WIK-Consult • Report

Study for CMT, Barcelona, Spain

Bottom-up cost model for the fixed access network in Spain

- Model description -

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Abbreviations

BDB = Building Distribution Box

BO = Building Owner

CAPEX = Capital Expenditures

CPE = Customer Premise Equipment

DP = Distribution Point

FTTB = Fibre to the Building

FTTC = Fibre to the Curb

FTTEx = Fibre to the Exchange

FTTH = Fibre to the Home

GPON = Gigabit Passive Optical Network

ICT = Infraestructuras Común de Telecomunicaciones

LLU = Local Loop Unbundling

LRIC = Long Run Incremental Cost

MDF = Main Distribution Frame

MDU = Multi Dwelling Units

MPoP = Metropolitan Points of Presence

NGA = Next Generation Networks

NPV = Net Present Value

ODF = Optical Distribution Frame

ONT = Optical Network Terminal

OPEX= Operating Expenditures

P2MP = Fibre Point-to-Multipoint Topology

P2P = Fibre Point-to-Point Topology

SRIC = Short Run Incremental Cost

TELRIC = Total Element Long Run Incremental Cost

TRAC = Telefonía Rural por Acceso Celular

ULL = Unbundled local loop

WACC = Weighted Average Cost of Capital

1 Introduction

The Comisión del Mercado de las Telecomunicaciones (CMT), the Spanish regulatory authority for the telecommunications market, mandated WIK-Consult, Germany, to develop a Bottom-up cost model to determine the efficient cost of the relevant elements of the fixed telecommunications access network in Spain. The model developed now allows to take into consideration the access network of the whole country in the given end customer distribution, instead of only calculating some access areas as samples, whose representativeness is debatable in many directions. The efficient cost is a result of the point of view, that an efficient operator will deploy a state of the art access network today instead of considering the existing network structure with all its historic inefficiencies.

The model takes the existing MDF (Main Distribution Frame) locations of Telefónica's access network, i.e. the existing local exchange locations, into account as so called scorched nodes, which we do not change. The access areas covered by such MDF locations are optimized by efficiency criteria, thus the existing MDF borders are not taken into account.

With growing demand for more bandwidth in the access networks the network operators have to overcome the restrictions copper access lines today have due to their physical characteristics. This is achieved by deploying fibre instead of copper lines, beginning at the MDF locations and replacing the main copper cables by fibre and, sometimes in one step, also replacing the building or even the inhouse access lines, thus reducing the remaining copper line length and allowing to transmit higher bandwidth over shorter copper access lines. One may describe this development as Fibre to the Curb (FTTC), Fibre to the Building (FTTB) and Fibre to the Home (FTTH). In Spain, the deployment of fibre networks in most cases is FTTH in one step, especially in new construction areas. Thus the model has not only to consider copper access network structures, but also FTTH. And, since it is deployed that way in Spain, the model does not only consider copper or fibre, but also a fibre overlay network beside the existing copper network, because most probably copper access lines will be used for a longer period in parallel. The minimum period of copper switch off will be 5 years in areas where the copper local loop is unbundled for collocated competitive operators.

There is an on-going discussion about how to value the copper access network, which in most areas has been installed many years before and should already be depreciated. It also experiences a decreasing demand due to competition with other access network technologies (TV-cable, mobile, fibre access lines). So the discussion arises if copper access networks shall be valued at historic cost (lower) instead of current cost (higher) as the EU regulation requires up to now. In contrary, fibre is new, will be doubtlessly valued at current cost, but may use already existing ducts, where available. We do not investigate the pros and cons of this debate in the study mandated, but we consider these circumstances and have developed a model which is flexible to implement different valuation methods, and which even allows to mix them among the network elements (e.g. copper and fibre cables).

The depreciation of the assets shall reflect their economic value as close as possible. The preferred methodology is economic depreciation - at least for the determination of termination fees in the switched networks[1]. Other methods like straight line depreciation, annuities and tilted annuities are supported in the model, too. The tilted annuity with consideration of a growth factor comes very close to the economic depreciation and overcomes some of its complexity. So the model first offers economic depreciation with different growth of demand over time which allows for modeling demand evolution in an individual manner, and second a depreciation method with constant demand growth rates over time.

In order to consider the different risks inherent in constructing copper or fibre networks the model also allows to apply different interest rates (WACC: Weighted Average Cost of Capital) to the relevant items by adding a dedicated fibre premium to the WACC for the related assets.

In the past many different approaches to connect buildings to the access network and also to construct the inhouse cables (e.g. façade, inhouse ducts (ICT), simple inhouse cabling, combining several houses) had been deployed. For modeling these the approaches are classified into typical methods, and also discriminators are determined in order to decide where to apply which type. To this extend the model therefore enables to deal with the historic development and not simply applies today’s state of the art methodology. Also a parameter allows to allocate which share of cost for inhouse cabling and building access cable is due to the constructor/ house owner and therefore out of consideration for the regulated prices to be determined.

Cost for operating the network, for providing wholesale support systems and common cost will be also considered.

This document describes the methods and criteria being relevant for the model development and the way the model proceeds to determine the requested cost for the physical infrastructure. It also details the relevant parameters being required to customize its application.

Chapter 2 will describe the relevant access network architectures as a reference in an overview manner. This allows to define some terms and expressions.

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[1] see EU Recommendation on the Regulatory Treatment of Fixed and Mobile Termination Rates, C(2009)3359 from May 7th, 2009, consideration (18), recommendation (7). The EU Recommendation on regulated access to Next Generation Networks (NGA), C(2010)6223 from September 20th, 2010, does neither prescribe nor even refer to the depreciation methods in the recommendation above.

Chapter 3 gives an overview of the modeling approach and the major steps and also describes, where the main input parameters will be introduced into the modeling process.

Before the cost model and the modeling process including the structure of the results are described in chapter 5, chapter 4 details the input data, the data sources and the demand estimation and distribution process.

Chapter 6 gives an outlook on model evolution. The document ends with the summary (chapter 7).

2 Access network architectures

The model allows to consider different access network architectures. This is on one hand an access network based on copper pairs, like it is installed today in most cases in Spain. On the other hand there are fibre based access networks, using one fibre per end customer, which ends in the end customers' homes/ locations. These architectures are called Fibre to the Home (FTTH). There are two types to be modeled, one described as fibre point-to-point topology (P2P) and one called fibre point-to-multipoint topology (P2MP) or GPON[2] (Gigabit Passive Optical Network). The majority of the fibre deployment taking place in Spain today is made as P2MP topology. The P2P topology is better suited for pure business areas and therefore is also considered.

All networks use existing MDF locations as scorched nodes i.e. are located at the currently existing Telefónica locations, so the MDFs are the points where the currently existing customer access lines are joined together in a tree like topology. These locations housing electronic network devices to concentrate, transport or even switch the end customer traffic are also called Metropolitan Points of Presence[3] (MPoP).

This section describes these access network architectures in brief and defines the terminology used in this document.

2.1 Copper access network

The copper access network covers a dedicated area and serves all end customers of this area with dedicated copper pairs. In the past the area has been determined by the maximum size of end customers a telephone switch could support and/ or the maximum length a telephone signal could be transmitted without intermediate amplification. While the switch capacity over time increased dramatically due to technological improvements the line length restrictions remained, thus being the main determinator for access size areas.

At the central site all access pairs end at the Main Distribution Frame (MDF), where each of it may be individually accessed and connected to a telecommunication system of one of the operators who is collocated at this MDF location. From MDF into the core network the use of fibre links is very common. Thus this solution is also called Fibre to the Exchange (FTTEx).

All copper pairs are jointly deployed in feeder cables running out to the homes, branching to the individual streets at cable connection points, which in the Spanish case are normally located in underground chambers/ manholes and which have a function to

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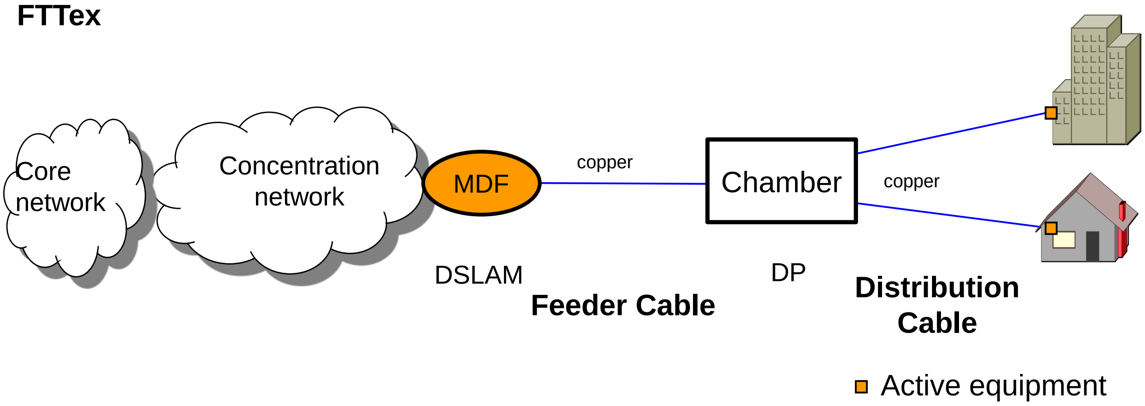
[2] GPON is one technology allowing to operate a P2MP fibre topology and is therefore often used synonymously. But GPON also could operate on a P2P fibre topology.

[3] EU Recommendation on regulated access to Next Generation Networks (NGA), C(2010)6223 from September 20th, 2010

flexibly connect or disconnect customers[4]. Distribution cables connect the chambers via building access with the end customer buildings, where they terminate in building distribution boxes (BDB). From the BDB each end customer home or business location is connected by the inhouse cabling. The end customer home is equipped with active customer premise equipment (CPE) which communicates with the central electronic systems at the MDF location (Figure 2-1).

Figure 2-1: Principle of a copper access network



MDF – Main Distribution Frame
DP – Distribution Point
DSLAM - Digital Subscriber Line Access Multiplexer

Following this principle real networks are a little bit more complex. In order to be efficient and save civil engineering investments there is in many cases not an individual cable and trench relation between chamber and MDF, but the path from a chamber to the MDF may be routed through another chamber closer to the MDF (see also Figure 2-3).

Thus some of the chambers may be connected in a chain or are cascaded. From the chambers smaller distribution cables sometimes pass through connection or branch sleeves, often housed in handholes, before they finally branch to the buildings (Figure 2-2 and Figure 2-3). One can further subdivide the distribution segment into the distribution segment itself, lasting from the chamber with the last distribution frame/ sleeve to a handhole or a buried building access sleeve at the edge of the street, where the building access cable branches out of the common duct/ trench to an individual building, and into a building access cable segment between that handhole and the building distribution box (BDB) at the building.

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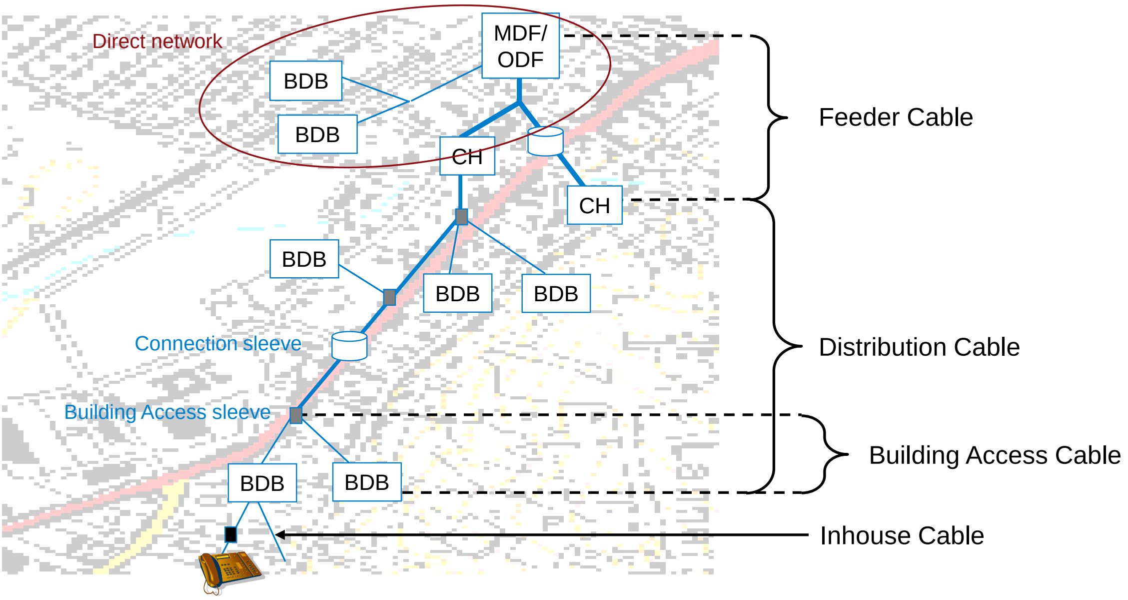
[4] We use the expression chamber only for those manholes, separating feeder and distribution cable segments. For other underground spaces we use the expressions manhole respectively handhole, depending on their size.

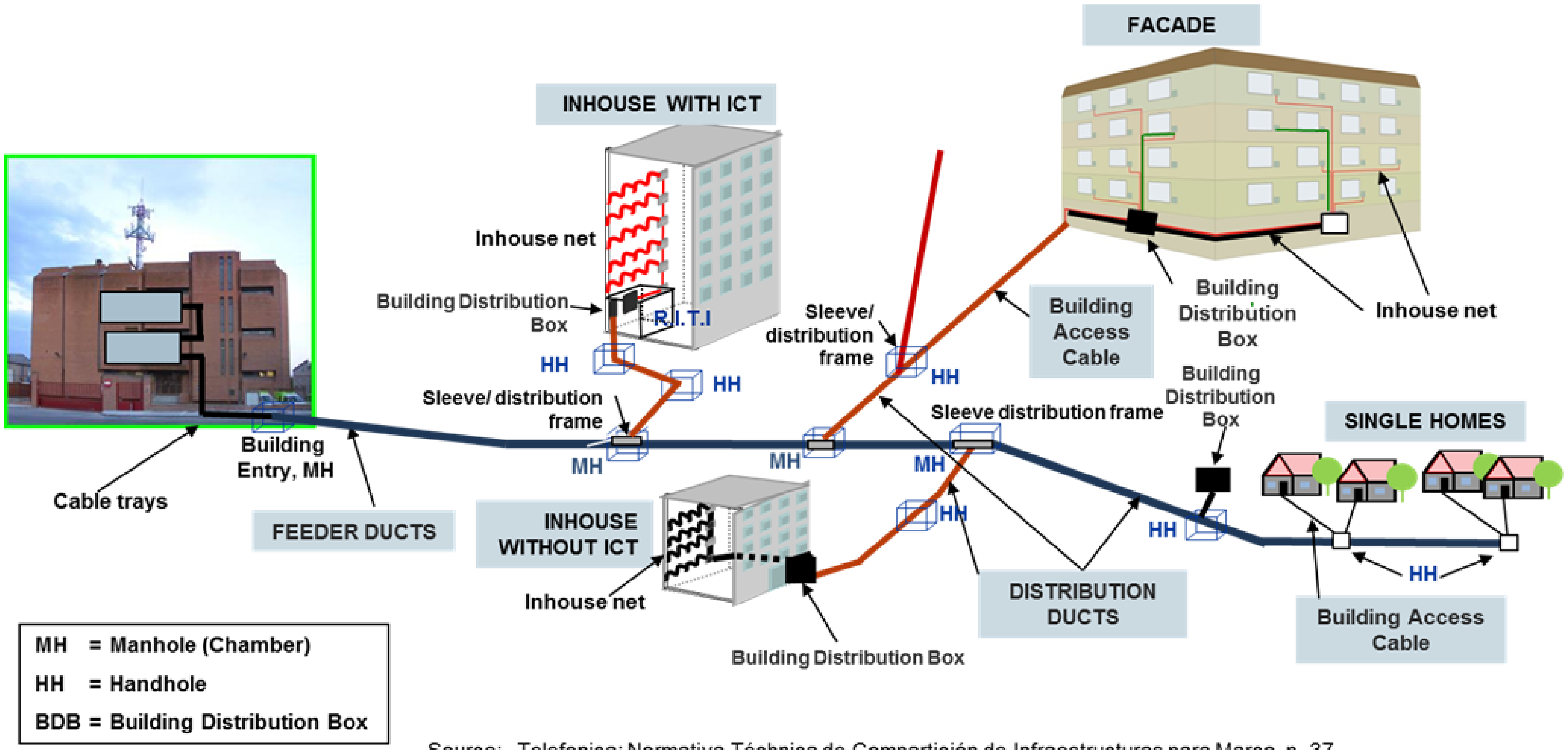
Figure 2-2: Principle of a copper access network, enhanced details



MDF: Main distribution frame; ODF: Optical distribution frame;
CH: Chamber (manhole); BDB: Building Distribution Box

In some countries BDBs nearby the MDF location are directly connected to the MDF without any intermediate cable distribution element in a chamber or street cabinet. This type of topology we call direct network and consists of distribution and building access segment, plus inhouse cabling, but without any feeder cable.

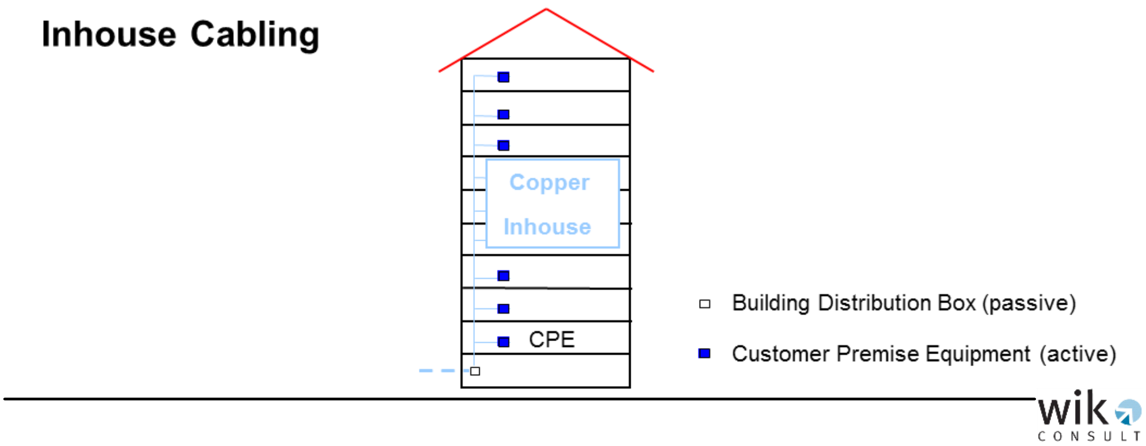
Figure 2-3: Copper access network in Spain



Source: Telefonica: Normativa Téchnica de Compartición de Infraestructuras para Marco, p. 37, English explanations by WIK-Consult

The inhouse cabling, which cost has to be taken into account in principle as long as the operators pay whole or a share of it, at least in Multi Dwelling Units (MDU) or business locations, starts at the BDB, where often outdoor cables turn into indoor cables (with a reduced fire load), and where they branch out to the individual homes or business locations (Figure 2-4).

Figure 2-4: Copper inhouse cabling



In Spain, inhouse cables may be constructed at the outside of the façade of the building[5], within a normal indoor installation on the wall/ underneath the wall's surface or in a dedicated cable tray system ICT[6].

A special form of copper access network is a Fibre to the Curb (FTTC) solution. With FTTC the DSLAMs are no longer located in the MDF buildings, but in street cabinets or rented rooms instead of (underground) chambers[7] as so called remote nodes. Between MDF locations and these DSLAMs fibres replace the copper line, thus reducing the copper line's length and its bandwidth restrictions. Between the remote DSLAMs and the end customers the existing copper access network can be used (Figure 2-5).

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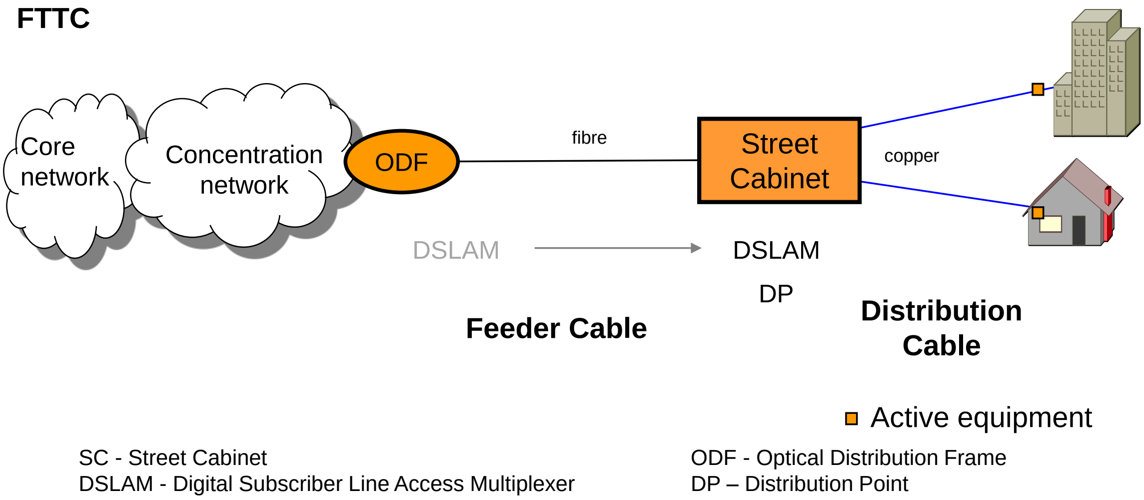
[5] Thus even when the cable is located outside, we classify it as inhouse cable, since it serves the inhouse homes and also could be constructed inside of the building. Details of outdoor and indoor differences in case of faceade cabling are described in section 5.1.8

[6] Abbreviation for: Infraestructuras Común de Telecomunicaciones, http://www.proyecto-ict.com/

[7] Electronic systems are sensitive to humidity, so underground chambers have to be dry (rain water and pressing water proof in any case) when they should host DSLAMs.

Figure 2-5: Fibre to the Curb with remote nodes



This type of access only has limited relevance in Spain with approximately 5448 remote node locations.

We consider the chambers with the cable distribution function or the street cabinets as the Distribution Points (DP) of the EU NGA recommendation.

2.2 Fibre access network FTTH P2P

Fibre to the Home point-to-point access network is a topology where each end customer is connected to the ODF with an individual single fibre[8] (or fibre pair), thus allowing each end customer to use the full and not shared capacity of a fibre. With respect to this option the FTTH P2P topology is qualified as the most future proof access network topology at all. In principle each fibre may be terminated individually to transmission systems according to the individual end customer demand.

The ODF location not necessarily has to be the copper cable MDF location. Since fibres do not experience the same length restrictions as copper cables a larger access line length may be considered. Since in reality many ducts already exist the fibre access network may orientate itself by existing duct network topologies and therefore by existing MDF locations as (passive) network nodes and boundaries.

