity to RBI DSLAM capital contribution

Scenario	Annuity (mNZD)			
	UBA	**SLUBH**	**Copper network**	**Fibre network**
Base case	108.02	83.45	377.88	347.86
Including RBI DSLAM investment	119.18	83.45	377.88	347.86

UCLL price	2016	2017	2018	2019	2020
Base case	29.75	30.22	30.70	31.19	31.68
Including RBI DSLAM investment	29.64	30.11	30.60	31.09	31.59

SLU price	2016	2017	2018	2019	2020
Base case	15.52	15.70	15.89	16.07	16.26
Including RBI DSLAM investment	15.46	15.64	15.83	16.02	16.21

UBA price	2016	2017	2018	2019	2020
Base case	11.44	11.22	11.01	10.83	10.67
Including RBI DSLAM investment	12.41	12.15	11.91	11.69	11.50

Source: TERA Consultants

10.5.6 Sensitivity to the cost adjustment method to select the cheapest technology

The costing of the UCLL is based on the cheapest roll-out scenario between the FTTH/FWA MEA and the FTTN MEA.

The choice of the cheapest configuration can be either performed at:

- The MDF level;
- National level.

In the base case scenario, the choice is performed at the national level.

The cost adjustment at the MDF level allows performing a greater adjustment on costs and therefore decreases the price of the access products (UCLL, SLU).

This leads to a reallocation of common costs and therefore leads to decrease the UBA price.

As the FTTH/FWA MEA network is cheaper than the FTTN MEA network, choosing a 100% FTTN network would lead to higher prices for the UCLL.

Furthermore, the costs of the core network are based on copper technology. Switching to fibre would lead to significant increase in UBA costs and slight decrease in UCLL costs due to common costs reallocation.

Table 21 – Sensitivity of the UCLL price to the cost adjustment method to select the lowest cost technology

	2016	2017	2018	2019	2020
Base case (fibre)	29.75	30.22	30.70	31.19	31.68
Costs based on copper	31.48	32.14	32.81	33.50	34.20
Cost adjustment at the exchange level	27.84	28.34	28.85	29.37	29.90
UBA based on fibre	29.35	29.84	30.33	30.84	31.35

Source: TERA Consultants

Table 22 – Sensitivity of the BUBA price to the cost adjustment method to select the lowest cost technology

	2016	2017	2018	2019	2020
Base case (fibre)	11.44	11.22	11.01	10.83	10.67
Costs based on copper	11.33	11.11	10.90	10.71	10.54
Cost adjustment at the exchange level	11.44	11.22	11.02	10.83	10.67
UBA based on fibre	15.29	14.88	14.49	14.12	13.82

Source: TERA Consultants

10.5.7 Sensitivity to the FWA approach

The fibre access network comprises areas covered by FWA network. Four FWA scenarios have been tested in order to optimize the FWA coverage and to reduce the costs of the fibre access network.

The four FWA scenarios are the following:

- FWA coverage provided from RBI sites located within the non-unbundleable areas (base case).
- FWA coverage provided from RBI sites located within the non-unbundleable areas and extrapolated to areas without RBI coverage;
- FWA coverage provided to all customers located in the non-unbundleable areas:
- No FWA coverage: all customers served with fibre.

The first scenario listed above is selected as the base case scenario, as it provides the most optimized costs for the access network.

Table 23 – Key metrics of the FWA scenarios

	FTTH lines	FWA lines	Total lines	FWA sites	Throughput per FWA customer
FTTH	1,895	-	1,895	-	#N/A
FWA base case	1,873	22	1,895	268	679
FWA extrapolated to non-RBI areas	1,853	42	1,895	787	1,066
FWA in entire non-unbundleable areas	1,734	161	1,895	4,154	1,456

Lines in thousands

Throughput per customer in kbps

- **Table 24 – Sensitivity of the annuity to the FWA scenario**

	FWA annuity	Access annuity	Opex	NNC	Total UCLL costs
FTTH	-	435.0	58.2	138.3	631.5
FWA base case	12.0	431.3	58.2	138.1	627.7
FWA extrapolated to non-RBI areas	35.2	442.8	63.1	139.0	644.9
FWA in entire non-unbundleable areas	111.2	477.5	91.3	141.9	710.7

Total UCLL costs are made of access annuity + opex + non network costs.