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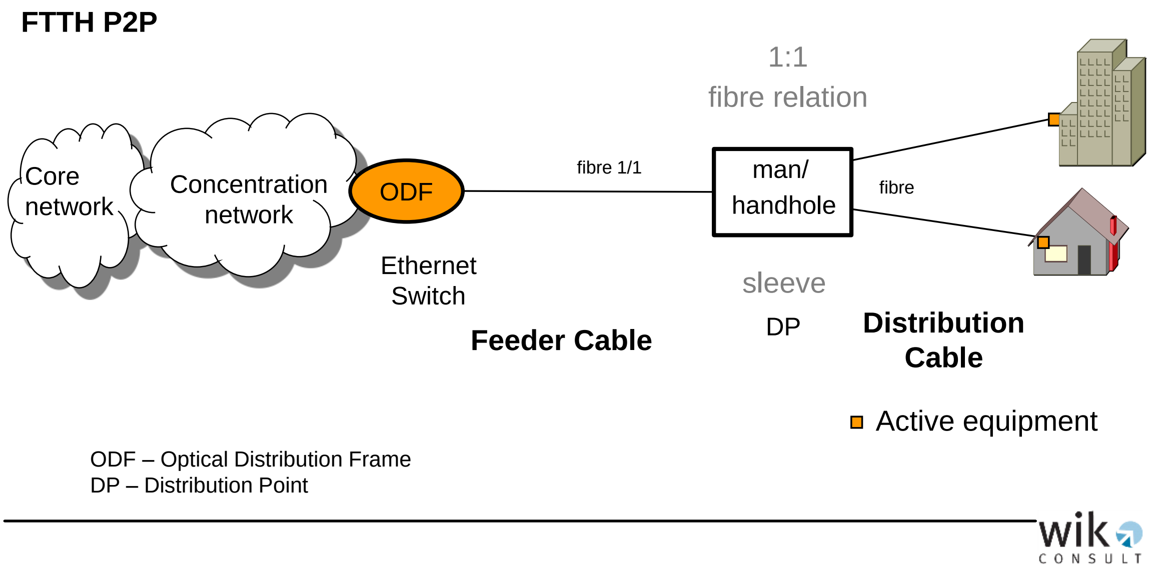
[8] In the past it was common to use one fibre per transmission direction. But with progress in the fibre interface development and the large scale of one fibre interfaces being produced nowadays we qualify single bidirectional fibre interfaces being more efficient than double unidirectional fibre interfaces. Thus we assume a single fibre per connection in all fibre topologies.

Our model will delineate the fibre access network boundaries from the ODF locations given as scorched nodes, which will be fewer than the copper access network MDF locations, comprising several of these as new fibre ODFs.

Figure 2-6: FTTH point-to-point access network topology

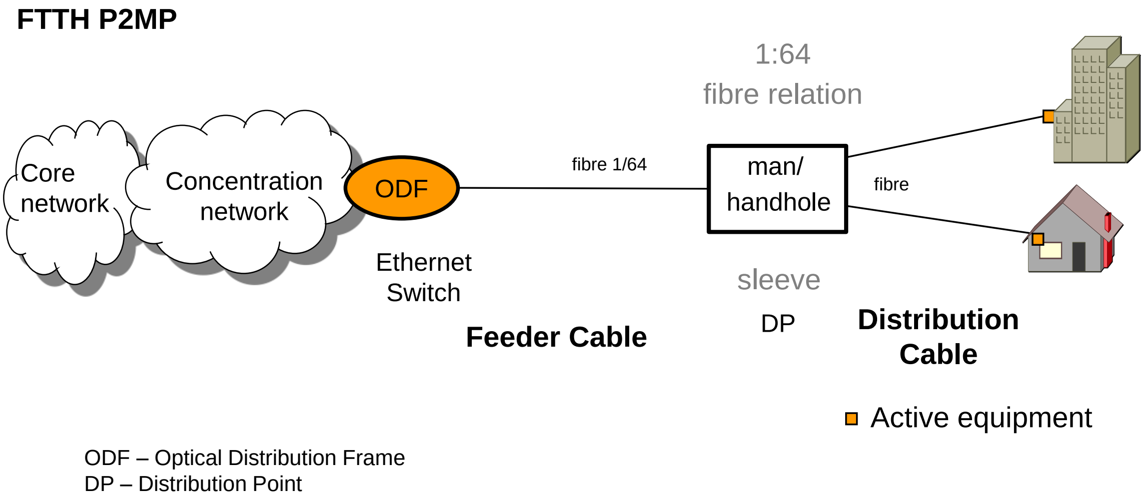


The fibre cable will be routed from a central Optical Distribution Frame (ODF) to the end customer premises and will be branched out in a chamber (DP) with either a small optical distribution frame or a sleeve. From there the individual buildings will be served comparable to the copper pair access lines via BDBs outside on the façade, inside ICT cabling systems or as normal indoor cabling.

2.3 Fibre access network FTTH P2MP (GPON)

In FTTH point-to-multipoint access network topologies up to 64[9] end customer fibre links are concentrated by a splitter onto a single fibre somewhere in the field, so one fibre with up to 64 end customer signals ends at a central Optical Distribution Frame (ODF) ODF. In the ODF location such a fibre terminates on an OLT (Optical Line Terminator) who has to manage the sending and receiving rights on the commonly used single access fibre in cooperation with the ONTs (Optical Network Terminator) at the end customer sites[10]. Thus a standardized protocol is required which today limits the capacity transmitted per ODF fibre to 2.5 Gbit/s downstream and 1.25 Gbit/s upstream[11].

Figure 2-7: FTTH point-to-multipoint topology with GPON architecture



The splitters may be cascaded, but the splitting ratio per splitter cascade is limited to a maximum of 64 end customers, due to the limitations given by the standardized optical attenuation budget of a single optical string and the OLT limitations. Many operators in Europe today do not completely design their networks with the upper limit of 64 end customers per OLT string, but will only aim for a maximum number of 32 end customers in order to retain spare capacity for future use. Thus the maximum number of end customers will be considered as a model input parameter.

The model allows cascading splitters at two locations, at the DPs and at the BDBs of the buildings, like it is rolled out by the incumbent operator in Spain. Design goal was to

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[9] With the new XGPON standard this figure will be expanded to 128, but also depending on access line length and attenuation restrictions.

[10] Any fibre point-to-multipoint architecture requires like any bus architecture (e.g. Ethernet) an arbitration system.

[11] XGPON will expand this limitation to 10 Gbit/s downsteam and 2.5 Gbit/s upstream.

comprise as many customers as possible in a splitter already at the end customer building (BDB). Cascading splitters introduce additional attenuation reducing the remaining optical budget. Thus cascading splitters may be less efficient from an optical budget point of view.

Figure 2-8: FTTH inhouse cabling (P2P and P2MP (GPON))

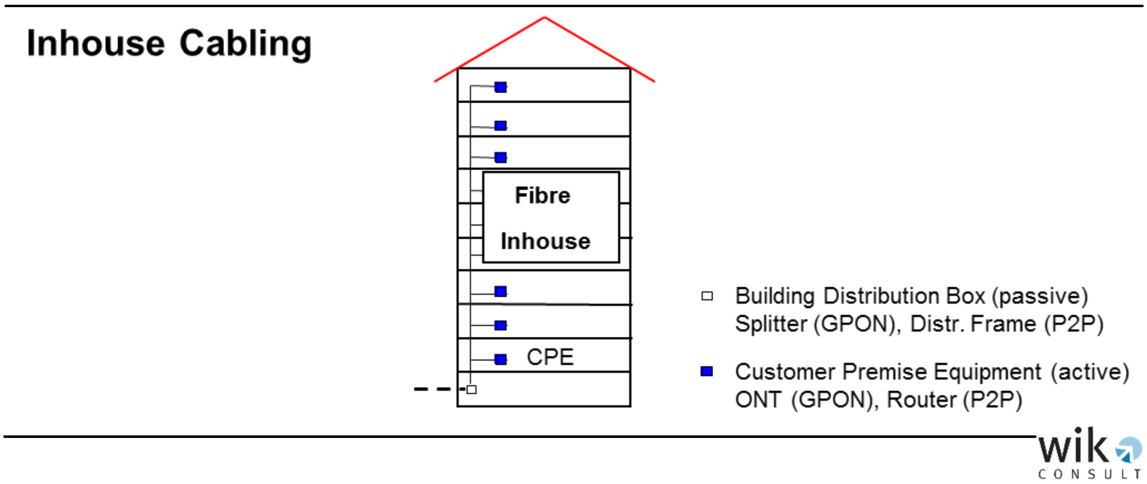

Figure 2-8 describes the inhouse topology[12] of both FTTH architectures. They do not differ between BDB and end customer home/ business location. With GPON there may be a splitter at the BDB site, and the CPE will require an ONT function in addition to the normal CPE functions, while the Ethernet P2P topology simply requires a router.

Today GPON architectures expand the access line length to 20 km, thus here also several MDF locations may be combined to one fibre based ODF. ODF delineation in a pure fibre deployment will be comparable to the case described above.

Main differences between the GPON P2MP and the Ethernet P2P topology are the lower amount of fibres in the distribution and feeder access cable segments, and the lower amount of ODF ports at the central site in case of P2MP. Regarding P2MP solutions splitter deployment in the field can be more expensive than at central sites (ODF locations)[13]. Important for the modeling goals is that a P2P fibre topology will be unbundable at the ODF, thus the cost for an unbundled local fibre loop may be determined. A fibre P2MP topology may only serve as input to a bitstream cost calculation since it is not unbundable at the ODF sites. Our model will allow calculating both passive fibre plants, one giving input for fibre unbundling and bitstream, one for bitstream only.

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[12] Even when the cable is routed outside the building on the façade.

[13] For discussion about advantages and disadvantages of the two architectures and topologies see: Hoernig, Steffen; Jay, Stephan; Neumann, Karl-Heinz; Peitz, Martin; Plueckebaum, Thomas; Vogelsang, Ingo: Architectures and competitive models in fibre networks, Bad Honnef, December 2010

2.4 Coexistence of cooper and fibre (networks overlay)

In all MDF areas where competitors are collocated in order to use the unbundled access to the local copper loops these copper loops only may be switched off 5 years after announcement of the incumbent to do so[14]. This implies that an incumbent will make use of all existing spare ducts of the copper access network topology which are available. And fibre and copper network will coexist in these areas for approximately five years at least, but being expected very long term coexistence. In areas without LLU by competitors the incumbent will be allowed to switch off copper already within one year. But even in these areas one might assume that existing ducts may be used to the most possible extent, due to the large investment share civil engineering work has on access networks.

Therefore CMT and WIK agreed to consider all copper fibre overlay constructions in a manner where the fibre topology follows the (efficient) copper topology. When, at a later stage of network development, the copper MDF will be dismantled, the fibres will be forwarded by backhaul lines from the dismantled MDFs to the new fibre ODFs. We assume that the remaining fibre ODF locations under these circumstances are a subset of the former copper MDF locations and cover a larger number of access lines.

The model will calculate the overlay network after having optimized the copper access network topology by calculating as many ducts/ subducts as required for copper and fibre together, assigning for each copper and each fibre cable a dedicated subduct (being the number of subducts per duct and the maximum cable size per subduct input parameters to the model) and taking into account a reasonable amount of subducts as operational spare capacity (parameter) for both networks together (see Figure 2-9).

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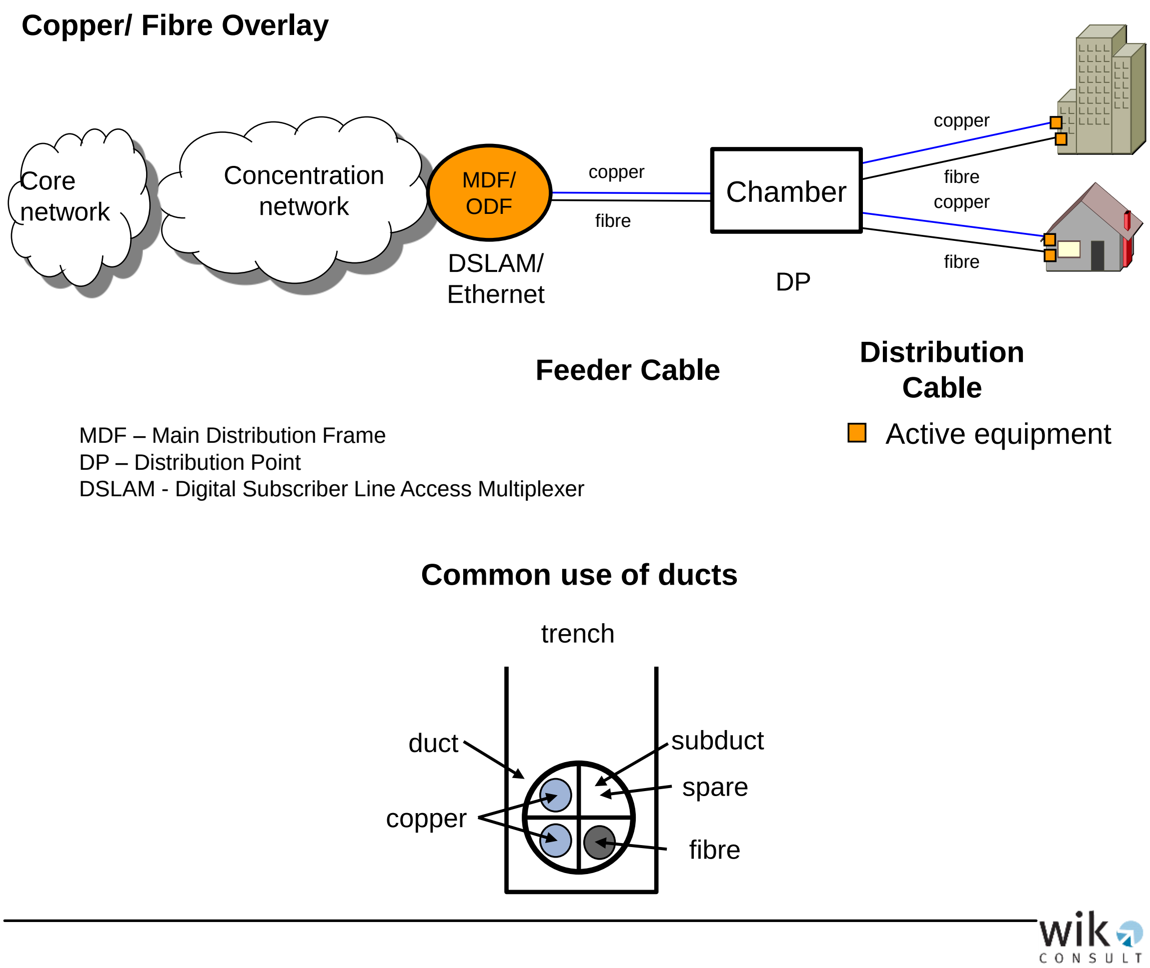
[14] According to Spanish and European regulation

Figure 2-9: Copper and fibre coexistence



Beside these overlay options there also exists, as already described in section 2.2, pure fibre access network designs, optimizing the access network independently from copper history by starting at the fibre scorched nodes (fibre ODF location).

3 General modeling overview

The idea behind cost modeling of access networks is that in markets being dominated by one party competition can only develop when the dominant party has to offer bottleneck infrastructure as wholesale input to the competitors at prices which would develop in a competitive market. Prices in a competitive market will be those a customer is willing to pay before he otherwise decides to produce the products by its own. Thus the adequate price would be those costs an efficient operator would experience in deploying an access network today with state of the art technology at current prices. In order to participate in scale effects the increment considered is the whole access network of a dedicated area. Typically this area today is the complete national market. This network then is supposed to be used for a long time. Such approach is called Long Run Incremental Cost (LRIC). If not only the increment of the access network is considered, but also an appropriate share of the common cost of the total business of the operator (e.g. by a mark-up) the approach is sometimes referred to as LRIC+. Our model considers the common cost as mark-up, but also allows setting the mark-up factor to zero[15].

Thus we use a bottom-up engineering approach to develop an efficient access network. We start with structural parameters such as the MDF locations as scorched nodes, the building, street and home/ business location distribution of the entire country, based on reliable public data sources, and also define the coverage of access lines being demanded by the market. This allows to derive the total amount of network elements an access network for the entire Spanish territory requires, by counting them bottom-up along all streets of Spain in very detail, thus describing all relevant elements of a real network which could be deployed in Spain in an efficient manner.

In a second modeling step we evaluate the required investment by applying prices to the required network elements, apply a depreciation method in order to generate cost, add operational cost and also consider appropriate common cost (Figure 3-1). For the purpose of economic depreciation we consider a demand period of 20 years into the future[16]. In certain cases, wholesale retail cost will be considered as an additional component of total cost. This results in the LRIC of the total access service, which also can be broken down for single network elements.

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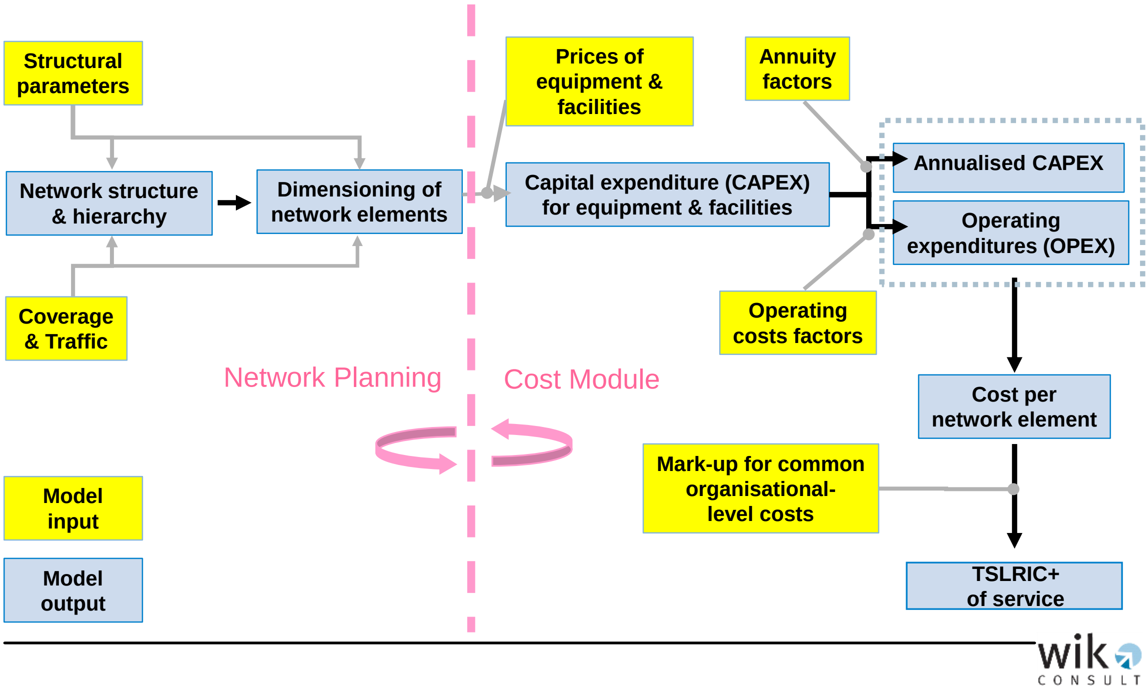
[15] In this document we refer to both approaches as LRIC, if there is no necessity for a distinction.

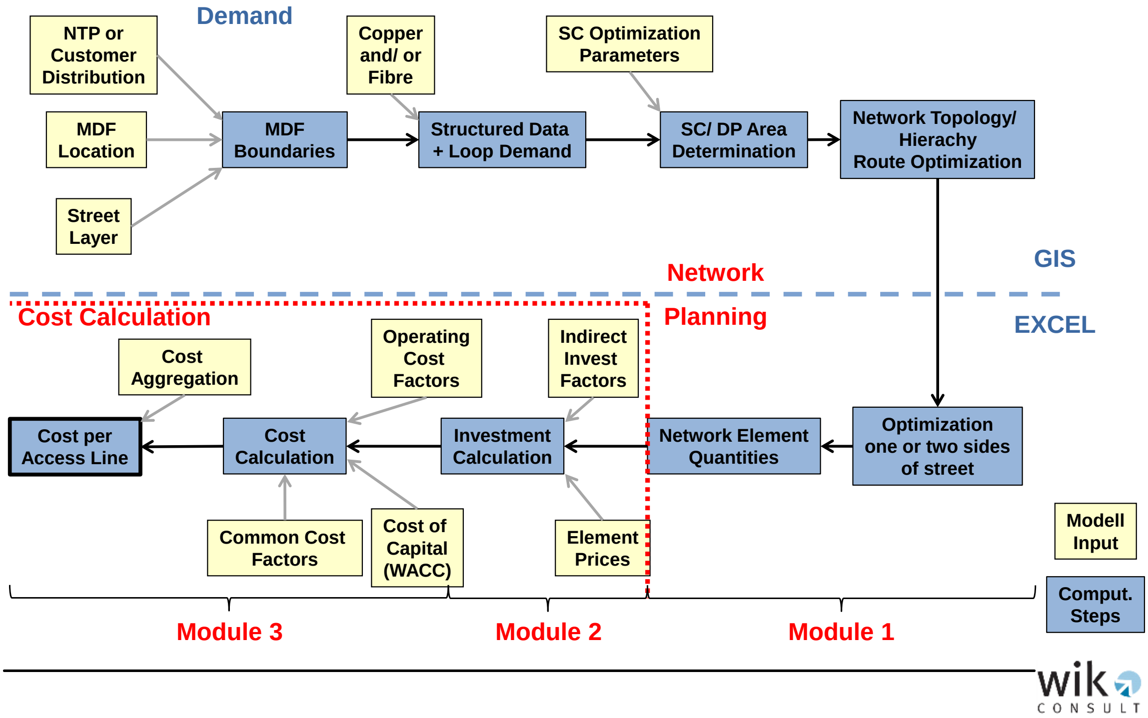
[16] Depreciation periods are independent from the demand forecast period and taken from expected component life time (market responses to questionnaire and regulatory state of the art in Spain).

Figure 3-1: Schematic view of BU cost modeling



Our modeling approach for the access network in more detail is described in Figure 3-2. Nearly all engineering is executed on the Geographic Information System (GIS) platform ArcView, added by some route optimization tools. In order to increase transparency for the users we add an Excel based tool which as first step optimizes the engineering approach deciding if the infrastructure is more efficiently deployed on one or both sides of each single street segment. Also the whole cost calculation is computed in the Excel tool.

Figure 3-2: BU access network modeling



In a data preparation step we estimate the addressable market (maximum amount of demand) by combining cadastral[17] and statistical information of the country in a very fine granularity (household per household), determining the maximum residential and business demand for access to the telecommunication network per building (being more precise, per portal). Thus all possible demand is concentrated to one geocoded point per building (portal) at the edge of the building closest to the street. We also use cadastral information to determine typical inhouse cabling structures, using parameters like construction year of the building or building height in number of levels, which will be evaluated in a later step and which is stored as information attached to that demand access point.

The first step of network planning is the derivation of efficient access network boundaries per MDF/ ODF by taking the MDF/ ODF locations as given (scorched nodes), delineating the demand building per building (portal per portal) to the nearest MDF/ ODF location. For the distance taking into account we calculate the street distance to the neighboring MDF/ ODF locations, assuming that the cable infrastructure in almost all cases will be deployed along the roads.

The second step considers which form of access line deployment has to be taken into account for each delineated access area: copper only, fibre only (either of P2MP or P2P), or copper/ fibre overlay. This step also classifies the possible demand access

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[17] Cadastral information of whole Spain obtained via Dirección General del Catastro (MEH).

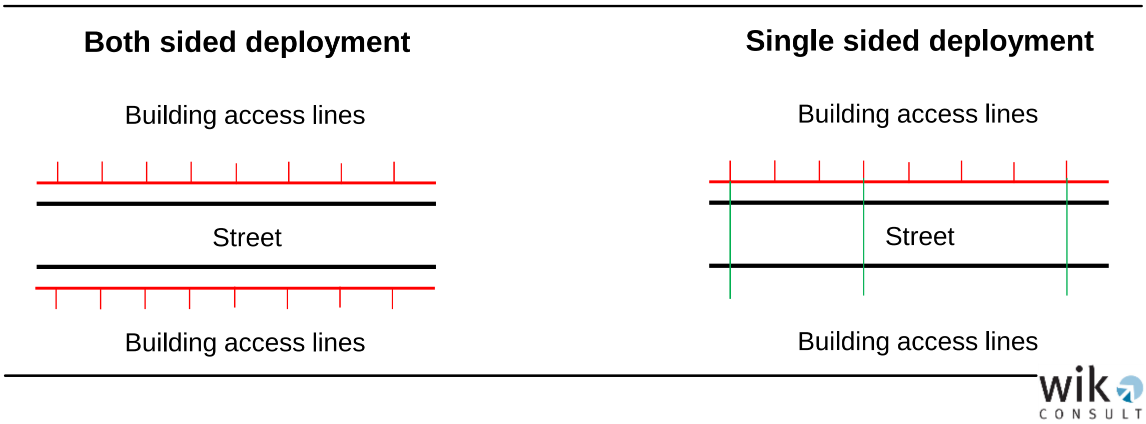
points into the different inhouse and building access typologies, also taking into account the common façade cabled buildings. The real demand used for access network design will then be determined by allocating the expected demand (active copper lines or final fibre lines) to the demand access points in an equally distributed random manner (see section 4.1). The demand coordinated over remote nodes, where no Local Loop Unbundling (LLU) can take place (the demand covered by Telefónica remote nodes), will be determined in this step, and also all those customer access lines based on radio access links not enabling an unbundled copper or fibre access line (called TRAC lines, Telefonía Rural por Acceso Celular). They are taken out of the demand considered for Local Loop Unbundling, but remain included for bitstream calculation purposes.

The next step subdivides the MDF access area into smaller access areas per Distribution point (e.g. chamber). Criteria to do so are the maximum amount of end customers being concentrated at that point and the maximum length a subloop might have, taking street distances into account. When these subareas have been determined the DP location will be exactly determined by either locating it at the border of the area, closest to the MDF location, or by locating it in the mass center of the area. In a comparative static analysis one can decide the more efficient solution, if required. This step also allows to consider a direct network subcluster (Figure 2-2).

In the fourth step the spanning trees serving the access subareas of the DP and the tree serving all DPs from the MDF downwards are calculated, collecting all relevant network elements per street segment along the optimal routes (shortest path tree). Thus we receive an optimal access network per MDF area with all network elements required.

This information is handed over to the Excel tool, which consists of 3 modules, where in module 1 the last step of network engineering it is analyzed per street segment if it is more efficient to deploy the trenches and ducts on only one side of a street and serve end customers on the other side by crossing the street (per two buildings (portals)) or to deploy the infrastructure on both sides (Figure 3-3) for the distribution cable. This will be decided by a cost comparison. Feeder cables are only routed on one side of the streets. This step finally results in the exact quantities of network elements required.

Figure 3-3: Single and both sided street deployment



In the cost calculation (module 2) at first the investment is calculated by multiplying the network elements with the appropriate element prices (historical or current cost). Then differentiated indirect investment factors will be applied in order to consider investment positions related to the access network which have not been taken into account already by the network planning. These for example are service cars required for the field engineers for constructing and operating the access network, or workshop facilities in order to test or maintain network elements. The investment positions remain in a fine itemized aggregation state.

Second step of cost calculation (module 3) is to transform the investment into cost per time period by applying a depreciation method, considering the appropriate Weighted Average Cost of Capital (WACC). In principle this can be performed individually invest item per invest item, resulting in the Capital Expenditures (CAPEX). Operating Expenditures (OPEX) are also calculated in this step, either by applying mark ups on the investment by being calculated per network items or other criteria, e.g. fixed absolute values or event or customer driven fixed values[18]. Finally common costs assignable to the access network are considered by a mark-up factor.

As last step the cost calculation aggregates the cost and distributes it to the number of access lines being installed in the MDF/ ODF access area.

Calculating the results per MDF/ ODF area allows to combine them to a national average, but also to averages defined by other criteria, e.g. subscriber density, urban/ rural, etc. It also allows to consider the development over time by assuming different network deployment per MDF/ ODF area over time (e.g. copper only, copper/ fibre overlay, fibre only).

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[18] For ease of model use, ease of data generation (availability of reference and benchmark data) and good averaging effects we normally apply mark-ups only.

3.1 Cost Approaches

In the telecommunication market the regulatory authorities i.a. have to answer the question, what are justifiable prices an incumbent operator may charge its competitors for bottleneck infrastructures like the access network and its components, when they are offered in a wholesale manner. In such a market there will not occur effective competition such that the answer is given by the market itself. In a competitive market the price would be that large that it will cover the effective cost plus a risk margin. One could say that in a competitive market an operator would not be willing to pay more for an asset or service than it would cost to produce the service by its own - the classical make or buy decision.

Following this assumption the upper limit for the price would be the forward looking cost for producing such a service or asset, in a comparable scale addressing the whole market, and in the most effective manner. This also implies that the decision would be made based on today's prices (current cost) and state of the art technologies. This approach is called **FL-LRAIC** (Forward Looking-Long Run Average Incremental Cost) or FL-LRIC (Forward Looking Long Run Incremental Cost). In order to emulate such a price one has to plan the required assets and all prerequisites bottom-up to be constructed in the most efficient manner. Another approach, to value the existing assets of the existing network with current prices would include possible inefficiencies inherent in the network deployed, e.g. caused by historic development or other reasons. Therefore state of the art regulatory cost/ price determination bases on bottom-up FL-LRIC cost modeling at current cost, as it is demanded also for the cost model described here.

Implicitly this evaluation approach assumes that the demand for the requested assets is in a longer term increasing or constant, but not decreasing, because no operator would decide to construct the assets new by its own when demand for the assets decreases, and that market has no longer term future. The price would be lower and ideally orientate itself at the **opportunity cost**, or the profits an operator still can earn in this decreasing business. To predict this is not easy to undertake, unless there is a reference price given by a sales deal where an operator bought such a set of assets from an incumbent. The bottom line for prices in a decreasing business is the cost incurring to operate and maintain the assets for the rest of its use. This cost is called Short Run Incremental Cost (**SRIC**).

Applying this economic theory to the copper and fibre access networks existing and being planned or already deployed in many European countries, so in Spain also, will doubtlessly identify the copper access network as a declining market, where demand decrease is caused by the poor broadband transmission capacity of the copper lines, accompanied by better performing offers of cable-TV operators and fibre access networks, and also induced by a general trend to mobile only solutions, especially by single person households. While the copper networks come to the end of its transmission capacities the fibre access networks are just at its infancy concerning capacity, and thus will experience a long term increasing demand future. Thus the copper access lines may no longer be evaluated at the FL-LRIC scale, and the bottom line of its evaluation will be at the SRIC. (For prices lower than SRIC no operator would operate and maintain copper access networks.) The evaluation of the fibre access network and its assets is determined by a long term increasing demand and therefore the price of the assets and services has to be set at the FL-LRIC level. This approach is supported by the fact that in many European countries not only the incumbent, but other investors also are investing in fibre access networks, thus are willing to spent bottom-up FL-LRIC cost for such assets.

Hence the wholesale price for fibre assets will be evaluated by the FL-LRIC approach. The prices for copper shall be between FL-LRIC, calculated at the highest demand as an upper and SRIC, calculated at the actual demand, as a lower limit. Typically cost for civil infrastructure and copper cables have been lower in the past than today. Thus one may wonder if the **historic cost** for these assets, taken from the incumbent operator’s accounts, may be an appropriate scale for copper price estimation. At least this approach may help to recover the expenditures of the past, if they are not recovered yet. If they are already recovered, the historic approach also finds its baseline in the SRIC. If they are not recovered yet, one may think about an appropriate uplift. In any case, copper access lines, which are no longer required, either from the incumbent or by the competitors due to the decreasing copper line demand, are **sunken investment**. They are of no use any longer. Thus SRIC and optional historic cost uplift have to be distributed to the requested decreasing asset demand, increasing copper access line cost over time. Hence the historic cost approach is, if not at already in a full depreciated state and therefore at SRIC, of doubtful use. One has to keep in mind that the historic cost approach has to emulate the opportunity cost, which is the only reasonable approach for declining markets, and which does not cover a price increase due to declining demand. The historic cost may be used as a proxy, neglecting the declining demand, but taking the initial demand as constant.

Typically it is not easy to get historic cost. The balance sheets of the operators normally show capital assets in larger items, describing complete projects or sub-blocks of it without any detailed itemization, which would be required in order to define historic cost per each item out of which a bottom-up cost model is constructed. Even if one goes down to the level of bills, which have been the original information as input in the balance sheet, these also often do not show itemized positions, but project prices for a total sum of single positions, which, if at all, could be itemized in the quotations only - at prices being adapted in later negotiations. Thus effort is getting larger and larger and the correct historic value nevertheless cannot be received. Therefore also due to practical reasons historic cost are more a theoretical than a practical approach.

WIK-Consult therefore recommends in one of its recent studies[19] to keep the copper access line prices during the installation period of a new and future oriented fibre access network at its passed high prices, based on current cost, calculated for the high demand of the past in a bottom-up FL-LRIC manner in order to motivate the incumbent investor for a fast transit, and already announce the cost decline to SRIC after a given period of time. The conclusions of this study are summarized in section 3.1.1. A second subsequent study WIK-Consult[20] conducted for answering the consultation of October 3rd, 2011 of the European commission is based on the model and cost figures of the previous study. It modifies and enhances the recommendations of appropriate price settings for copper and fibre. The main findings of this study are summarized in section 3.1.2.

Applying this theoretical approach to the deployments described in the chapter above (copper only, fibre only, copper/ fibre overlay) for fibre only the start point of the copper pricing will be the initial (high) copper demand and its FL-LRIC investment and cost. The SRIC may be calculated by setting the investment values to zero.

In a fibre only environment the highest demand of fibre lines within the consideration period, e.g. the final fibre demand, determines the bottom-up FL-LRIC calculation, since the access network will be installed at the beginning in order to serve the future demand of the consideration period. (Nobody would dig twice.) Eventually existing old copper access network assets are of no use any longer, thus sunk investment and out of consideration.

In a copper/ fibre overlay environment one assumes that the ducts for both, the copper and the fibre access lines, exist already from the beginning. The assets for both access networks are distributed among them according to their use. Significant advantage of this consideration method is the synergy resulting from the common civil engineering and construction. Both, the copper access lines and the fibre lines, will be evaluated as described before. The concrete decreasing copper demand will be considered within the band of FL-LRIC and SRIC, neglecting the concrete decreasing amount of copper lines in an economic depreciation, the concrete increasing fibre demand may be considered by an appropriate depreciation method, which incorporates an increasing demand within the consideration period.

While the section 3.1.2 gives an overview of the depreciation methods applicable in the model the application of the cost approaches described here are detailed in section 5.4.4.

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[19] Hoernig, Steffen; Jay, Stephan; Neu, Werner; Neumann, Karl-Heinz; Plueckebaum, Thomas; Vogelsang, Ingo: Wholesale prices, NGA take up and competition, Bad Honnef, April 2011

[20] Neu, Werner; Neumann, Karl-Heinz; Vogelsang, Ingo: Cost Methodologies and Pricing Schemes to Support the transition to NGA, Bad Honnef, December 2011

3.1.1 Summary of a study about Wholesale Pricing in migration to NGA

WIK-Consult conducted a study[19], investigating the migration from copper access networks to NGA under different wholesale price settings. Since the study deals with comparable topics, it may be worth repeating here the major conclusions. Input to a game theory based competition model had been cost functions derived out of a WIK NGA cost model. The study was based on access network structures of a typical, but hypothetical European country with approximately 40 Mio. inhabitants, called Euroland, which MDF access areas had been clustered into 8 clusters of descending population density. Core of the study is the game theoretic model and its results. Several market entrants are playing against an incumbent deploying a copper and fibre access network. Equilibrium will be achieved when all players make profit, but with one more player the entrants will make losses. In addition a cable operator joins the game. Main variables are the wholesale prices in the competitive market and its influence on the operator's profits and customer surplus.

- Our model analysis is restricted to clusters 1 through 4 and therefore does not include most suburban and all rural areas. Changing the areas covered will affect costs and thereby the quantitative results, although we believe the qualitative results to be robust.

- In the case of an integrated incumbent (operating copper and fibre) the decision to switch to fibre is driven primarily by the access charge differences between copper and fibre relative to their respective costs. Obviously, the incumbent's profits are influenced by many factors (e.g. costs, market share, retail prices), wholesale access charges being only one of them. Our results, however, suggest that their influence can be substantial. The relative wholesale charges determine the profitability of one technology compared with another.

- The absolute level of aF[21] plays a role in the investment decision only in so far as profits from fibre investment have to be non-negative in order to enable investment financing. However, absolute pricing levels for copper and fibre access have significant implications for the levels of retail prices, number and profitability of competitors, and consumer welfare.

- An equilibrium with both copper and fibre is possible, but unlikely. It can occur because duplication of downstream costs can be avoided and because the overall number of entrants can be lower. A speedy migration strategy is therefore essential in stimulating fibre roll-out.

- We can distinguish three scenarios of wholesale access charge combinations:

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[21] aF: wholesale fibre price, aC: wholesale copper price,

  - At the current European national average copper access charge of aC = 8.55€ a fibre access charge of €19.49 (significantly above the cost-based rate) would be needed to induce investment in fibre. At these wholesale rates, fibre ARPUs would be approximately €42 compared with copper rates of €29. Consumer welfare under copper would be 18% lower than in the CS maximising case. This scenario is unlikely to reach the Commission’s Digital Agenda ultra-speed broadband targets.

  - If fibre unbundling charges are set on a Brownfield LRIC basis of €11.65 per month as calculated through the Euroland model, the corresponding copper charge at which fibre would be more profitable than copper would be €3.42. In this scenario fibre ARPUs would be €36 compared with copper ARPUs of €21. Consumer welfare would be maximised.

  - If Brownfield adjustments do not apply (for example if existing ducts cannot be re-used for fibre), then Greenfield LRIC for fibre would be €13.92 per month and copper prices would need to be set at €6.06 in order to stimulate fibre investment. In this scenario copper ARPUs would be €27 and fibre ARPUs €38.

- Although efficiently low levels of aC would help better capacity utilization of copper while it is in use (i.e., stimulate take-up of broadband) and would increase incentives for a switch to fibre, such low levels of aC may lead to a rate shock[22] when the switch to fibre occurs. Other investment triggering scenarios involving higher aC would also generate rate shocks of €11 per month or more.

- The avoidance of a rate shock associated with a switch to fibre could be achieved in a number of ways. One way could be to facilitate retail price differentiation on fibre (e.g., charging “copper” prices for lower speeds over fibre). However, this approach raises competitive challenges and necessitates equivalently higher charges for “fibre” speeds.

- Our modelling favours an approach under which regulators **signal** that they plan to decrease copper prices to the relevant levels (e.g., through a glide-path), but would allow rapid switch-off of copper if fibre is installed on fair terms and conditions with LRIC-based unbundling charges. In this scenario investment should be triggered and a potential rate shock limited to the gap between current ARPUs of approximately €29 to the marginally higher fibre Brownfield ARPUs of €36 associated with LRIC fibre unbundling charges. Consumers would immediately benefit from higher capacities offered by fibre.

- Our results are founded on a base case assumption that in the long run customers (including both consumers and business users) would be willing to

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[22] A rate shock is a sudden price jump from a low to a high level.

pay an average of €40 per month for fibre-based services compared with €32 for copper-based services. If this price premium cannot be sustained – i.e. if customers value copper more highly relative to fibre than under this base case scenario (we examine copper ARPU of €33.50 compared with fibre ARPU of €37.50), copper would be profitable over a wider range of prices, and therefore the gap between the copper and fibre access charges would have to increase relative to the base case to trigger the investment in fibre.

- We have included cable as a player within our base case scenario. We assume that this technology offers capabilities which lie between copper and Point-to-Point fibre and that consumers' willingness to pay for cable is determined accordingly. Whilst the retail prices for the market as a whole are strongly influenced by the underlying wholesale charges, the presence of cable adds an additional constraint in that higher copper (and/or fibre) charges will in the presence of cable, cause some customers to migrate away from the incumbent towards what is viewed as a superior (or cheaper) technology. Other things equal lower profits for copper and fibre will result from the presence of cable. The effect of the presence of cable on the incumbent's incentive to invest in fibre turns out to be ambivalent, since it affects both copper and fibre profits.

- The business case of an independent fibre investor is only viable either at copper charges which are so low (below SRIC) that the incumbent would logically exit the market, or at access charges which are so high, in both copper and fibre that consumer welfare would be significantly compromised.

- Unless access charges are very high, profitability of a technology usually requires a high market share, which can be achieved by a combination of incumbent's and entrants' end-user sales.

- Entrants help the incumbent of a particular technology because they take away customers from the other technology and because they buy access at wholesale charges that contribute to cover fixed network costs.

- We have modeled alternative consumer valuations of copper and fibre in the spirit of sensitivity analysis. However, there is also a dynamic interpretation, according to which the relative valuation of fibre against copper increases with time. This would hold because of expanding new applications for fibre only. This could mean that the increased valuation would be a function of fibre networks actually being built under the motto of the movie *(Green-) Field of Dreams*: “If you build it they will come.”

- Welfare is mostly depending on the switch to fibre and the relative valuation of fibre against copper. Welfare under fibre is generally higher than welfare under copper, because of the higher consumer valuation for fibre that, in this case, exceeds cost differences. If fibre is valued highly a switch to fibre significantly increases welfare. Further increases could result from spillover effects not covered in our analysis.

- Consumer surplus is depending on both, the switch to fibre and the level of access charges. A switch to fibre generally increases consumer surplus, while increases in access charges tend to significantly decrease consumer surplus. The latter effect is augmented by the exit of entrants as a result of higher access charges.

- Under a Brownfield[23] LRIC scenario in which fibre access charges are €11.65 and copper prices are set at or below the switching point of €3.42, the market supports one cable operator with 28% market share, the fibre incumbent with 23% and 3 unbundling-based entrants with 16% market share each. With copper charges at today's average rate of €8.55, no fibre investment would occur, and the market would support one cable operator with a market share of 33%, and incumbent with 20% and 3 entrants with just over 15% market share each. This market structure does not exist in many markets today and reflects an assumption of perfect regulation. In practice, incumbents in Europe maintain an average of 45% of retail market. In contrast, our model is free of margin squeeze and discrimination and therefore leads to higher market shares of entrants than we find in a less perfect world.

- The retail profits of entrants and the incumbent's retail operations generally decrease in access charges but the effect may go in the opposite direction for the remaining entrants if higher access charges force the exit of entrants. Higher access charges significantly increase the incumbent's total (wholesale and retail) profits. Cable profits always increase in access charges except for a switch to fibre triggered by an increase in the fibre price.

- Entrants' profits mostly depend on the number of entrants and vary substantially. They are highest just before the point where additional entry is induced and lowest at the point at which entry has just occurred.

3.1.2 Summary of a study about Cost Methodologies and Pricing Schemes to Support the Transition to NGA

Based on the model and findings of the study mentioned above (section 3.1.1) a subsequent study[20] enhances the view onto appropriate wholesale copper and fibre access line pricing in order to motivate and accompany the copper fibre migration constructively. The main results are:

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[23] Existing ducts can be used at lower cost in contrast to greenfield deployment

1. There are two different perspectives on cost which are of a fundamental nature. The one perspective is that of a decider who has to decide on a future course of action regarding his or her business. Typically, such decisions involve the use of resources and it is the costs of these resources that need to inform the decisions. This is the so-called forward-looking perspective. The other perspective on cost concerns the recovery of the investment cost once it has been incurred. These two perspectives need not be the same, but there is reason to assume that the two coincide under effective competition. Both perspectives have lead regulators to widely focus on the FL-LRIC cost standard to determine cost-based regulated wholesale prices.

2. The FL-LRIC cost standard, however, no longer is appropriate to be applied for the copper access network for five reasons: (1) Copper access is no longer the modern equivalent of a fixed-line access infrastructure; (2) Demand for copper access is declining; (3) No newly entering operator would invest in a copper-based access network anymore; (4) Given the actual lifetime of the copper access network and its status of depreciation, applying FL-LRIC furthermore would lead to a (significant) over-recovery of costs for the network owner; (5) Given the cost drivers of an access network, applying FL-LRIC furthermore would lead to increasing costs, in contrast to the real market value of the copper access network assets and the opportunity costs of the operator.

3. In section 3[24] above we argue that in the case that the demand for copper is steadily declining, the cost concept for the copper access network should be SRIC+, which would be the short-run cost of maintaining the network plus an opportunity cost component reflecting consumers' valuation of the network to be determined on the basis of incentive pricing. We also argue that if an independent estimate of SRIC+ is required, cost on the basis of HCA might be a default solution, lying as it does between SRIC and a cost determined as if FL-LRIC were still applicable. Regulators should take care to reflect depreciation when applying HCA such that fully depreciated assets are not subject to double compensation.

4. For fibre the decision-relevant cost is a mix consisting of FL-LRIC for the fibre part and the so-called Brownfield approach for the duct part, whereby “Brownfield” reflects the extent to which existing ducts may be reused or there is a need for installing new ducts for the purposes of installing fibre. In respect of the Brownfield cost of ducts we argue in Chapter 1 that, if the information for determining the proper Brownfield cost is not available, cost on the basis of HCA can be used as default solution.

5. For regions in which either copper networks or ducts are in a situation of nearly steady state, the costing concept of Investment Renewals Accounting (IRA),

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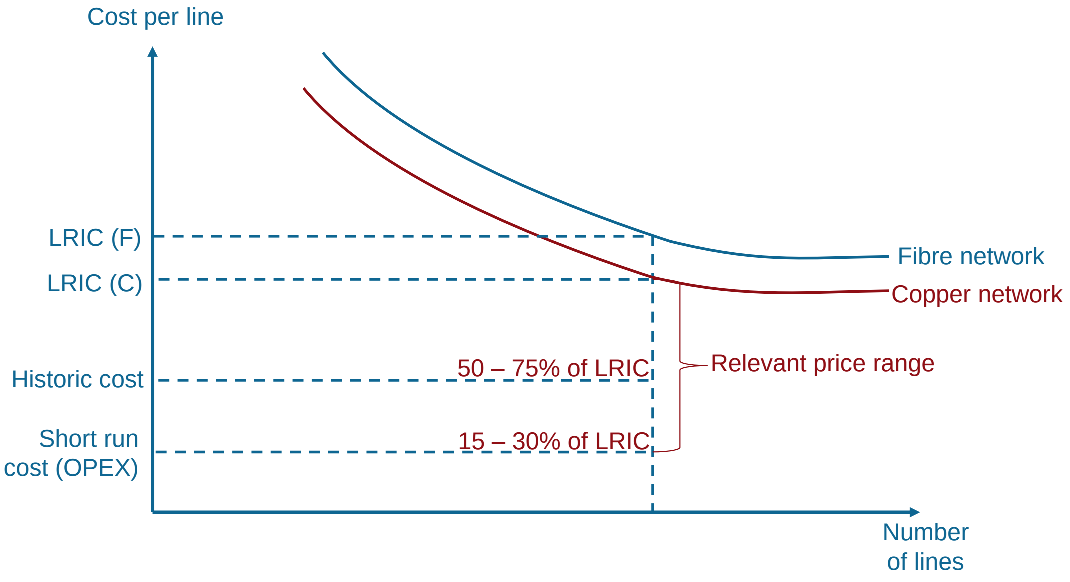
[24] reference to this study

whereby only the cost of renewal investment are recognized as a depreciation equivalent, is applicable.