Access annuity comprises of FWA annuity (i.e. annual cost of FWA sites and their backhaul)

Table 25 – Sensitivity of the UCLL price to the FWA scenario

	2016	2017	2018	2019	2020
FTTH	29.93	30.41	30.90	31.40	31.91
FWA base case	29.75	30.22	30.70	31.19	31.68

FWA extrapolated to non-RBI areas	30.57	31.03	31.51	31.99	32.49
FWA in entire non-unbundleable areas	33.68	34.08	34.48	34.90	35.33

Source: TERA Consultants

Table 26 – Sensitivity of the BUBA price to the FWA scenario

	2016	**2017**	**2018**	**2019**	**2020**
FTTH	11.42	11.21	11.00	10.82	10.66
FWA base case	11.44	11.22	11.01	10.83	10.67
FWA extrapolated to non-RBI areas	11.38	11.17	10.96	10.78	10.62
FWA in entire non-unbundleable areas	11.21	11.01	10.82	10.65	10.50

Source: TERA Consultants

10.5.8 Sensitivity to the HFC demand and vacant sites

In the base case scenario, the total UCLL demand does not include the HFC demand.

Also, in the base scenario, the vacant buildings are removed from network footprint.

Inclusion of HFC demand in UCLL demand and inclusion of vacant buildings in network footprint have been tested in parallel.

Table 27 – Sensitivity to HFC demand and to the vacant buildings footprint

Scenario	**Annuity** (mNZD)			
	UBA	**SLUBH**	**Copper network**	**Fibre network**
Base case	108.02	83.45	377.88	347.86
Including HFC demand	108.02	83.45	377.88	347.86
Including vacant buildings	108.03	83.12	395.22	359.88

UCLL price	**2016**	**2017**	**2018**	**2019**	**2020**
Base case	29.75	30.22	30.70	31.19	31.68
Including HFC demand	28.70	29.15	29.61	30.08	30.56
Including vacant buildings	30.34	30.81	31.30	31.80	32.30

SLU price	**2016**	**2017**	**2018**	**2019**	**2020**
Base case	15.52	15.70	15.89	16.07	16.26
Including HFC demand	14.47	14.63	14.80	14.97	15.14
Including vacant buildings	16.30	16.50	16.69	16.89	17.09

UBA price	2016	2017	2018	2019	2020
Base case	11.44	11.22	11.01	10.83	10.67
Including HFC demand	11.43	11.22	11.01	10.83	10.67
Including vacant buildings	11.39	11.17	10.97	10.79	10.63

Source: TERA Consultants

10.5.9 Sensitivity to the lead-in contributions

In the base case scenario, within-property underground infrastructures (ducts, trenches) are excluded from the model as they are incurred by the end-user ("lead-in contributions").

If the within property underground infrastructures for the lead in were included in the model, UCLL and SLU prices would significantly increase.

Table 28 – Sensitivity to RBI DSLAM capital contribution

Scenario	Annuity (mNZD)			
	UBA	SLUBH	Copper network	Fibre network
Base case	108.02	83.45	377.88	347.86
Including lead-in infrastructures	108.02	83.16	461.73	408.31

UCLL price	2016	2017	2018	2019	2020
Base case	29.75	30.22	30.70	31.19	31.68
Including lead-in infrastructures	32.74	33.31	33.88	34.47	35.07

SLU price	2016	2017	2018	2019	2020
Base case	15.52	15.70	15.89	16.07	16.26
Including lead-in infrastructures	19.16	19.45	19.75	20.04	20.35

UBA price	2016	2017	2018	2019	2020
Base case	11.44	11.22	11.01	10.83	10.67
Including lead-in infrastructures	11.22	11.01	10.80	10.62	10.46

Source: TERA Consultants

10.5.10 Sensitivity to the major unit cost changes

The cost of UCLL is made of annualized capex, opex and NNC.

Joints and trenches are the most significant assets of the annualized capex.

If trenches or joints unit costs increased by 10%, the UCLL price would increase by respectively 1.73% and 1.27%.

As well, in opex and non-network costs jointly increased by 10%, the UCLL price would increase by 2.94%.

Table 29 – Sensitivity to major unit cost changes

UCLL price	2016	2017	2018	2019	2020
Base case	29.75	30.22	30.70	31.19	31.68
Joints +10%	30.26	30.74	31.23	31.73	32.24
Trenches +10%	30.12	30.60	31.09	31.59	32.10
Opex and NNC +10%	30.63	31.11	31.60	32.10	32.60

SLU price	2016	2017	2018	2019	2020
Base case	15.52	15.70	15.89	16.07	16.26
Joints +10%	15.90	16.09	16.28	16.47	16.67
Trenches +10%	15.37	15.55	15.72	15.91	16.09
Opex and NNC +10%	15.98	16.17	16.36	16.55	16.74

UBA price	2016	2017	2018	2019	2020
Base case	11.44	11.22	11.01	10.83	10.67
Joints +10%	11.44	11.22	11.02	10.83	10.67
Trenches +10%	11.45	11.23	11.03	10.84	10.69
Opex and NNC +10%	12.01	11.79	11.58	11.40	11.23