6. Only detailed cost modeling for each individual Member State can tell where the relevant access costs according to the cost concepts used in this paper actually are. The following graph can, however, provide the relevant structural relationship between the relevant cost concepts in a stylized form. The current European average for the copper ULL price is at 8.55 €, in most cases calculated on the basis of a FL-LRIC concept. From the rough available information on the actual historic cost of the copper access line, we expect that value to be in the range of 50% - 75% of the current ULL price. The SRIC of the copper access lines will only amount to 15% - 30% of the current prices, which in absolute term means a value between 1.50 € and 3.00 €. Fibre access is somewhat more expensive than copper access. In our previous Euroland cost calculations fibre access amounts (at a 40% coverage ration) to around 14 € per line in a Greenfield deployment and to around 12 € if (some) existing ducts can be used (Brownfield approach).

Figure 3-4: Relevant access price range for copper and fibre



wik CONSULT

7. A copper incumbent will invest in fibre if total expected profits from such an investment exceed the expected profits from staying with copper. This decision is influenced by the copper and fibre wholesale access charges, because these are main factors influencing the profitability of both these technologies. High copper access charges (relative to relevant cost) and low fibre access charges (relative to

relevant cost) make fibre investment less attractive to the extent that they would result in high copper profits relative to fibre profits.

8. While the incumbent's decision to build out fibre would be favoured by a low copper access charge, the resulting low copper end-user prices could prevent such customers to switch to fibre, when it is available. Thus, after the fibre network has been built copper subscribers may not want to switch to fibre, as long as the price difference between copper and fibre is large and copper remains available.

9. In the WIK study "Wholesale pricing, NGA take-up and competition" we put forward the proposition that a rate shock could be mitigated in the transition from copper to fibre by signalling that copper charges would come down through a glide-path, thereby encouraging the dominant firm to invest before copper prices decline significantly. This remains a relevant option. However, in its consultation of October 3, the European Commission has put forward an alternative "incentive pricing" scenario whereby incumbents would be allowed to keep wholesale copper access charges high, provided they credibly commit to a timetable for building out the NGA network and follow through on the build-out. We have assessed such incentive pricing schemes in the current report.

10. In cases where the incumbent has entered into a commitment for fibre build-out we discuss the following pricing options for the time after commitment and for the transition phase, in which both copper and fibre services are offered:

    (1) Copper and fibre charge both at the level of LRIC of FTTH.

    (2) Same average price for copper and fibre, based on copper and fibre costs and the relative weights depending on the share of fibre build-out. Within this option we differentiate the case that the copper component of the average price is determined by the relevant copper costs according to HCA or SRIC+ (Option 2a) from the case where the copper component is equal to the current price for copper (Option 2b).

    (3) Only the price of copper is based on averaging (as in Option 2), the price of fibre is based on the LRIC of fibre.

    (4) The price for copper remains at its current level in case of commitment and faces a glide-path downwards in case of no commitment.

11. Any commitment to NGA build-out should address the type of NGA investment, regions covered and the time frame for build-out. The NGA network to which the commitment applies should be open to wholesale access, preferably through unbundling.

12. The incentive pricing options proposed by the Commission rely on attracting a commitment to invest by maintaining copper access charges above relevant cost levels. However, this will only incentivize NGA build-out if there is a credible commitment by the regulator to keep following the policy that has been the basis for the incumbent’s commitment. This requires that there are sanctions in place that induce the incumbent to follow through with the commitment (profits should be lower if the commitment is not met) and that the regulator will actually want to apply if the incumbent violates the commitment.

13. Raising or maintaining copper access charges above relevant cost could also raise issues of consumer welfare and competitive neutrality since contributions to excessive copper profits come to a large extent from consumers and alternative operators who pay the higher copper access charges. They should also benefit e.g. by lowering initial fibre access charges or by having access to the same funds in order to support their own investments. Only one of the options suggested by the Commission – averaging copper and fibre costs – would avoid these concerns. In effect, this would be a form of penetration pricing, in which fibre is cross-subsidised by copper during the period of parallel operation.

14. In order to compare the options considering all relevant factors, we calculated the corresponding wholesale prices over an assumed time frame of several periods. Relevant cost data were taken from our previous study on this subject matter. In our overall assessment, Option 2 appears to have the largest net advantages over the other options. The uniform wholesale price for copper and fibre access increases in this option over time in case there is commitment to invest in fibre and ends at the LRIC of fibre. It is the increased fibre share that triggers this increase, thereby incentivising the dominant firm to maximise the planned proportion of fibre in the network. Because wholesale charges for copper and fibre would be the same, migration would be encouraged.

15. Our overall assessment of Option 2 to become the option with the largest net advantages rests on the five criteria (1) incentive to commit to fibre investment, (2) incentive to deliver the fibre investment, (3) migration incentive for customers, (4) consumer welfare and (5) competitive neutrality. Within these criteria consumer welfare is basically driven by the degree of access profits and competitive neutrality by the issue of whether access profits are either repaid or can be used by all market players for fibre investment. The following table provides the evaluation of all options according to these criteria.

Table 3-1: Pricing options and their effects on copper/ fibre migration and economy

Option	Objective	Incentive to commit	Incentive to deliver	Migration incentive	Consumer welfare	Competitive neutrality
1	Fibre as MEA for copper (Brownfield LRIC)	Highest	Low	High	Least	Least
2a	Fibre = copper price = average of costs (Brownfield LRIC, HCA)	High	High	High	High	High
2b	Fibre = copper price = average of current copper price and Brownfield LRIC fibre	High	High	High	High	Medium
3	Copper averaged, fibre LRIC	High	Medium	Medium	Medium	Medium
4	Copper held at current charge	Medium	Medium	Medium	Medium	Medium

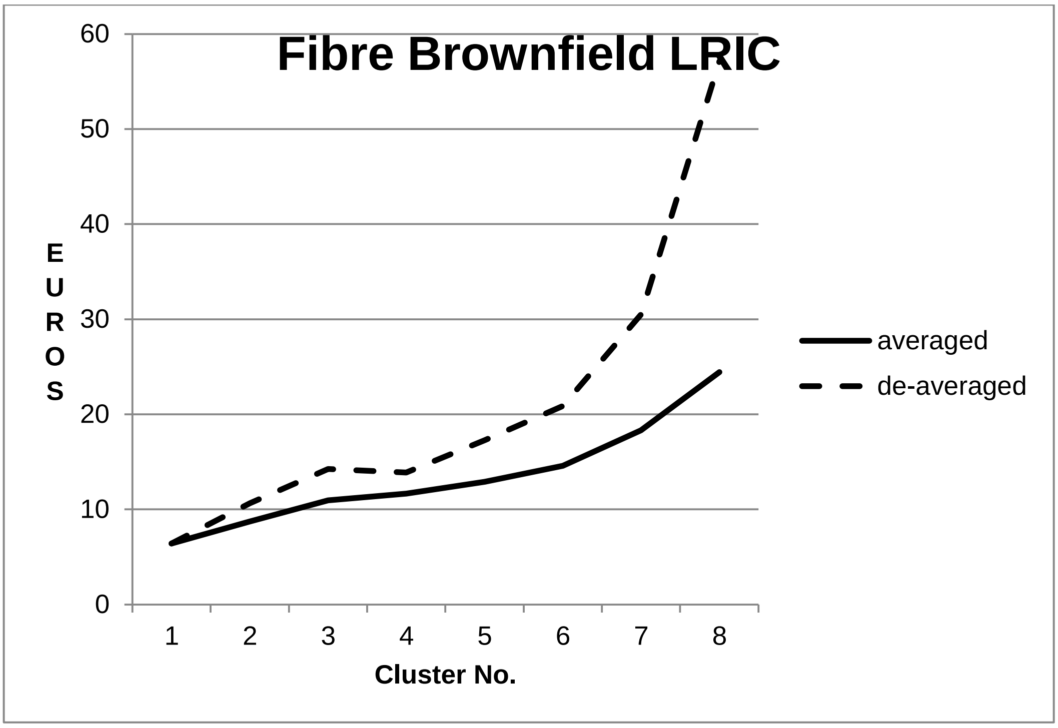
16. In order to enforce the commitment for fibre build-out we consider the following proposal: In case the incumbent does not live up to the commitment any funds generated by the incumbent above the funds, that would have been generated under the no-commitment case, should be returned to the access seekers who overpaid. Additionally, we consider a suggestion that any excess profits from copper access charges may be used for NGA build-out. This would require the establishment of a fund or surcharge, potentially outside the scope of the cost-based charging regime, which could be made available to any investor in open fibre infrastructure. This kind of scheme would be relevant only in circumstances where alternative investors to the incumbent exist.

17. Over the whole country there should be an additional retail-minus option for the access seekers. Thus, the wholesale access charge should always be the lower of the cost-based regulated access charge (including glide-path and/or averaging) and the retail-minus access price. This also allows the incumbent to compete with other access modes in high-density and low-density areas and to use penetration pricing for fibre if deemed necessary.

18. Because there are areas where FTTH is too costly to be installed, because there are only very few areas where network replicability of fibre networks is viable and areas where FTTH is a viable investment, we have to face geographic diversity in terms of deployment. This diversity may be accompanied with a certain degree of

geographic de-averaging. The graph below shows how fibre costs vary depending on whether they are averaged over the roll-out area or set on a regional basis.

Figure 3-5: Effect of price averaging vs. de-averaging for access lines



19. The effects of such de-averaging may be ambivalent. Because of the ambivalent effects, if geographic de-averaging is chosen it should always be accompanied by a retail-minus option. In case of de-averaging of wholesale access charges this would also allow the incumbent to use geographically uniform retail charges (with the consequence that wholesale access charges may have to be adjusted via retail-minus regulation). If no fibre de-averaging is chosen the relevant fibre LRIC should be based on the actual or planned economic footprint of fibre, not on the LRIC for the whole country.

20. When assessing incentive pricing, some options such as option 2 (averaging the cost of copper and fibre) would allow significant flexibility over the geographic area chosen. This could range from a single exchange, to a group of exchanges or similar areas to nationwide averaging. Regulators should take account of the effect of the geographic scope on practical implementation, retail pricing, investment incentives and consumer welfare when taking decisions about the geographic scope of incentive and pricing regimes.

3.2 Economic Depreciation

According to the given number of households the network planning tool carries out optimisation procedures which determine the quantities of network elements that are required for serving the demand. These numbers are then multiplied by the element specific prices so that the investment values are calculated. By an adequate depreciation method the investment could be transformed to cost on a per year basis (or a per month basis). There are numerous depreciation methods and which of them is best to be used depends on the given network demand evolution.

Linear depreciation is a commonly known and less complex depreciation approach. According to the economic lifetime of a network element, the investment is allocated equally over the given time period such that each period bears the same share of the total investment. During the economic lifetime cycle of an element the total investment is amortized equally year by year. Generally, depreciation approaches take into account that the price level of the network equipment could change over years. The price change of a network element that is given from one lifecycle to the next lifecycle has an impact on the amount of cost that needs to be borne in each year. An increase in investment means higher cost to be borne in each time period.

The consideration of the linear depreciation method is reasonable for markets that could be generally seen as sustainable with regards to the demand. In this project the demand is expressed as the required number of access lines (either base on fibre or copper). A demand that is stable in the long run leads automatically to an equal distribution of cost over the total demand occurring in the time period. The equally distributed costs over the time periods are distributed to the relatively stable demand leading to equal cost shares that are borne by each demanded unit over the considered time period.

In case of markets with variations of demand over time the linear depreciation method may need some adjustment, as will be shown in the following. Let’s assume that the depreciation approach is applied in a market with increasing demand. As already mentioned, the same amount of cost will be distributed to each time period. Let’s assume further, that the demand is 10 in the first year and 20 in the second. A look at the cost per demanded unit indicates that in the first year the value is twice as high as in the second year. The same amount of cost is distributed to a lower number of units in year 1. There is reasonability to take into account a depreciation method that distributes the cost to the years not equally, but equally to the demanded units. Or more precisely, to the demanded units that are accumulated over the considered time period. In the example, for the two years, the accumulated units are 30 and the cost per unit should be the same regardless of the year.

The augmented tilted annuity formula takes into account growth of demand over the years and therefore it is a commonly used depreciation method for emerging markets.

The formula includes a parameter that reflects the average growth rate per year. The factor reflects the average growth considering demand at the beginning and at the end of the time period and assumes average demand growth for the whole period. The depreciation method distributes cost to the accumulated demand equally. The approach is a reasonable depreciation method when demand is increasing over the considered time period and when this demand evolution is (more or less) the same over each year. However, the augmented tilted annuity formula is not considering volatility in the demand. For instance it considers 10% of growth for each year, even if in the first year the growth is 5%, in the second year it is 10% and in the third it is 15%. Moreover, the same growth rate factor would be applied if the growth for the three years would be 5%, 20% and 5%.

The economic depreciation is an approach that takes into account the individual demand for each year of the consideration time frame. The approach considers volatile demand evolution over the year and distributes cost equally to the accumulated demand. The economic deprecation as a method is best to be used when demand values could be provided for each year of the time period. The detailed demand provision allows to allocate cost to demand as best and has no restrictive conditions as given for the depreciation methods above.

The cost model will consider the economic depreciation as the relevant method for the calculation of cost for fibre access lines. The fibre network is regarded as an emerging market so that in our perspective the economic depreciation is the reasonable approach. The details on this method will be given in section 5.4.2. The model will be based on the demand values given for each year of the consideration time period of 20 years and that data will be provided by the regulatory authority.

By parameterizing the growth rate in the proper manner the economic depreciation formula also can be used to calculate linear depreciation (growth rate = 0, constant demand), or tilted annuity (growth rate constant <> 0).

4 Input data

4.1 Demand for access lines

The task of demand estimation which needs to be solved conducting a cost estimation survey for whole Spain requires up to date input data that allows to approximate the real demand as accurately as possible with respect to its geographic distribution and the amount of lines demanded. Fixed network access lines, in their large majority, end at buildings connecting private households and business entities to the MDF/ODF in the local exchange location.

CMT has access to cadastral information. Therefore we have been able to base the demand estimation on an almost complete set of real estate information, covering entire Spain with the exception of the Basque and the Navarra region.[25] For each cadastral parcel the type of use is known so that the number of all residential and business users per parcel can be extracted from the data. To derive the location of demand, the number of portal numbers per parcel are counted and distributed along the street sided boundary lines of the buildings inside the parcel polygon. In Figure 4-1 a cadastral parcel is depicted, for which 9 portal numbers were counted. These 9 points are distributed to the street side the portal belongs to, which is indicated by the green points beside the portal numbers. These points serve as aggregation points for the locally available information on residential use of real estates (featuring households), which will be differentiated between holiday and permanent use. The portal points serve also as aggregation points for the business type of use of real estates per parcel.

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[25] For Basque and Navarra, real estate information is not available so that we use a workaround with demand locations derived from street layer information and household and business demand derived from census block statistics, approved by CMT.

Figure 4-1: Aggregation points per parcel

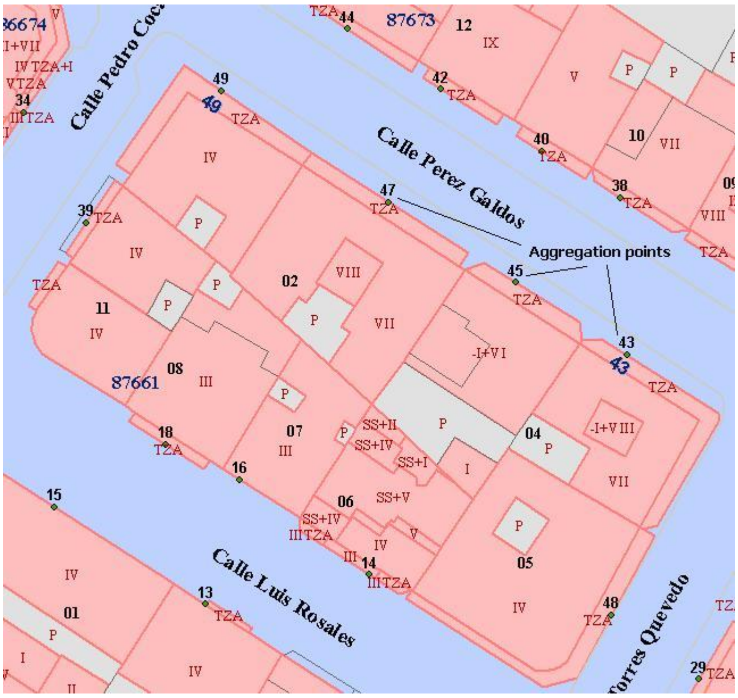
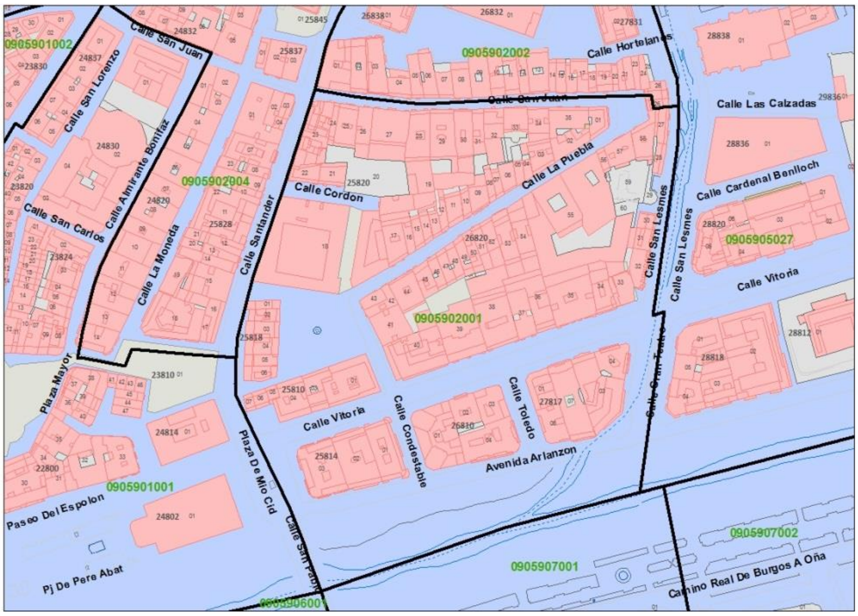


Figure 4-2: Example census areas



In the case of Navarra and the Basque region the information available is much simpler. The location of demand will be derived from the portal number information provided by the street layer information and the number of households, flats and businesses will be derived from the census block information. For each census block the number of households, flats and businesses will be randomly distributed to the portals within a census block area.

At the end of the data preprocessing, for each portal the number of households, the number of businesses and the number of flats is known. This information will be available for every building in Spain.

Furthermore from the cadastral data the construction date of the building and the number of floors and apartments per building is extracted, which is important in the process to derive the number and location of the building access cables and the type and cost of in-house cabling. For the Navarra and Basque region such information is not available. Thus we have to use average values derived from the neighboring provinces.

Now, all potential end points of the access network lines are known. These form the entire potential access market. In the next step the number of demanded fixed network access lines[26] has to be allocated to the potential end points.

The total number of demanded lines is distributed to the portal locations according to the number of households, buildings and business entities per portal. This is executed in a random allocation process described below. The total number of copper lines and the total number of fibre lines to distribute will be considered according to the maximum of the predicted demand of each in the long run period under consideration. The total current line demand for copper will be used as demand estimate for copper. In the case of fibre lines the demand is rising over time so that the maximum demand can be expected for the end of the long run period under consideration. Both figures, the expected total number of copper pairs and the expected total number of fibre lines, will be determined at this stage of the process together with CMT.

For the copper and fibre only deployment cases the demand is distributed to the potential end points by considering a high priority for business customers, allocating an access line per business customer first, before the rest of the available access lines is distributed to the residential homes (flats) with equal probability. This will also reflect

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[26] Normally one can assume the demand for fixed network access lines to be lower than the potential market (that includes in addition mobile only, cable and non-users). And of course the demand for copper access lines needs not to be equal to the demand for fibre access lines. Even the initial existing copper access line demand needs not to be the same as the final fibre access demand at the end of the consideration period (of 20 years).

that there is a higher probability for a building to become connected if it houses many residential endpoints[27] (or even business customers).

For copper/ fibre overlay the demand distribution considers for copper the same demand allocation as described for copper only above. This reflects that the copper access lines already are widely deployed and its demand distribution does not follow a roll out strategy of a new infrastructure. For fibre we assume a higher commercial interest of the operator deploying an access network to serve denser populated areas first, because they are more profitable. This will hold for the start phase of fibre deployment which we assume to be up to 40% of the total possible demand. If the final fibre demand goes beyond this penetration, we assume the penetration process already described for fibre only above, since the demand is already in a grown up state and will be widely spread. In addition one has to keep in mind that in the copper/ fibre overlay case the ducts required for fibre deployment are already in place.

For a final fibre demand below 40% the model allocates the fibre access lines, described by the relevant demand, to the potential end points with an additional probability which depends on the size of the building. More precisely, the additional probability depends on the number of business units and flats being assigned to a portal. This process requires per ODF/ MDF area - or easier per group of MDF/ ODF areas (clusters) - a parameterization of the portal size and the appropriate probability, described as an integer multiple of the one flat per portal probability. An example is described in Table 4-1. This demand distribution will serve larger buildings with a significantly higher probability[28].

Table 4-1: Probability of access line distribution in relation to portal (building) size (example)

No. of business and residential home entities per portal	Higher access line probability compared to one flat per portal
1 - 2	**1**
3 - 6	**2**
7 - 12	**3**
> 12	**3**

In the Spanish access network, according to CMT, there are 148,000 lines connecting households via radio access (TRAC) links. This demand will not be relevant when calculating copper and fibre fixed access networks. Since radio access is typically used in areas where fixed line access is not available or too expensive, those lines most

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[27] The probability of a building to become connected is the multiple of the residential home's probability to get an access line assigned with the number of residential homes.

[28] The probability for a building to become connected is the multiple of the natural probability of the residential and business locations' probability to get a fibre access line assigned (see footnote above) and the probability of the building in Table 4-1.

distant from the MDF will be determined and excluded from demand. To determine the number of radio access links per MDF to be excluded CMT provides figures on the amount of radio access lines per province. In each province for the 50% of the MDF having the largest area those homes are determined, which have current copper demand and the longest street distance to the MDF location, until the number of TRAC lines per province is achieved[29]. Those homes are then considered as TRAC connected homes and will therefore be deleted from copper and fibre demand. For the calculation of bitstream cost the radio access links will be included in the calculation with their average cost per line.

The existing copper access line demand, but even more the estimated future fibre access line demand, varies over the regions. Thus this demand is described per MDF/ ODF area. In order to ease the model parameterisation one can also group MDF/ ODF areas into groups of the same access line penetration (same share of penetration in relation to the total MDF/ODF homes). We would expect groups with fibre access lines only, with copper lines only, even after the consideration period of 20 years, and with a copper/ fibre overlay mix of different demand growth and final penetration rates of the potential market.

At this step the demand for cooper and for fibre will be determined to process the pure copper, the pure fibre and the copper/ fibre-overlay model computations. In the copper/ fibre overlay the location and the amount of demand for fibre may differ from the demand for copper.

The consideration of cascaded splitter architectures in FTTH P2MP networks makes it necessary to determine the number of fibres to be considered at each portal. The splitter to allocate at each portal with line demand will be determined by the smallest possible splitter size chosen out of a list of typical splitter sizes, which satisfies line demand, under the constraint of the maximum allowable splitting factor. If the line demand exceeds the maximum allowable splitter size, additional splitters and feeder fibres will be allocated in the same way, so as to meet the remaining demand. For each splitter per portal one fibre line will be counted (headed to the direction of the ODF), determining the correct line demand in the network routing in case of the GPON-architecture.

4.1.1 Homes passed and homes connected

In this section it is highlighted how the demand distribution used in the model relates to the well-known expressions of homes passed and homes connected.

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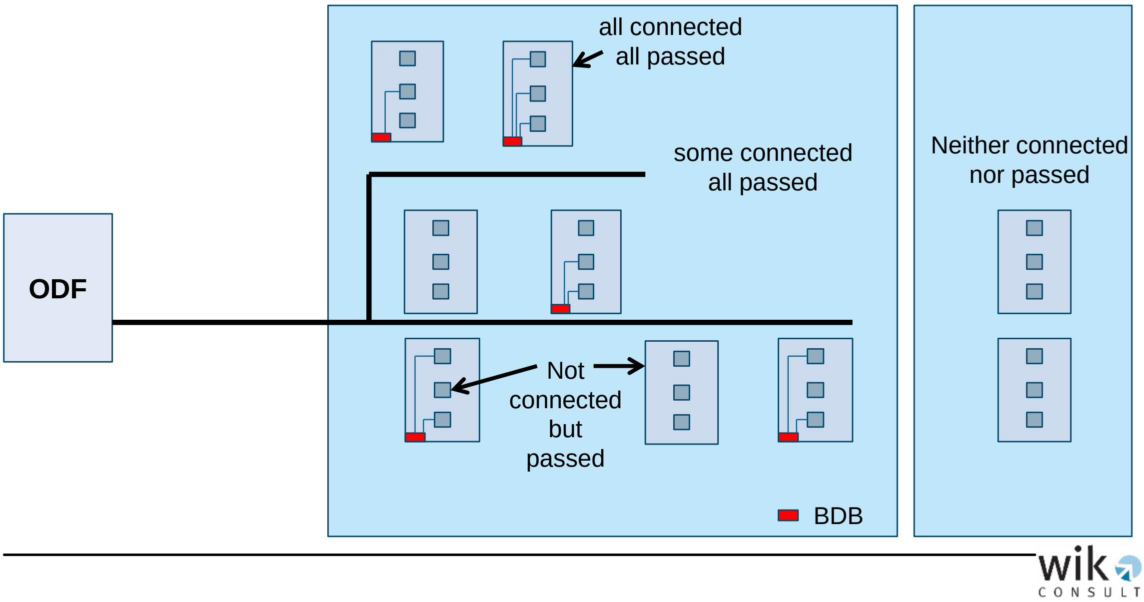
[29] Another iteration with the next 25% of MDF would be chosen if the number of TRAC lines is not achieved yet.

The potential market is described by all households and enterprises. Both, households and enterprises, are called homes in the discussion of this section. Thus, 100% of homes are the potential market. Due to mobile and cable only households and some no telecommunication using households the addressable market will be lower than 100%. Typically one can assume it to be 70%, knowing that this may be less in some countries, e.g. Portugal, thus there also will exist a Spain specific value, which has to be taken into account defining the demand per MDF/ ODF area. The demand is distributed on a per home basis, not on a per house basis. The demand determined as a share of the potential market will be distributed according to the demand distribution described in section 4.1 above.

Thus: depending on the demand allocation process one can imagine that in pure business buildings there could be all business units connected to the fixed network. In buildings with households one can expect that not all households will be connected to the fixed network. Also there may exist buildings where no home is connected. This only is determined by the random distribution of demand. The probability depends on the final penetration rate chosen. If a building without any fixed network connection is at least passed by a fixed network line in the street, the homes in the building are homes passed. Also homes not connected to the fixed network, but being located in buildings which are connected due to other homes in it being connected, belong to the set of homes passed. Only homes being connected to the fixed network count as homes connected. Buildings without any home connected, which are located such that there is no fixed network distribution cable passing the building (e.g. at the end of a street), is neither passed nor connected, and so the homes are not connected also. Thus we have to consider three sets of homes: homes connected, homes passed and homes neither connected nor passed (Figure 4-3). Homes connected are a subset of homes passed.

Figure 4-3: Homes connected and homes passed



The homes connected are modelled by the random distribution described before. The total amount of homes connected is described by a percentage of the potential market. This value directly reflects the homes connected, thus the parameter “homes connected” is an input parameter to the demand distribution process of the model. The homes passed are a result of the modelling process, thus not an input parameter. By connecting all homes being selected as fixed network access points the model constructs an efficient graph, which will pass by buildings without connections and buildings with connections, but also including homes not being connected. Thus the figure of homes passed only can be determined after the model run. Then, and only then, one can also determine those homes neither being passed by nor being connected[30].

4.2 Street data

The network optimization is based on the street network for entire Spain. This network is used to route the demand for fixed access network lines of an exchange area from the buildings to the MDF. It is also used during the geocoding of demand connecting buildings to the closest street segment and it is used for the service area delineation to derive MDF/ ODF areas and distribution boundaries (see 5.1.1 and 5.1.2).

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[30] Both, the determination of homes passed and of homes neither passed nor connected, are an additional effort not planned to be implemented in the model. One can of course expand the model in order to generate these values. It requires a check to identify, if the building is passed by a fixed network access line.

CMT provided WIK-Consult with a street-layer from TOMTOM Release 2011/3 for entire Spain, with the highest granularity available. The street layer is connected and sub-network problems are resolved. For the network optimization task the street network will be used without routing restrictions like one-way restrictions, bridges or other barriers.

The TOMTOM street layer is connected and allows to route network connections along the streets throughout the MDF/ ODF areas. The TOMTOM street path and the exact path of the street between the buildings and the exactly geocoded portals, as described in the cadastral information and its Tramos street layer, in some cases deviate from each other. The Tramos street layer is more exact with respect to this, but contains less street information and does not allow routing of network connections. Therefore the two street layers will be combined in order to profit from the advantages of both. For the determination of the building's distance to the street and the decision of right and left deployment along a street segment the model operates with the Tramos street layer. For routing procedures the model uses the TOMTOM street layer. By taking both sources into account the model on one hand becomes more complicated and requires more computing power and time, but on the other hand delivers results of a much higher reliability, so that one can expect results of high exactness.

4.3 MDF locations

We received information about the MDF/ ODF-locations of Telefónica in a table with geographical coordinates. These include copper exchange locations and FTTH exchange locations[31] depicted in Figure 4-4.

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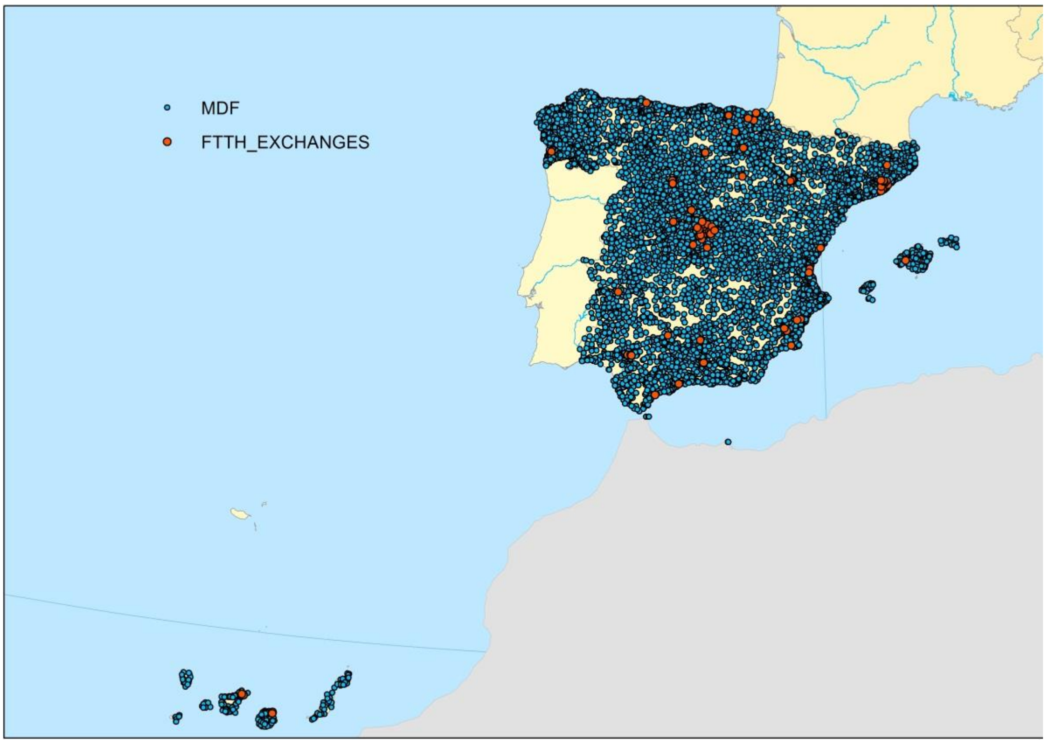
[31] The number of fibre exchanges is constantly rising. The figure shows the situation of Mai 2011 with 114 fibre exchanges as an example..

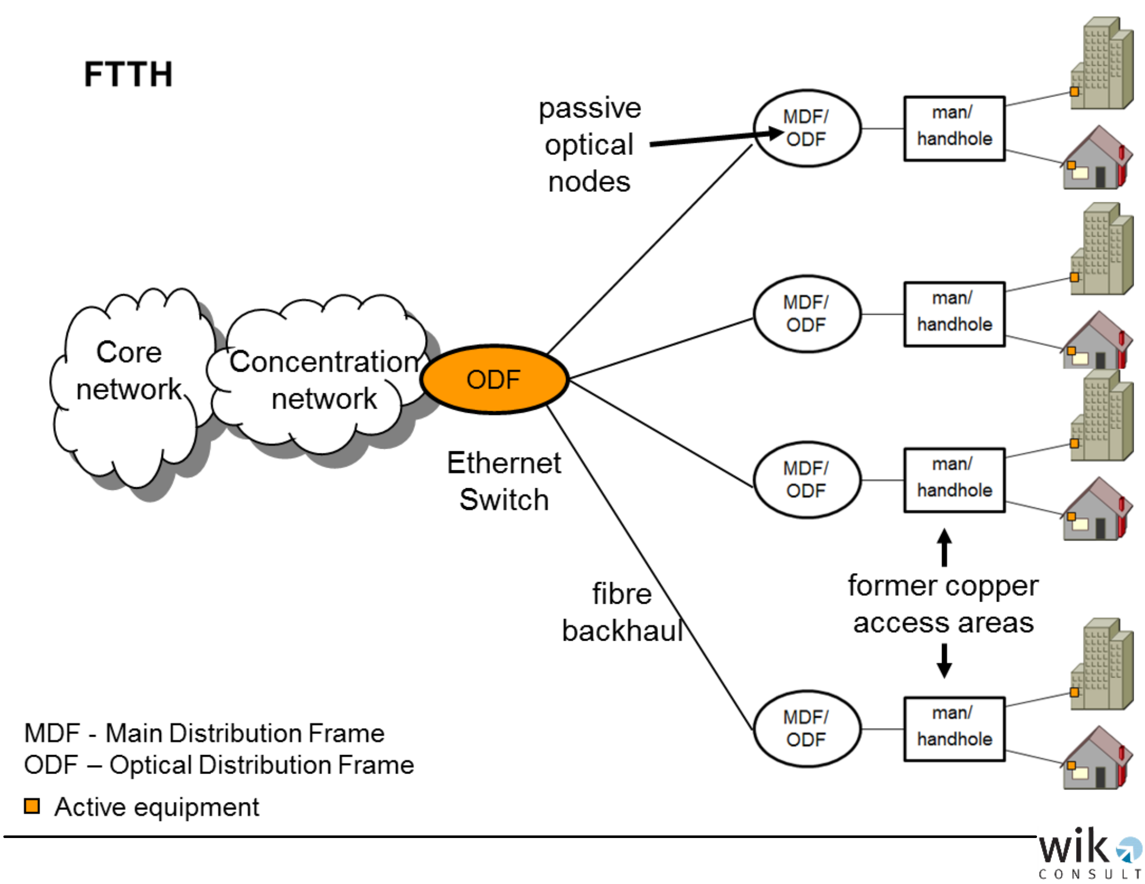
Figure 4-4: MDF and ODF locations in Spain



MDF/ ODF-locations are used as a starting point for the service area delineation in the scorched node approach of the network modeling. The procedure to derive the service area is a shortest path assignment of all street segments to the exchange location being closest by street distance. The precise procedure is described in section 5.1.1.

Separate service area delineations will be conducted for fibre only and for copper only computations since fibre allows larger service areas. For fibre only the same algorithm is used, but starting with less fibre (ODF) scorched nodes. Copper/ fibre overlay will follow the copper network topology, thus uses the copper only delineation for the combined MDF/ ODF access area. This is due to the basic assumption that in the case of two access networks in parallel (overlay) the fibre topology follows the (efficient, but earlier installed) copper topology (section 2.4). If, at a later stage of network development, the copper MDF will be dismantled, the fibres will be forwarded by backhaul lines from the dismantled MDFs to the new fibre ODFs. We assume that under these circumstances the remaining fibre ODF locations are a subset of the former copper MDF locations and cover a larger number of access lines (Figure 4-5). Hand in hand with longer access lines the concentration network will become smaller or can be replaced, so only the core network remains in operation[32].

Figure 4-5: MDF dismantling in case of copper fibre overlay, final state



As can be taken out of Figure 4-4 there are MDF areas at the Spanish exclaves in Ceuta and Melilla located at the coast of North Africa and of course at the Spanish islands that have to be considered. Exclaves and islands pose no problem to the service area delineation and access modeling as long as the street network is complete in these areas, and of course if the line demand can be estimated according to location and size.

As a characteristic of the Telefónica network there are some areas that are served via remote nodes and only indirectly via exchanges (MDFs) (Figure 4-6).

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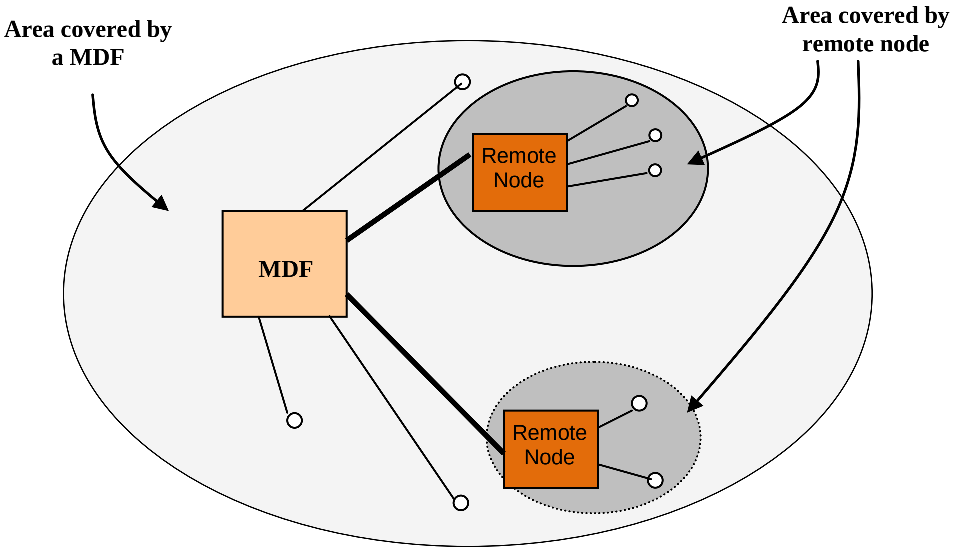
[32] Such development, based on WDM-PON Access network technology, is described in: Hoernig, Jay, Neumann, Peitz, Plueckebaum, Vogelsang, Architectures and competitive models in fibre networks, Bad Honnef, December 2010, www.wik.org

Figure 4-6: Exchanges and remote nodes



The demand connected via remote nodes has to be excluded in the study for the price of local loop unbundling, but it has to be considered in the modeling of bitstream access. To take the demand connected to remote nodes out of consideration, we have to identify the demand served by these nodes. For this purpose service areas are delineated and the line demand covered by these areas is eliminated during the calculation of ULL-prices. Table 4-2 shows the number of cases arising in the Telefónica network. There are 5,815 exchange(MDF)-areas without remote nodes. 1,786 remote nodes are within MDF areas. 3,662 are remote nodes without an exchange and account for 327,535 lines which is 2.2 % of the line's total. Telefónica has been asked to procure the location and the number of lines served by remote nodes. Such situation corresponds to the remote node deployment in year 0. Future roll out of additional remote nodes will require a new model run, since MDF delineation and demand allocation will change.

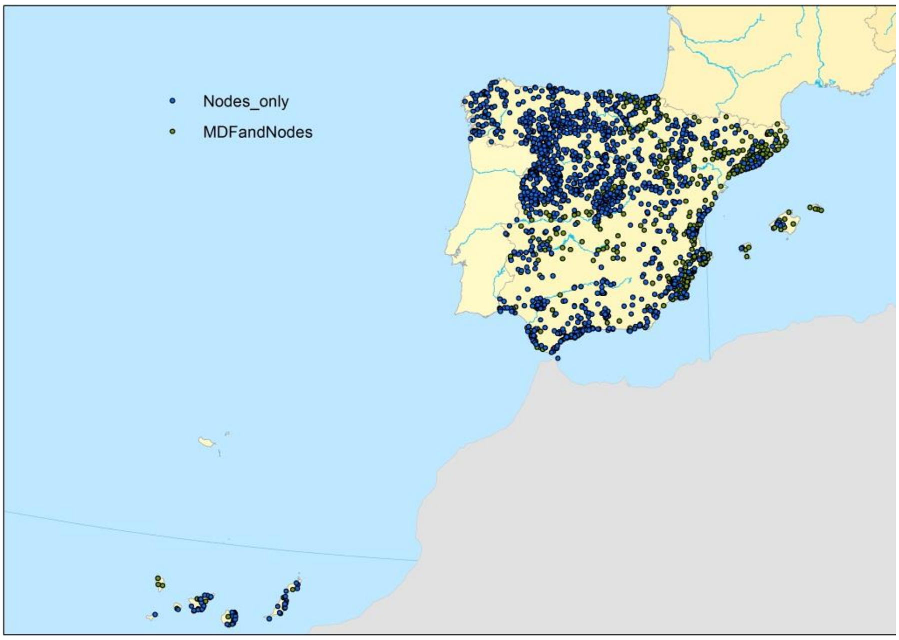
For details of the remote node cost considerations with respect to the different access network structures and the LLU and bitstream calculation see section 5.1.10.

Table 4-2: Exchanges and remote nodes

Type	Number of area codes (MIGA)	Sum of exchanges	Sum of remote nodes	Active local loops
Exchange areas without remote nodes	5,814	5,815	0	8,882,085
Exchange areas with remote nodes	721	721	1,786	5,460,346
Remote nodes without exchanges	1,746	0	3,662	327,535
Sum	8,281	6,536	5,448	14,669,966

The geographic distribution of remote nodes is depicted in Figure 4-7

Figure 4-7: Geographical distribution of remote nodes



4.4 Investment and cost data

Calculation of monthly cost for the unbundled local loop requires numerous input data on prices and on financial data. Prices for network elements and for civil engineering are only considered when these elements are being used by the service in question. Other services using the same network infrastructure as the unbundled local loop are considered according to the principles of the TELRIC (Total Element Long Run Incremental Cost) approach allowing an adequate cost allocation to the different services.

Regarding financial data, the model requires information that allows to transform investment values into annualised cost (CAPEX). The required data are economic lifetime, expected yearly average of price change and WACC. The model allows to consider such financial information for each network element individually. It operates in a consideration period of 20 years and requires the individual annual demand for the next 20 years in order to calculate the cost per access line according to the economic depreciation method.

The input requirements on prices and financial data are concentrated in a questionnaire that was sent to the Spanish network operators asking them for providing adequate answers. The operator's supply of data was reflected by taking into consideration WIK's own internal benchmark data base and expertise knowledge for generating an input parameter set to be applied for the cost study.

Other inputs considered in the model have been obtained from neutral databases managed by public institutions, like the cadastral information or the street layer.

4.5 Network topology

The model requires detailed information about the structure and topology of the access network, which was collected by the same questionnaire addressed to the Spanish operators as mentioned before. This information covers all elements of the access network:

- civil engineering, cables, ducts, chambers and manholes, deployment forms, etc.
- MDF/ ODF and its locations, remote nodes, TRAC areas, and
- all network segments (feeder, distribution, building access, inhouse cabling with its different implementation forms).

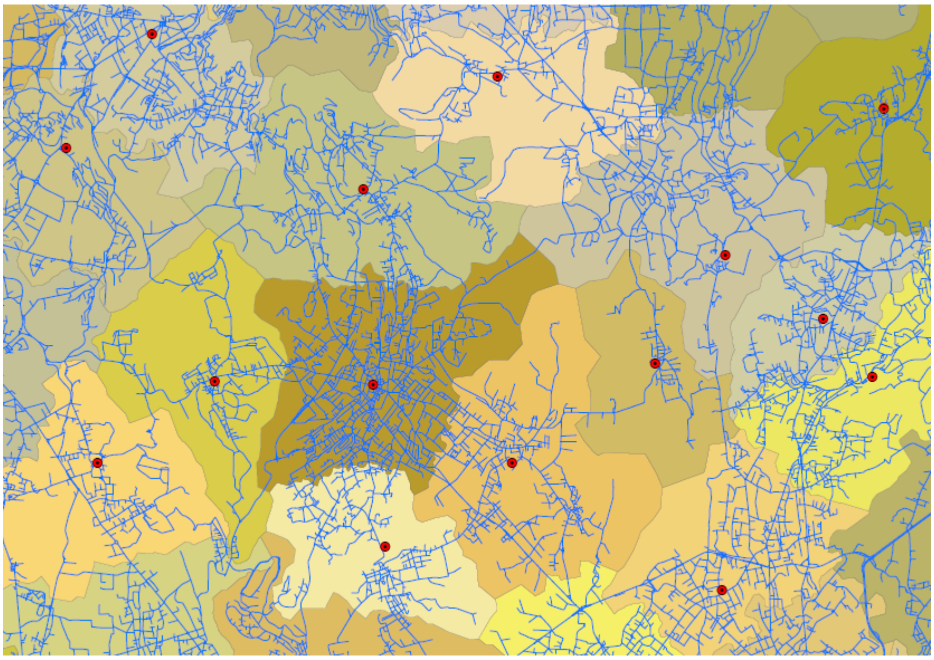
5 Cost model

5.1 Network topology and optimization

5.1.1 MDF/ ODF access area delineation

The model applies a scorched node approach with respect to the locations of the Main Distribution Frames (MDF) and the Optical Distribution Frames (ODF), it considers MDF/ ODF locations as given. Starting with the locations of the exchanges in the network of Telefónica, optimized exchange areas are derived using an algorithm that allocates each street segment to the closest MDF/ ODF by routing length (along streets). For each considered MDF/ ODF such an exchange service area is computed by the model. This approach assures by its construction that all demand within such a service area is routed to the closest exchange. Figure 5-1 shows an example of such an exchange area delineation for a few exchanges.

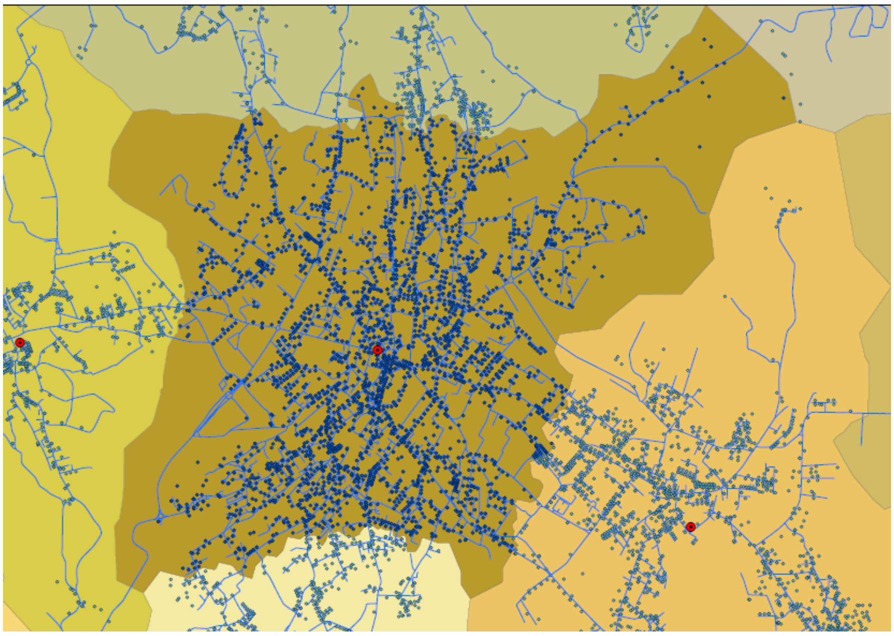
Figure 5-1: Exchange area delineation



Source: WIK-Consult

These exchange areas are used in a subsequent step to define the buildings and the subscriber demand that has to be served by a given exchange. For this purpose the exchange area identification number (ID) is passed on to the buildings falling into a given exchange service area as shown in Figure 5-2.

Figure 5-2: Defining buildings and demand served by an MDF/ODF



Source: WIK-Consult

All subsequent steps for defining and optimizing the distribution areas and the feeder network are done separately for each exchange area, starting with the building information derived by clipping the building layer for each MDF/ ODF service area.

The modeling task is designed to compute a pure fibre network (as P2P and P2MP), a pure copper network and a copper/fibre overlay architecture.

For the network design task, the main distinguishing feature between copper and fibre is that fibre networks can handle longer local loop distances. Therefore the allowable extent of the service area is larger in case of a fibre network. This implies that the service area delineation has to be computed separately for copper and fibre and the number of ODF-locations (for fibre) used as input is lower than the number of MDF-locations (for copper). Since we use a scorched node approach where the set of MDF-/ ODF-locations are used as starting points for the service area delineation, this task will result in different service areas though the allocation mechanism is the same for both network designs.

In the copper/fibre overlay architecture the basic assumption is that fibre uses the trenches of the copper network and follows the copper service area structure. Therefore in the case of copper access and in the copper/ fibre overlay the MDF locations are used as starting points for the service area delineation.

During the demand distribution to each portal the number of copper and fibre line demand is allocated. By this allocation procedure the demand for fibre is distinguished into the number of lines in the pure fibre case and in the overlay case, since in the overlay case the maximum fibre line demand can be restricted to a subset of the fibre lines in the pure fibre allocation (maximum fibre deployment threshold in the 20 years consideration period).

In the overlay case the service areas as well as the distribution areas follow the copper network delineation. The aggregation of the fibre lines along the distribution and feeder network paths is considered during the copper network computations in the way discussed in the following chapters.

Because of the differing service area delineations and the different fibre line demand the network topology optimization affords a completely separate network topology optimization run in the pure fibre case.

When in the future several overlay MDF/ ODF service areas are migrated to fibre only and are combined in a common ODF location, which may be one of the old copper MDF locations out of this set of MDF/ ODF locations, a new model run for the new fibre only ODF service area will result in new, efficient cost.

5.1.2 Distribution Point area delineation

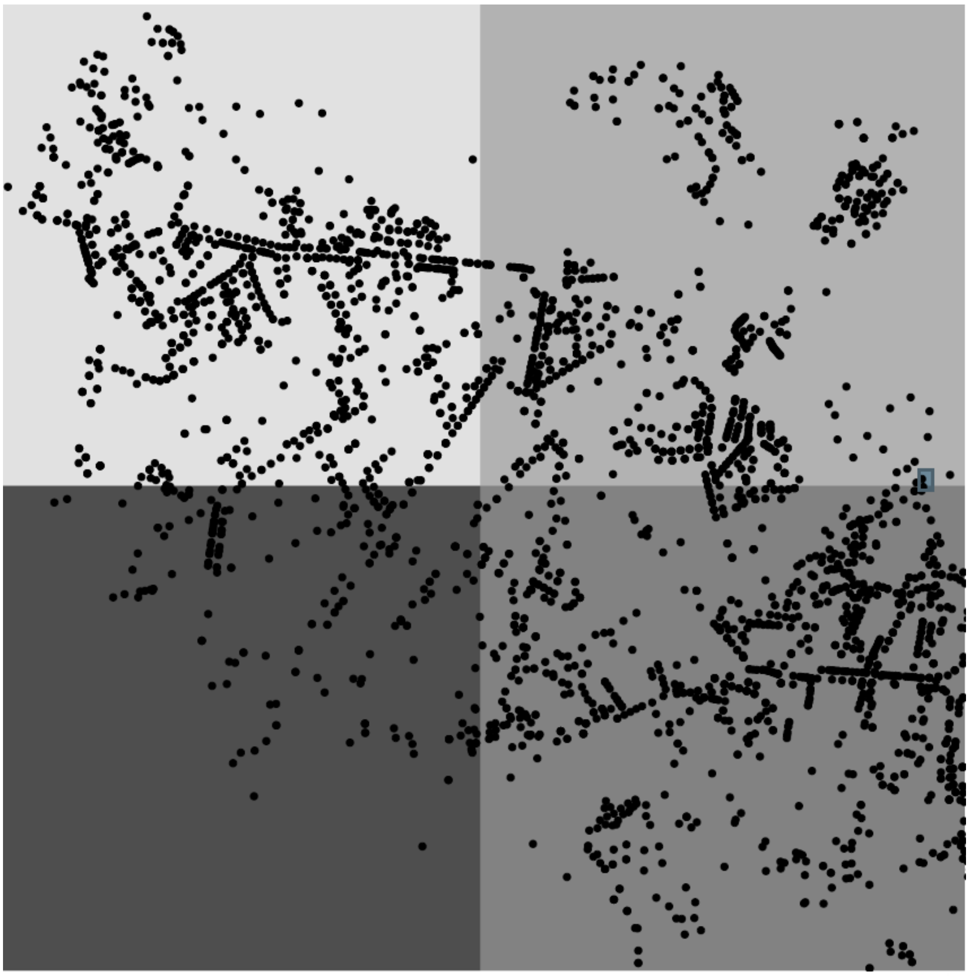
For each exchange area distribution areas (subloop areas served by underground cabinets in chambers) are delineated using a stepwise algorithm such that a certain maximum number of lines per distribution point (the DP capacity) should not be exceeded. A second criterion also limits the size of the distribution area, which restricts the maximum sub-loop length between distribution point and customer home. In a second step the placement of the distribution point (chamber) is processed before the feeder and distribution network will be computed.

Because of different aggregation characteristics the distribution areas for pure copper and copper/ fibre overlay differ from pure fibre. The size limits for distribution areas may also differ in the pure fibre P2P architecture and the pure fibre GPON P2MP architecture which both are considered by the model. This requires to conduct separate distribution area delineations with possibly different line demand and probably different line and length restrictions. The subsequent steps of network optimization for the feeder and the distribution network consider the correct demand for the different topological scenarios (copper, fibre and overlay). In the GPON P2MP case (overlay as well as pure fibre) a cascaded splitter architecture is computed so that in this case a transformation of the customer line demand to the number of fibres to be routed to the distribution point (chamber) is required. An optimal combination of splitters is derived for each portal so that the combination of splitter sizes can be determined and the fibre demand to be routed to the chamber can be counted. In the chamber a splitter allocation is implemented that matches the demand per fibre in the buildings (portal point) such that the upper limit (parameter, e.g. set to 64 customers) per feeder fibre is assured.

For the distribution area, delineation square grids of a defined maximum size are projected over the exchange area, counting the number of access lines in each of the raster areas. This maximum raster size (“maxRSize”) is a parameter to the model and can be changed. In the processing example below, we chose maxRSize= 3,200 meters as starting value in the process to assure that the building distribution in large and sparsely populated exchange areas can adequately be treated. On the one hand the process should not end up in a high number of chambers that serve a low number of customers only. On the other hand, the length of the access lines should be limited in those areas.

Figure 5-3 demonstrates the start of such a raster process showing the buildings of an exchange area and the first raster computed covering the buildings of the exchange area. The colours of the raster cells indicate the number of copper pairs counted in each raster cell.

Figure 5-3: Start of grid process

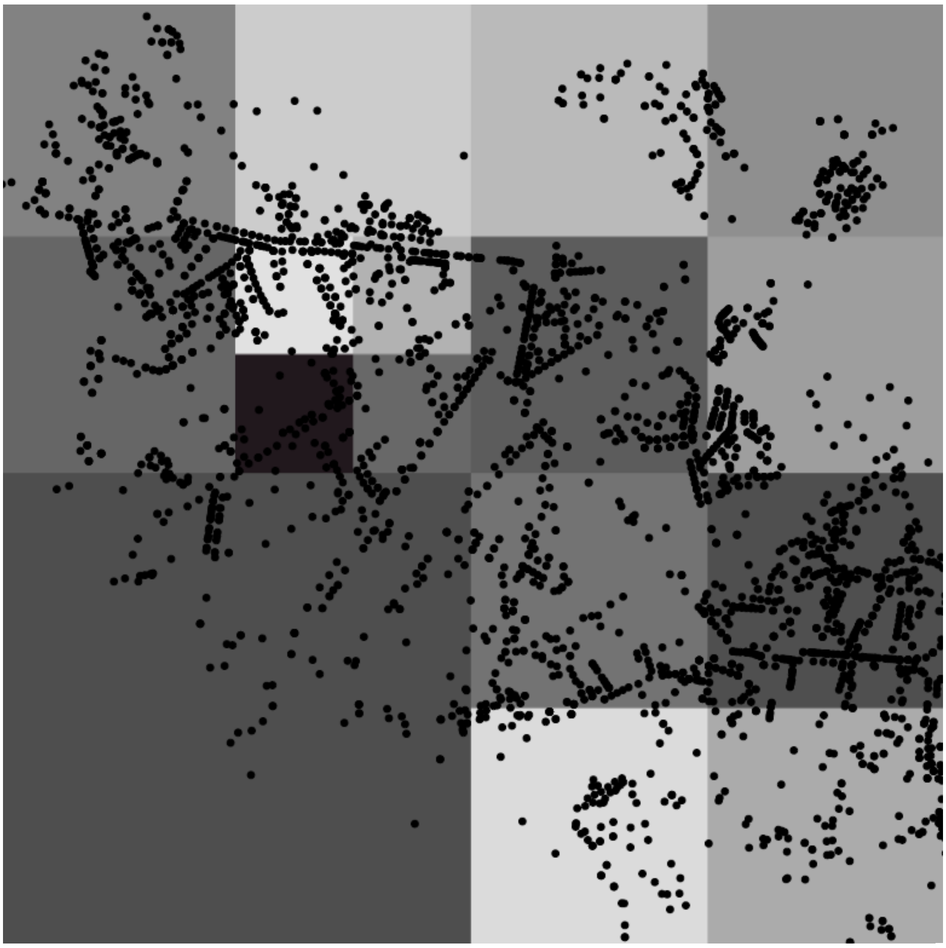


Source: WIK-Consult

Subdivisions of raster cells are applied for those raster cells that exceed a given maximum number of lines. This procedure is repeated until the condition “< maxLines” is met for each of the subdivided cells. The maximum size is an upper bound for the amount of copper pairs/ fibres served by a distribution point.

Figure 5-4 shows the end of the raster subdivision process in this example. All of the initial raster cells except the lower left initial raster cell have been subdivided because the number of copper pairs exceeded the upper bound of maxLines. Out of these subdivided grids only one (the cell on the left side above the midpoint) experienced a further subdivision step.

Figure 5-4: End of grid process



Source: WIK-Consult

For each of the resulting raster cells we compute the most centrally located building[33] of all the buildings falling into the respective raster cell. This is shown in Figure 5-5. The red points mark the resulting central points.

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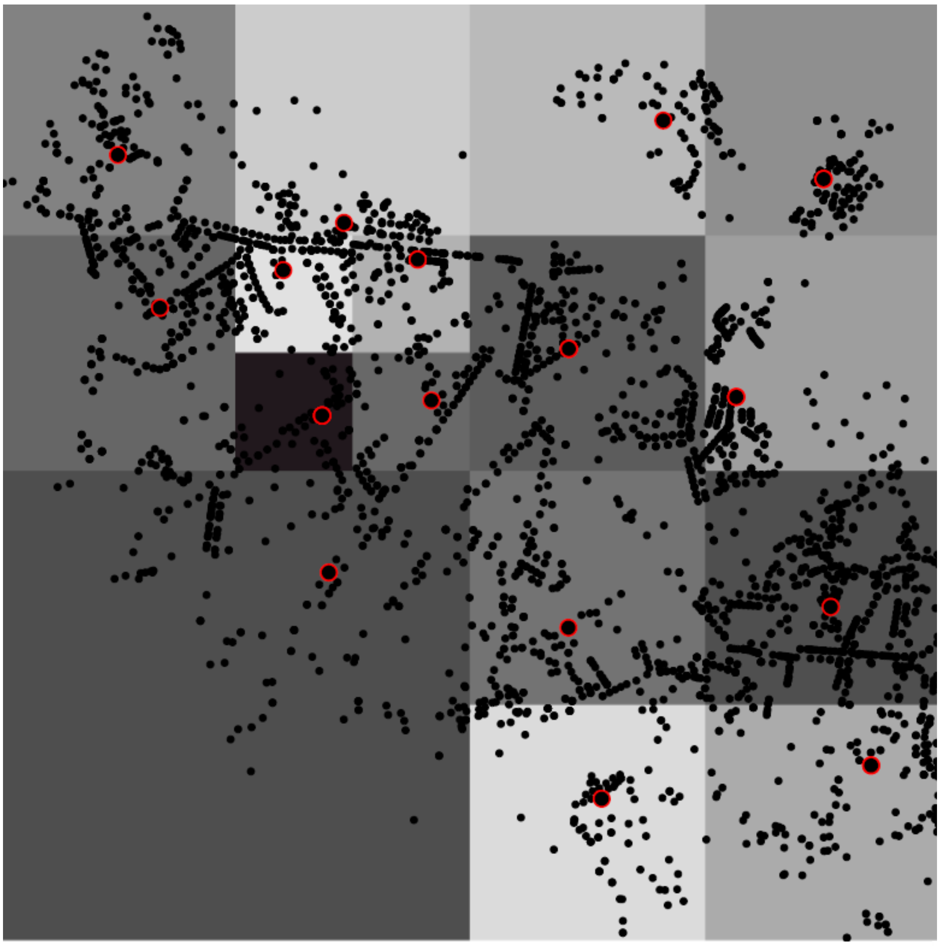
[33] The building that is closest to all other buildings by crow flight distance.

Figure 5-5: Choosing the centre points of the service area

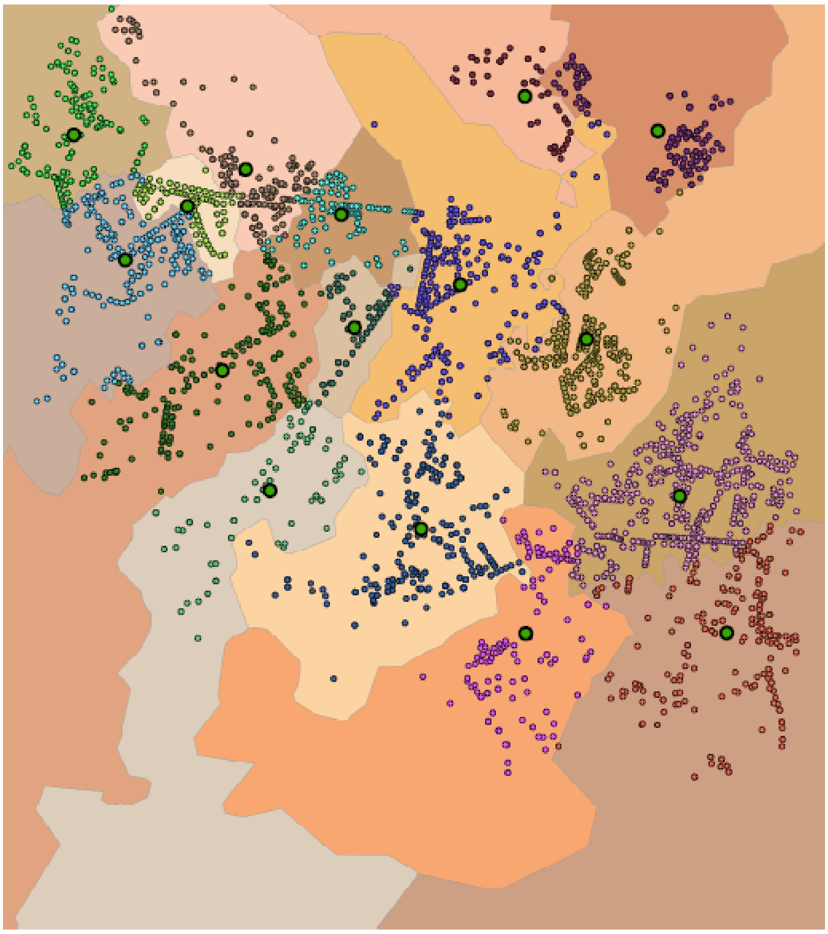


Source: WIK-Consult

These central points serve as the starting points around which we delineate the distribution or service areas for each chamber by allocating each street segment of the exchange area to the closest central point. This approach is analogous to the exchange area delineation described in chapter 5.5.5 and takes the street network topology into account.

The resulting distribution areas of this example are shown in Figure 5-6, each area marked by a different colour. The buildings falling into each of a so defined distribution area define the buildings to be served by the respective distribution point.

Figure 5-6: Distribution areas and allocation of buildings served



Source: WIK-Consult

To consider direct network links, which is an architecture that connects customers directly to the MDF (Figure 2-2), the MDF location is introduced as an additional starting point in the service area delineation. The direct network area is determined by a maximum distance from the MDF. Therefore the direct network delineation is conducted in advance to the delineation of the distribution areas, to assure the desired size of the direct network.

Remote nodes (see Figure 2-5 and Figure 4-6), 5,448 in the network of Telefónica, serve customers via copper lines in the distribution area, but have fibre in the feeder part, so that for the copper local loop unbundling within these areas have to be taken out of consideration. Nevertheless the distribution network costs of these service areas are computed to be used in Bitstream assessments.

We consider these nodes as scorched nodes and process a service area delineation for remote nodes much in the same way as we consider the direct network. The delineation of remote node areas is conducted before the main delineation computation step, and the demand of the resulting remote node areas is ignored in the subsequent delineation of the distribution areas.

5.1.3 Determination of the DP location

The next modeling step concerns the placement of the distribution point in each distribution area. In the model two distinct options are implemented. On one hand, as also shown in Figure 5-6, the distribution point is placed in the mass centre of the buildings of each area (green points). This option leads to efficiently short sub-loop lengths in average[34]. The other option is characterised by locating the distribution point to the boundary of the distribution area at the position that is closest to the MDF by street length. This approach in most cases leads to shorter feeder network lengths and optimizes the total local loop length, but may increase the distribution network length for at least part of the customer access lines. Thus the first approach is better suited for FTTC deployment in order to keep the maximum copper subloop length as short as possible and by this way achieving maximum transmission bandwidth for all end customers connected. Since FTTC is not considered in Spain we recommend the second approach.

5.1.4 Determination of the feeder cable segment

Next, an optimized feeder network is computed for each local exchange area. The feeder network connects the distribution points to the MDF/ ODF. Starting from the distribution point locations derived above, a minimum spanning tree is computed routing the line demand from each distribution area to the MDF/ ODF. The routing algorithm uses the street length as the edge weight and is thus minimizing the network trench length. This step is illustrated in Figure 5-7 for the exchange area example. The green points depict the chamber locations and the red point stands for the MDF/ ODF location. The cumulative sum of lines along the feeder routing path is given by the numbers depicted.

The main output of this processing step is a list of the streets in the optimal path and the information about the number of lines at each street segment.

The division of trenches into distribution and feeder cable is considered in subsequent modeling steps. It will be considered for all street segments that are in the optimal path of both, the feeder and the distribution network.

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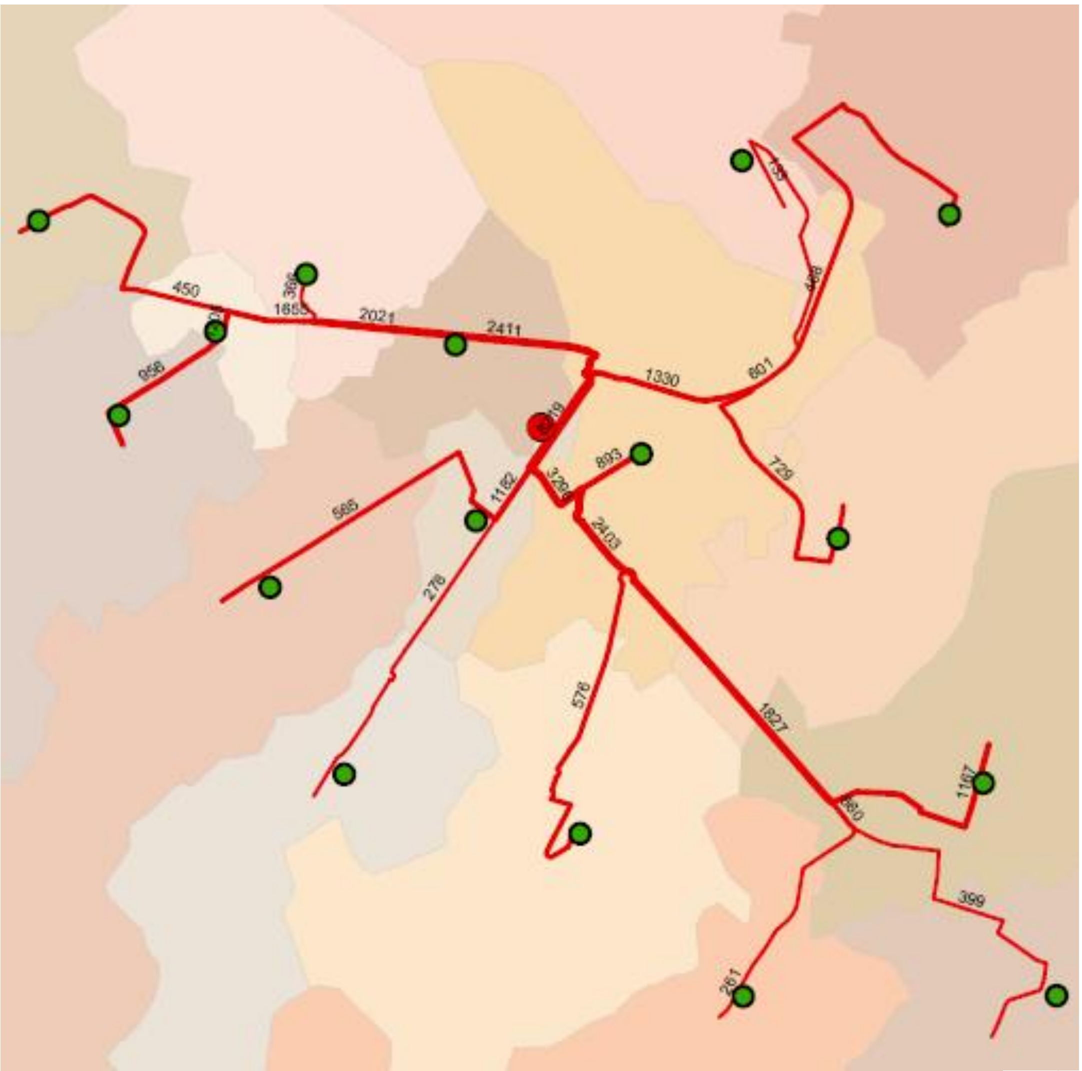
[34] Short sub-loops are important for FTTC VDSL networks, since the bandwidth for the end customers decrease with increasing sub-loop length.

Figure 5-7: Feeder network optimization



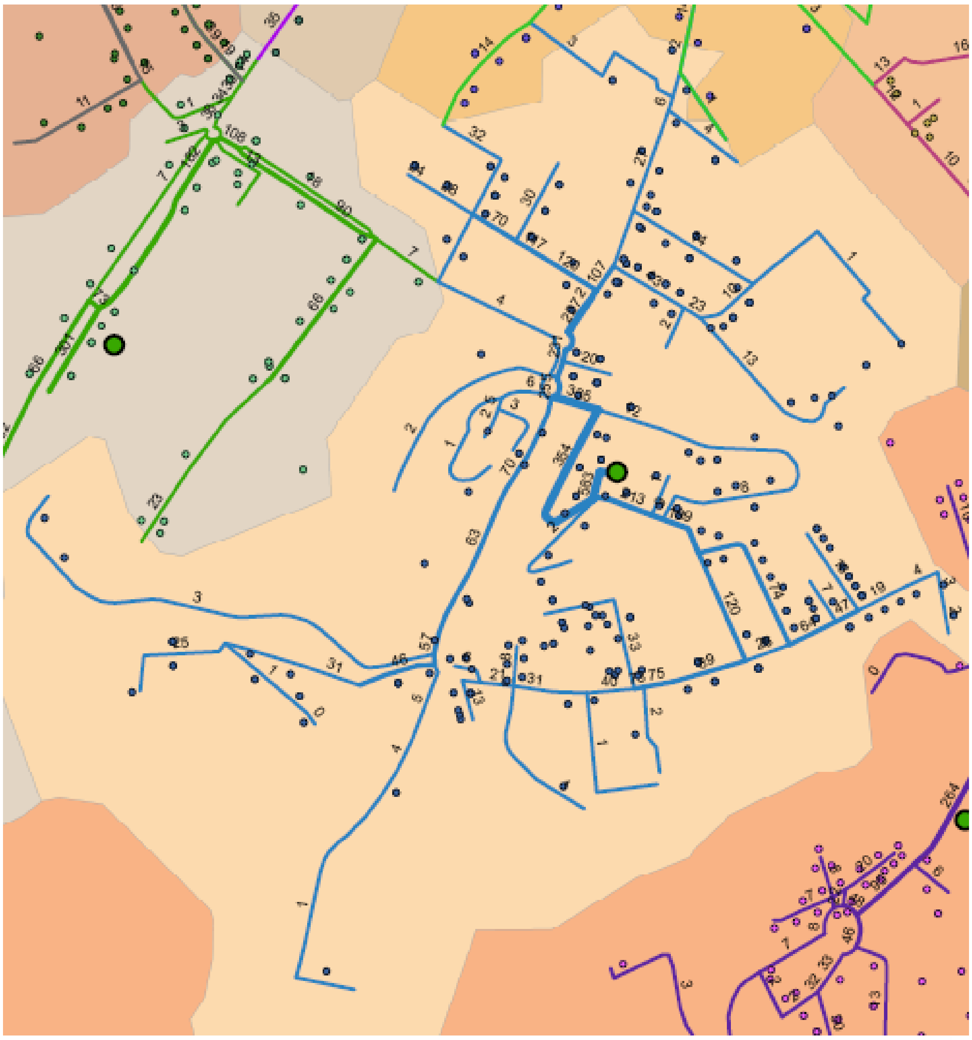
Source: WIK-Consult

5.1.5 Determination of the distribution network segment

The last step consists of computing the distribution network for each sub-loop area. This is realized by computing a minimum spanning tree for each service area that connects all buildings within a service area to the assigned chamber. The routing algorithm uses the street length as the edge weight and is thus minimizing the network trench length. Since trenching is the most expensive part in access networks this approach generally leads to minimum network investments.

As a result of this process, the allocation of the number of lines to each street segment in the optimal path is determined. This is illustrated in Figure 5-8, which shows the example of an optimized spanning tree for one distribution area. The root of the spanning tree is the distribution point (chamber) that is placed at the centre of mass distribution of the buildings within the depicted distribution area. The tree connects all buildings to the root and assigns the information about the sum of the subscriber lines to each street segment (edge of a graph) on the path to the root. The list of the streets in the optimal paths and the information about the number of access lines at each street segment are the main output from the distribution area optimization process.

Figure 5-8: Optimized distribution area



Source: WIK-Consult

5.1.6 Determination of two sided construction alongside the streets

The spatial distribution of buildings along a street course determines the approach of constructing the trenches – one sided or two sided - which the cost model considers for each street segment in order to construct in a cost efficient manner. Whenever the mean distance of the buildings on the street side with less buildings surpasses a given threshold the construction will be one-sided and the houses on the street with less buildings will be connected by street crossings. Here, the threshold value reflects a trade-off between costs of crossing the street and the costs of the deployment on both sides.

When buildings are primarily located on one street side, trench deployment will be considered only on that very side. Buildings that may exist on the opposite street side will then be connected to the trench by so called street crossings. The street crossing is generally a relatively expensive deployment form. Therefore it is only reasonable to apply it if the cost of the alternative, namely trench deployment on both sides of the street, will result in lower cost.

Let p_t be the investment price per meter trench, let l_t be the length of the trench in meters, let p_c be the investment price for street crossing (price per meter times length of crossing) and n_c the number of street crossings to apply at the street segment, then street crossing should be considered

(1) whenever $p_t \; l_t \geq p_c \, n_c$ which means $l_t / n_c \geq p_c / p_t$.

This means, that the mean distance between buildings l_t / n_c on the street segment is higher than the ratio of the investment prices. This threshold value has to be determined on the basis of the investment price information and be applied in the decision of one- and two-sided deployment.

With rising the investment prices for street crossings, the value of the mean distance threshold will ceteris paribus have to rise to bring condition (1) back to equilibrium. Higher threshold values lead to the situation that street crossing is less often applied which also means, that deployment on both street sides will take place more often.

The parameters influencing the decision on one and two-sided deployment are given by the investment for trench deployment along streets, the price for street crossings and the number of houses on each side of the street. The financial parameters are input parameters which can directly be changed by the model user. The structural information on buildings is based on geographic data. The number of houses per street side will be determined for each street segment individually by the given situation described in the cadastral data of Spain.

If there is demand for wholesale subducts in the distribution segment it will always be assigned to one side of the road.

5.1.7 Determination of the building access cable segment

The building access cable segment is defined as the segment between building access sleeve in the distribution cable and BDB location. The BDB locations are derived during the geographical data processing, measured by the portal locations. The perpendicular line segment between the street and the BDB serves us to measure the length of the access cable segment. This measure overestimates the length of the building access segment since the street layer depicts the middle of the street, whereas the trenching will typically take place at the curb of the street. Therefore the distance between the middle of the street and the pavement has to be subtracted from the total perpendicular length, connecting street and BDB, i.e. the building access length has to be reduced by half of the average street width.

As already mentioned the deployment cost for the building access is determined by individual building access length and the average deployment price per metre. A length is determined by the model for each portal endogenously. Of course, portals that do not have building access in terms of not being directly connected to the distribution cable in the street are taken out of consideration (e.g. façade wired portals without building access). The average deployment price per metre is an input parameter that can be changed in the model’s Excel interface.

5.1.8 Determination of the in-house cable segment

The in-house cable segment is for our purpose defined as the cable segment connecting the individual customer home with the BDB. Depending on the deployment form, this segment consists of different network elements. In Spain several deployment forms are in use. As already described in sections 2.1 and 2.3, in-house cables may be constructed on the façade of the building, within a normal indoor installation on the wall or in-wall or in a dedicated tray system (Infraestructuras Comunes de Telecomunicaciones (ICT)).

If façade mounted cabling is used in many cases more than one building is served by a single building access cable. These buildings are directly neighbored to each other without interrupting spaces, wall to wall, along a street block. The building access cable ends at the first BDB. The neighbored buildings are connected by an horizontal cable, before the vertical cable starts to serve the homes and business locations outside of the buildings, directly mounted on the façade[35]. The façade cabling may be mounted at the front side of the building, at its rear or within internal patios.

The indoor cabled buildings normally are accessed by a building access cable for each of the buildings. But in a minority of cases more than one building is addressed by a

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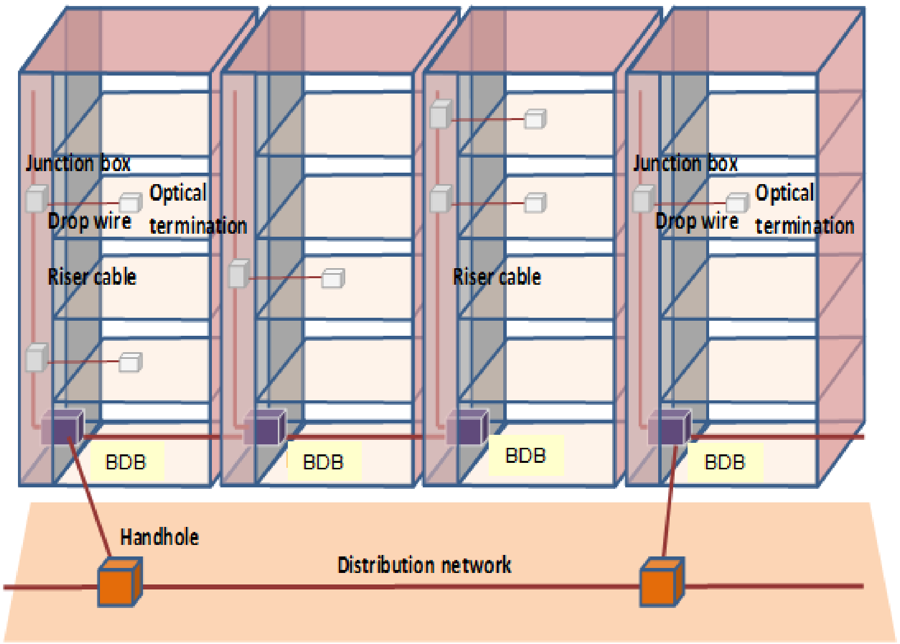
[35] Façade mounted cabling is cheap and economically efficient. Many buildings in Spain are served that way.

building access cable. This may cause problems in accessing the building and the cable in case of faults observed by customers outside of this building, since there is no original interest in giving access for other than the own customers/ inhabitants. Giving access generally means: experiencing network interruptions or other inconveniences (noise, dust,…). Thus we concentrate on single building access as the efficient indoor cabling access approach.

Each type of in-house cabling shows up with building specific investment components and additional subscriber specific components. Building specific components of the in-house cabling are installed during the access network deployment and need to be dimensioned according to the total potential demand in the network. Subscriber specific investments are deployed only according to the active demand in each period. This distinction is of significance if the evolution of the network over time shall be considered since the timing of these investment expenditure is different.

Figure 5-9 shows the case of in-houses wiring in multi-dwelling buildings. Building Distribution Boxes (BDB) and riser cables inside buildings are installed during the access network deployment. However, individual connections (junction box in every floor, drop wires and household wiring up to an electrical or optical termination point) may be installed on demand to specific customers that request service provision.

Figure 5-9: In-house cabling in multi-dwelling units*



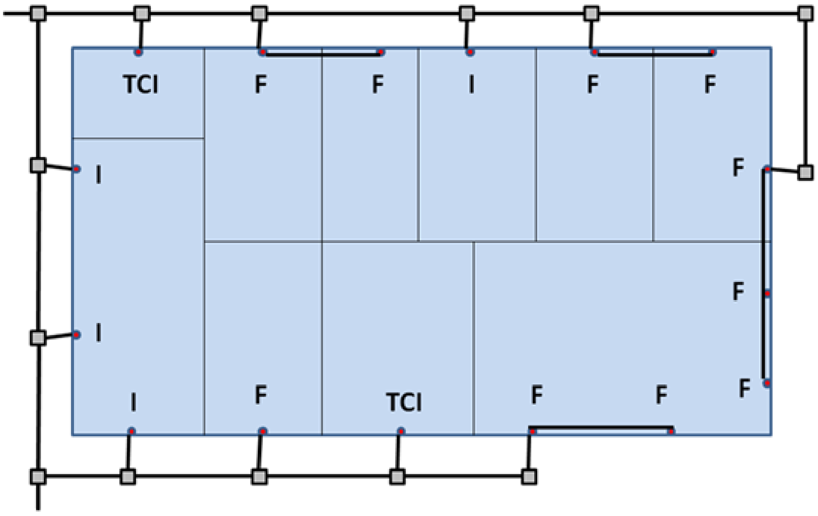
* Source: CMT

In the model in-house cabling is considered individually on a per portal basis and distinguishes between single homes and multi-dwelling units. In single homes an average investment price for the in-house cabling will be considered per portal. If it turns out, that the owner has to pay the in-house cabling in case of single homes, the investment value can be set to zero.

In multi-dwelling units inhouse cabling are realised either as (a) typical ICT (buildings not equipped with fiber access, normally constructed before 2012), (b) new ICT (buildings equipped with fibre access, normally constructed after 2012) (c) plain wiring without ducts (internal wiring in building not equipped with ICT) or (d) façade wiring. A portal with more than one flat, store or office is tagged as multi-dwelling. Furthermore, the portals have to be distinguished according to the deployment type in use. This labelling of portals is realised according to the construction year of the building. At this, geo-typed shares of the deployment forms in Spain are considered, which are provided by CMT. The share of each deployment type may be different depending on the considered area type (urban, suburban and rural). At the end of this process each multi-dwelling portal is tagged by the type ICT (a), Conventional cabling (b) and Façade cabling (c).

In the case of façade wiring additional geo-processing is necessary to distinguish F-clusters of neighbouring portals that are jointly served by a single building access. Each portal of type Façade (F-portal) gets a F-cluster number identifying neighbouring F-portals that are served by the same building access. Additionally, for each F-cluster the BDB location has to be determined and the sum of the distances between neighbouring buildings in a F-cluster serves as an estimate of the length of the horizontal cable used in case of façade wiring. Furthermore the BDB-location in each F-cluster serves as aggregation point of the demand within the cluster. In case of GPON the number and size of splitters to be installed in the facades are determined for the aggregated demand at the BDB-location of each cluster.

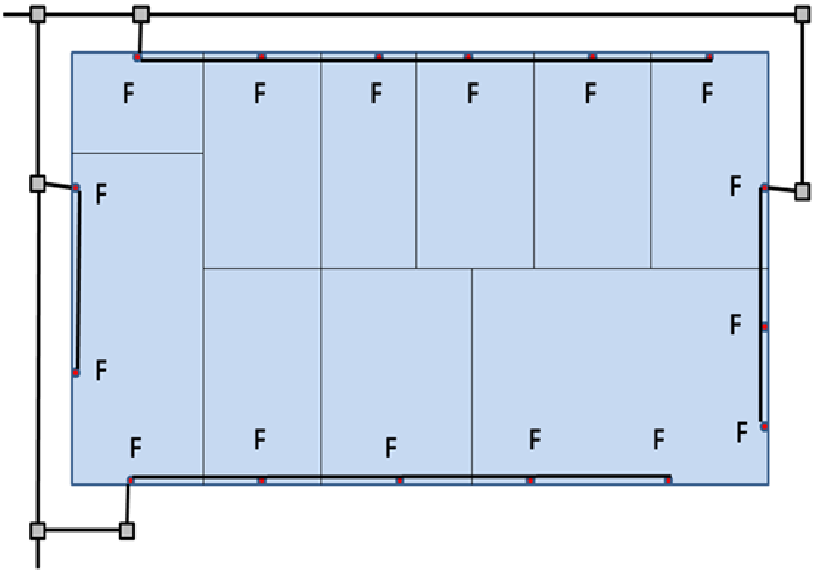
Figure 5-10: Mix of inhouse cabling types in a building block



Source: CMT 2011

If one assumes a mix of inhouse cabling types as described in Figure 5-11, having ICT cabling, indoor cabling without ICT (I) and façade cabling (F), the F-clusters are determined per building block and street by a row of neighboured house numbers, which are not interrupted by other deployment forms.

Figure 5-11: Building block with pure façade cabling



Source: CMT 2011

Thus, in a pure façade cabled building block there is one building access cable per building block and street (Figure 5-11).

The number and size of building distribution boxes are considered on a per portal base, which form the location of the BDBs. Since for each BDB location the potential demand for copper and fibre lines is identified in the demand distribution data processing, the size of BDBs can be determined by choosing from a menu of BDB size types typically used which is requested from the operators. In case of overlay deployment we assume two separate BDBs, one for copper and one for fibre. The box type is chosen by taking the smallest available box size which can serve the demand. If the specific demand for copper lines and fibre lines is higher than the largest available box size, a second box is installed that can serve the rest of the lines. This process is repeated until all demand is served. The investments are calculated by multiplying the requested investment prices for each box type with the number of boxes of the specific size at each BDB location.

The size of the BDB may be influenced by the option of coinvestment of operators in the inhouse cable segment, resulting in larger BDB in order to also house the other operators' access lines. This can be considered by an additional mark-up parameter on the BDB size, which can be set per MDF/ ODF group (cluster), thus reflecting different behaviour in these areas.

The different types of in-house deployment in multi-dwelling units are reflected in the model by three input parameters, indicating the investment price for the in-house cabling per floor and riser for each of the deployment forms. The prices will take into account the investment of the in-house solutions (material and installation) that will result for the deployment of one floor. It should include all components that are deployed to enable the service for the potential demand and which would be regularly implemented during network rollout, independently from active demand. If junction boxes in every floor, drop wires and household wiring, up to an electrical or optical termination point, are considered building specific, these investment cost should be included in the investment price per floor and riser. If not, only the riser cable and its installation should be integrated in the investment price. The subscriber specific cost components will be accounted in the calculation of subscriber specific investments.

To consider the fact that a riser cable will typically serve a restricted amount of flats per floor, the number of risers per portal are computed as follows:

$$N_{\text{risers}} = \text{ceil}((N_{\text{Demand}}/N_{\text{Floors}})/N_{\text{max Demand per Riser}}))$$

The maximum number of potential demand per floor that could be served by one riser cable is an input parameter of the model. The demand and the number of floors is generated during the data preparation and is known per portal.

The total in-house deployment per portal is calculated as:

$I_{inhouse} = N_{Floors} * N_{risers} * p_{Inhouse\ per\ floor\ and\ riser}$.

Since each portal is labelled according to the deployment type, the respective investment price per floor and riser is applied.

In the case of façade wiring additionally to the per portal investment calculation of inhouse cabling just described, the investment for the horizontal part is computed per F-cluster by multiplying the length of the horizontal cable per cluster, which results from model calculations, with the price per meter of the horizontal cable which is requested from the operators as model input.

The option of coinvestment of different operators in the inhouse infrastructure segment of the access network may have impact on the single operator's cost. The model considers this by a reduction parameter on all inhouse cabling elements (from BDB to wall socket), which can be set according to the different inhouse cabling construction forms (façade, internal wiring without ICT, ICT until 2011, new ICT) and for groups of MDF/ ODF individually. The reduction by coinvestment is applied on top of the inhouse construction cost resulting from the cost sharing with the building owners described in the section below.

The share by which a building owner or its construction company participates in the cost of connecting a building to the telecommunication network differs. The solution being cheapest for an operator leaves the cost for trenches from the last handhole in the street to the building (building access line) and the installation of inhouse ICT facilities including the cables to the building owner (new ICT), but until today, cost for ducts and cables is paid by the telecommunications operator (ICT). The model allows to parameterize a share of the cost of the building access infrastructure (building access cable incl. required civil infrastructure (trenches and ducts) which has to be paid by the network operator per inhouse deployment form individually. Also a second parameter describes the network operator's share of the inhouse infrastructure cost individually per deployment form. While for façade cabling there is no form of cost sharing with the building owners (BO) at all, internal wiring (without ICT) may be shared in the building access segment, but not for the inhouse cabling part. The sharing of inhouse cabling cost starts with today's ICT infrastructure, where the building owner pays for the cable tray system and its construction, while the cost for cables and cabling are borne by the network operator. With new ICT all these cost may be due to the building owner. An overview of these forms is described in Table 5-1.

Table 5-1: Sharing of inhouse cabling cost between network operator and building owner

	Share of cost with BO	
	Inhouse cabling paid by BO	**Building access infrastructure paid by BO**
Copper access		
Façade	-	-
Internal - no ICT	-	%
Traditional ICT	%	%
New ICT	%	%
Fiber access		
Façade	-	-
Internal - no ICT	-	%
Traditional ICT	%	%
New ICT	%	%

5.1.9 Determination of civil works

The total demand for civil engineering (trenches, ducts, manholes/ handholes, sleeves …) is derived out of the individual copper and fibre demands. While in decreasing markets the relevant copper demand is the actual demand of active lines, in increasing markets the relevant fibre demand is the final and maximum state planned to serve. Both demands are valued with some additional technical and operational spares, and may get additional spares due to fixed cable sizes. The share of the technical reserve is at about 1-2% relative to the total number of access lines. A different value can be considered in the model. An economical reserve is also considered in order to meet growing demand for access lines. The already deployed lines could be used to serve the increase of demand. We consider a mark-up of 3-7% on the total number of access lines as economical spares. In both cases, the operators were asked to provide adequate figures for the spares[36].

The demand for the fibre access network is calculated either for a P2MP or a P2P topology. In the overlay case the capacity required is determined by the initial copper demand[37] and by the final fibre demand plus technological and economical spares. Both demands may differ from each other. They in principle may be determined for

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[36] One has to keep in mind that the capacity is already dimensioned to the highest demand of the consideration period, thus for fibre already takes intoi account the increasing demand. Thus this spare is intended to cover unexpected new buildings or additional demand per building above the demand already considered.

[37] Active lines plus efficient spares

each MDF/ ODF individually, but grouping into clusters would ease model parameterization.

During the network optimizations for the three network topologies copper only, overlay and fibre only, for each street in an MDF/ODF area the optimized number of copper lines and the number of fibre lines that pass the street is determined. Further the number of lines is distinguished according to the part of the network they belong to. According to this for each street segment the number of copper and fibre lines of the feeder network and of the distribution network that will be deployed per street side is determined. From this total demand the number and type of cables, the duct and manhole infrastructure and the dimensioning of the trenches and aerial tracks is derived for each street segment and street side.

Each street segment with a positive number of copper and or fibre lines passing through is partitioned into a ducted, aerial and buried infrastructure part according to the trenching type fractions used as model input, which is evaluated in the operator survey.

Table 5-2: Trenching types

	Feeder network	Distribution network
Percentage of buried cable [%]	%	%
Percentage of in duct cable [%]	%	%
Percentage of aerial cable [%]	%	%

The length of ducted, buried and aerial tracks is determined by multiplying the length of each street segment with the appropriate trenching type fraction.

In ducted networks subducting is assumed and one cable per subduct is allowed. For copper and for fibre the lines of the distribution and the feeder network are deployed in separate cables. For the copper network and for the fibre network a maximum cable size per subduct is applied. The number of subducts needed for each technology (copper and fibre) and for each network part (distribution network and feeder network) is determined separately by dividing the number of lines each by its respective maximum cable size and rounding to the next integer number. Additionally for each street segment one[38] empty subduct is considered as common usable duct spare capacity allowing the replacement of broken cables. Furthermore, a demand for wholesale subducts can be derived by setting a mark-up parameter on the number of existing sub-ducts which is complemented by a lower threshold parameter and maximum number of sub-ducts deployed for wholesale. From the number of subducts the number of ducts is determined and the smallest trench size needed is derived.

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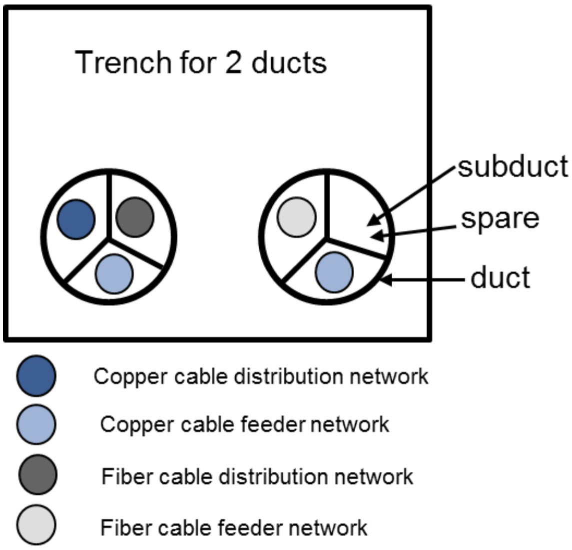
[38] Parameter, may be changed

Whenever ducts are shared, the cost allocation will be according to the fraction of subducts in the total number of subducts for each street segment. In Figure 5-12 the deployment of two ducts will suffice for the demand of 3 copper cables, 2 fibre cable and a spare subduct supposed.

Figure 5-12: Duct deployment



In the pure copper and also in pure fibre architectures a trench can be shared between the distribution and the feeder network. In the overlay network sharing will also be considered between fibre and copper.

Manholes are dimensioned for each street segment separately according to the total number of ducts to meet the total demand for ducts in the street segment. The number of manholes of each size type is computed as a fraction of duct length by the mean distance between manholes which is an input parameter of the model. For the buried cable network the same rationale applies. It is assumed that manholes are commonly jointly used for distribution and feeder cables and for copper and fibre.

Connection sleeves are computed in the same manner as manholes, by dividing the duct and buried cable length by the mean distance between connection sleeves, which is an input parameter of the model.

In aerial cabling segments the number of poles is derived from the aerial cable track length divided by the mean distance between poles. These values are computed for each street segment and are summed up over all network street segments within a service area.

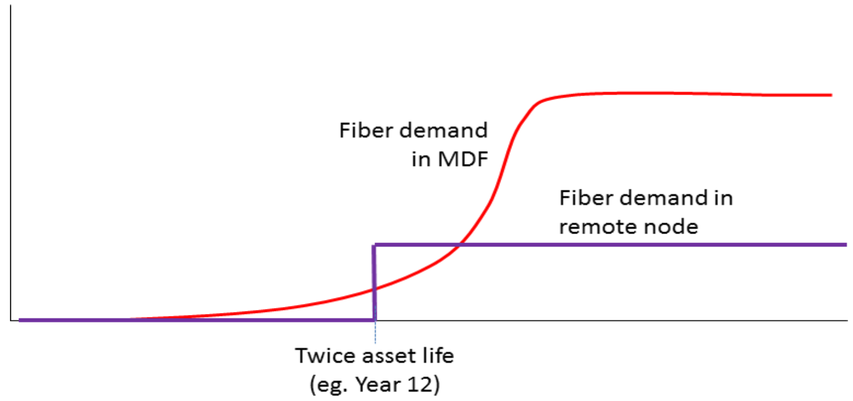
5.1.10 Specific aspects of remote nodes

For the LLU computation the remote nodes areas will be excluded from consideration, since there cannot be offered LLU unbundling, while for bitstream infrastructure cost determination they will have to be included, because wholesale bitstream access can be offered in remote node areas also.

The consideration of remote nodes in the modelling process requires some specific treatment, depending on the kind of deployment in the MDF (copper only, copper/ fibre overlay, fibre only), the state the remote node infrastructure will have (copper or fibre) and the purpose of the computation, LLU or bitstream.

It is assumed, that the remote node copper based infrastructure (copper subloops) will only be operated for a certain time, before it will also be replaced by fibre. We assume the exchange will be triggered by two times the expected equipment life time for the active remote node element (e.g. 12 years). When that period expires remote nodes and copper subloops will be dismantled and replaced by fiber subloops and feeder fiber. This change over will be executed within a short time period, when the remote node has to be exchanged (Figure 5-13). We assume the future fibre topology will follow the topology chosen for the surrounding MDF area, either fibre P2P (point-to-point) or fibre PMP (point-to-multipoint, e.g. PON).

Figure 5-13: Copper/ fibre switch over in a remote node area



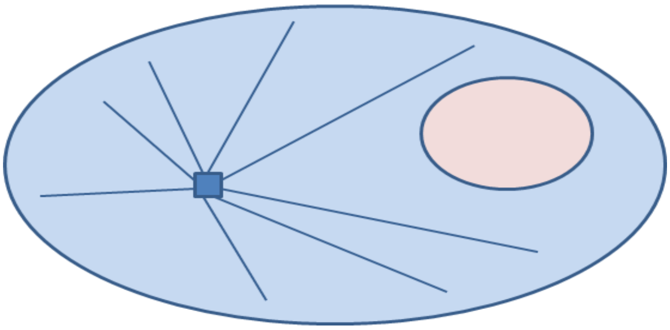
Source: CMT

In areas with **fibre only** deployment (MDF fibre only, whole country fibre only) a consideration of remote nodes would be against the regulatory philosophy of assuming the most efficient (FTTH) deployment method a new operator would choose today. This then will be the fibre topology of the surrounding MDF area without taking remote nodes as scorched nodes any longer, and optimized with regard to efficient distribution area delineation. Thus the consideration of remote nodes are not executed in fibre only deployment areas (MDF or larger). Hence for bitstream and LLU calculation the same infrastructure cost will be considered. For fibre LLU only a fibre P2P topology may be assumed, because fibre PMP can only be operated in a bitstream manner[39].

In case of a **copper only** MDF at first the remote node area is delineated, identified by the remote node location and the number of end customers being closest to it. The remote node is a scorched DP, so determined not by an optimization process, but is given as external input into the model. Then the rest of the MDF area is delineated and the DP locations are determined. Both, the copper distribution cable infrastructure for the remote node and for the rest of the MDF are determined individually. Also the feeder cables, efficiently deployed together with the distribution cables, are determined individually for the remote node (being a fibre) and the rest of the MDF area (copper), and the incremental cost for the remote node feeder cable is determined.

For the copper LLU cost calculation the cost of the remote node infrastructure is taken out of consideration, incl. the incremental feeder cable cost (Figure 5-14). This is also true when the remote node infrastructure changes from copper to fibre access lines.

Figure 5-14: Copper LLU calculation with remote nodes



Source CMT

For the bitstream cost calculation the remote node distribution cable cost and the incremental remote node feeder fibre cost are included in the cost consideration (Figure 5-15). Thus together with copper loop costs in the MDF area, the model incorporates costs of a feeder fiber from the nearest MDF to the remote node (red dotted line) as well as copper sub-loops (blue lines) from remote node to end-users. In case that the remote node infrastructure changes after a certain period to fibre the copper distribution cable cost have to be exchanged by fibre cable cost. The copper cables then are sunk investment.

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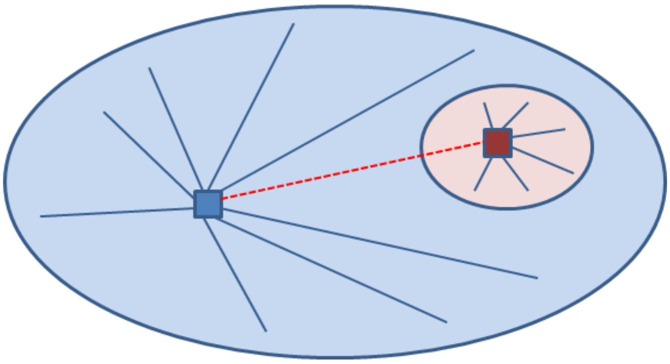
[39] …unless one should include fibre subloop unbundling.

Figure 5-15: Bitstream over copper calculation with remote node



Source CMT

In the case of **copper/ fibre overlay** infrastructure of a MDF area the same principles have to be applied. First the copper demand is distributed throughout the whole MDF area. Then the remote node area will be delineated. The fibre demand then will be distributed in the MDF area except the remote node area. The process continues comparable to the copper only case with the delineation of the rest of the MDF area, followed by the individual distribution area and associated feeder cost determination. The computation of the copper (and fibre - in case of fibre P2P topology) LLU cost is executed without the remote node cost (distribution and incremental feeder fibre). If the remote node infrastructure changes to fibre, the copper distribution cable cost has to be replaced by fibre, according to the surrounding MDF fibre topology (either P2P or PMP). Also the remote node feeder fibre cable has to be recalculated, since it differs, depending on the fibre topology (P2P feeder has more fibres than PMP feeder, which still has more than the one remote node fibre).

The bitstream cost calculation has to include the remote node cost, being it copper first or fibre later on, appropriately.

5.2 Network element quantities (summary)

The network design module will provide quantities for network elements as an output that will be adopted by the cost module for investment and cost calculation. The output of the design module provides quantities for a number of network elements that are classified by their network segment. Network elements could be trench length of duct deployment and directly buried deployment, number of poles in case of aerial deployment, cable length classified again by duct deployment, directly buried deployment and aerial deployment, chamber and MDF equipment etc.

5.3 Investment calculation

The investment calculation of the fibre based or copper based local loop takes into consideration direct investment and indirect investment positions. Direct investment results from those elements that could be directly assigned to the network construction itself such as cables, trenches and chambers. The quantities of such network elements are multiplied by corresponding price values resulting in direct investment figures that will be provided for each network element group separately.

The direct investment values are required for determining the indirect investment which itself is based on positions that could not be directly assigned to the network part, but that are required for its realisation. A position that could be seen as indirect is for instance the investment for motor vehicles which are required by field technicians visiting the construction locations of the access network. Furthermore workshop facilities where technicians could store their equipment are regarded as such a position, too.

Indirect investment values result from mark-up factors that are applied on direct investment positions. The following formula summarizes the indirect investment calculation:

$$II_{NE_i}^{j} = I_{NE_i} \cdot iif_{NE_i}^{j}$$

where II is the indirect investment for the network element group i resulting from the indirect investment position j, I is the direct investment, and iif is the mark-up factor. As indirect investment the model will consider the following positions.

- Motor Vehicles
- Workshop Facilities
- Office Equipment
- Land and Buildings
- General IT
- Network Support Systems[40]

The mark-up factors are input parameters that will be given for each network element group separately and that can easily be adjusted by the model user in the input mask. Network element groups are positions such as MDF, chambers, trenches, cables etc.

The mark-up factors have been requested from the Spanish telecommunications operators, so that country specific values will be available beside benchmark values

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[40] Network support systems include investment for network documentation systems.

from other countries. Since investment calculations are done per MDF area, mark-ups are more practical than using absolute values from accounts or top down analysis. Furthermore a comparison of the mark-up values from different operators and international benchmarks is easier to conduct than a comparison of absolute values, which always refer to singular network situations.

In case that the operator will not provide any information on the mark-ups- as it is the case in Spain -, it will be referred to benchmark values taken from the WIK benchmark database. These values were already used in former projects and are based on operator’s data, published papers and models and on expertise knowledge. The mark-up factors were generally accepted by the parties in former projects.

5.4 Cost calculation

5.4.1 OPEX

The model also takes into consideration the cost resulting from network operation such as maintenance, power supply and rental fees for houses. Depending on their individual characteristic, operational expenses (OPEX) could be included in the model either as mark-up factors, as absolute cost values or as event-driven cost positions. Positions such as regular maintenance may be represented by mark-up factors, by absolute values or by a combination of both. Other operational cost such as fault maintenance may be considered most appropriately by the event-driven approach leading to cost positions determined in a bottom-up manner.

In most cases, OPEX are determined by mark-up factors that will be applied to direct and indirect investment positions leading to operating cost for each network element group individually. For direct investment the calculation is as follows

$$OPEX_{NE_i} = I_{NE_i} \cdot ocf_{NE_i} .$$

And for indirect investment the considered formula is

$$OPEX_{NE_i}^{j} = II_{NE_i}^{j} \cdot ocf_{NE_i}^{j} .$$

where ocf is the network group specific OPEX mark-up factor. Distinct mark-up factors are applied to copper and fibre for asset groups that are specific to the corresponding network type. For commonly used assets like trenches the same factors apply.

The values for the factors to apply are requested from the telecommunications operators in Spain so that they account for the country specific circumstances. Using mark-up factors is suitable in the modeling context since different future demand and network options are considered. Compared to the use of absolute values from accounts, which always reflect historic and singular network situations, mark-up factors are more flexible and practical since they easily adapt to sub-national network computations and to changes in the modeling context. Absolute values from accounts and top down analysis may be applied to validate the mark-up factors. The bottom-up modeling of OPEX would in many circumstances turn out to be too complex or would require input data that cannot be procured so that the analysis is unfeasible.

As already indicated above, in case that the operators will not provide mark-up information on operational expenses - like in Spain -, the model will be fed with values of the WIK benchmark database. The internal database contains OPEX mark ups that were used in former projects and that are based on operator information, publicly available documents and cost models and on expertise knowledge. The mark-up factors were used in numerous projects for public and private customers and were generally accepted by these parties.

OPEX may be considered as cost that must be recovered in the period in which it occurs. Alternatively, the Net Present Value of OPEX over the whole consideration period can also be annualised in line with the investment. Such an approach would instead reflect that the operation and maintenance in early years is necessary to provide services in later years, too.[41] Both methods are available in the model.

The latter approach (OPEX annualisation) also allows determining the present value of OPEX over all years and considering this like an investment into the asset in addition to the actual payment for the asset itself. This perspective is justified by the fact that installing the relevant facility or equipment implies a commitment to maintain it adequately throughout its useful life. The determination of the amounts to be amortized of the present value of OPEX in the current period should then follow the same procedure as for CAPEX. The final results have been determined with annualised OPEX.

5.4.2 Annualization

The investment positions are transferred into annualized cost positions by taking into account the Weighted Average Cost of Capital (WACC) and the economic lifetime. Depending on the annualisation approach, expected price changes as well as the demand in the future are taken into account in order to determine an appropriate per unit price. The considered growth period is 20 years. Within the 20 year time frame the model accounts for any renewal investments that might be required for assets with shorter lifetimes.[42]

The model allows the following annualisation methods to determine the CAPEX:

- Simple annuity (linear),
- Tilted annuity and
- Economic depreciation

The simple annuity spreads the investment in a linear manner over all periods, i.e. the same depreciation will be assigned to every year. When applying the simple annuity for the copper network the model also assumes a constant copper demand at the level of year 1 in order to determine CAPEX per line. This assumes that all MDF remain in operation. For all fibre cases the CAPEX per line is determined through the forecast of fibre subscribers.

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[41] With fibre demand initially low and increasing only over time the first approach leads to high OPEX per line in the first years even when the CAPEX per line (based on economic depreciation) is low.

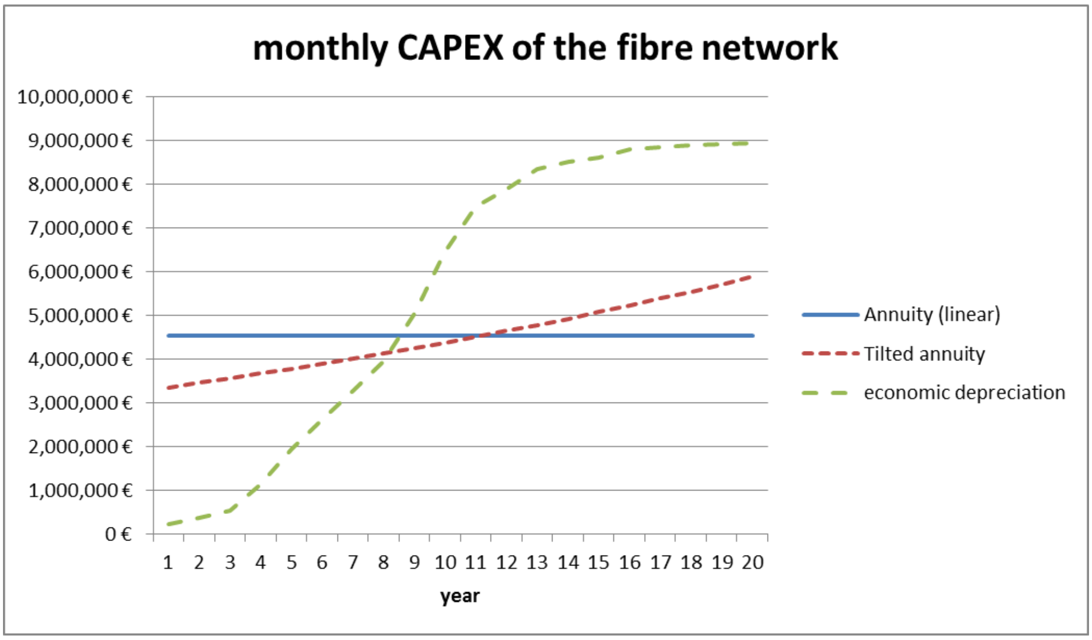
[42] All input parameters will be frozen at their year 20 value for later periods. This is described below in more detail.

The tilted annuity employs a tilt factor to shift annualisation between earlier and later years (reflecting e.g. low utilisation of assets in early years). In addition, an asset specific price trend can be configured which tilts the annualisation. In the case of copper, CMT has forecast the (falling) demand for copper for each MDF. As soon as there are no more active customers at a given MDF the cost is considered sunk and removed from the CAPEX determination.[43] CAPEX per line calculation also follows this demand forecast (in contrast to the simple annuity for copper where the demand is considered constant). By setting both price trend and tilt factor to zero one can obtain the results of a linear annuity for the demand evolution with decreasing customers (see below).

Under economic depreciation the CAPEX follows the demand profile forecast by CMT. (Copper) sunk cost removal and CAPEX per line determination is the same as described for the tilted annuity above.

The three methods are visualised in Figure 5-16.

Figure 5-16: Exemplary CAPEX evolution for fibre



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All depreciation methods always lead to (present value) of investments I equalling the sum of the discounted amortisation payments A (defined as price p multiplied with quantity Q) as shown in the following equation

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[43] The lifetime of the asset remains unchanged, so there is effectively sunk cost that is not considered anymore for the determination of the (remaining) copper network lines.

$$I=\left[\frac{A_1}{(1+i)}+\frac{A_2}{(1+i)^2}+\frac{A_3}{(1+i)^3}\ldots+\frac{A_n}{(1+i)^n}\right] \tag{1}$$

in which *i* stands for the applicable rate of interest. As discussed later depreciation is conducted for each asset independently and until the end of the asset's lifetime. In many cases this will lead to depreciation until years beyond year 20.

Because of the fact that the network consists of assets with different lifetimes the network investment outlay has to be aligned with the consideration period n by using the net present value of the network investments including necessary reinvestments of assets with shorter lifetime during the consideration period. Therefore, the investment value “I” needs to be the net present value of the network outlays during the consideration period.

We express equation (1) slightly differently by factoring out A_1. As a result the amortisation payments within the brackets are expressed as percentage of the level in year 1.

$$I=A_1\left[\frac{1}{(1+i)}+\frac{\frac{A_2}{A_1}}{(1+i)^2}+\frac{\frac{A_3}{A_1}}{(1+i)^3}\ldots+\frac{\frac{A_n}{A_1}}{(1+i)^n}\right] \tag{2}$$

With A=p*Q one may also interpret the nominator of each summand as the demand in the given period expressed relative to the demand in period 1. The CMT and WIK have made a demand forecast over 20 years separately for fibre and copper customers for each MDF which forms the basis for the economic depreciation.

An alternative expression is to introduce growth factors in relation to A_1 as shown in equation (3) where the Amortisation in period 1 is multiplied by $(1+g_2)$ with g_2 being the implied growth rate to obtain the Amortisation in period 2. To obtain the Amortisation in period 3 A_1 is multiplied by the compound $(1+ g_2)*(1+ g_3)$, and so forth:

$$I=A_1\left[\frac{1}{(1+i)}+\frac{(1+g_2)}{(1+i)^2}+\frac{(1+g_2)(1+g_3)}{(1+i)^3}+\ldots+\frac{(1+g_2)\ldots(1+g_n)}{(1+i)^n}\right] \tag{3}$$

Such a growth factor (as a constant) is used for the tilted annuity.

When introducing yearly price trends Δq_n the formula becomes more complicated (see equation (4)) because both growth factors g_n and price changes Δq_n stack up as compounds in each consecutive year:

$$I = A_1 \left[\begin{array}{l} \frac{1}{(1+i)} + \frac{(1+g_2)(1+\Delta \mathrm{q}_1)}{(1+i)^2} + \frac{(1+g_2)(1+g_3)(1+\Delta \mathrm{q}_1)(1+\Delta \mathrm{q}_2)}{(1+i)^3} + \ldots \\ + \frac{(1+g_2)\ldots(1+g_n)(1+\Delta \mathrm{q}_1)\ldots(1+\Delta \mathrm{q}_n)}{(1+i)^n} \end{array} \right] \qquad (4)$$

Essentially, equation (2) and (4) show that there is a global level parameter A_1 that is multiplied with discounted yearly level parameters. The yearly level parameters themselves can be expressed as the demand of the given period relative to the demand in period 1 and adjusted for price trends that have occurred between year 1 and the considered period.

This formula is not only applicable to the economic depreciation but also to the other annuity methods simply by setting the relative demand and price trend in accordance with the selected method.

For the simple linear annuity price trend *Δq* and growth rate g are set to zero yielding the following simple equation that results in the desired even spread over all periods:

$$I = A_1 \left[\frac{1}{(1+i)} + \frac{1}{(1+i)^2} + \frac{1}{(1+i)^3} \ldots + \frac{1}{(1+i)^n} \right] \qquad (5)$$

Since the tilted annuity has a constant growth tilt factor the equation can be expressed with one constant growth factor g instead of individual growth factors for each year (for simplicity the following equation shows the example where the price trend for each year is zero):

$$I = A_1 \left[\frac{1}{(1+i)} + \frac{(1+g)}{(1+i)^2} + \frac{(1+g)^2}{(1+i)^3} + \ldots + \frac{(1+g)^{n-1}}{(1+i)^n} \right] \qquad (6)$$

For all depreciation methods the model will determine the yearly level parameters first because i, g_n (derived either from the demand forecast of CMT for economic depreciation or from the growth tilt factor) and *Δq_n* are all known parameters. Since the investment at net present value is also known the remaining task is to determine the global level parameter A simply by equivalently transforming equation (6) to equation (7):

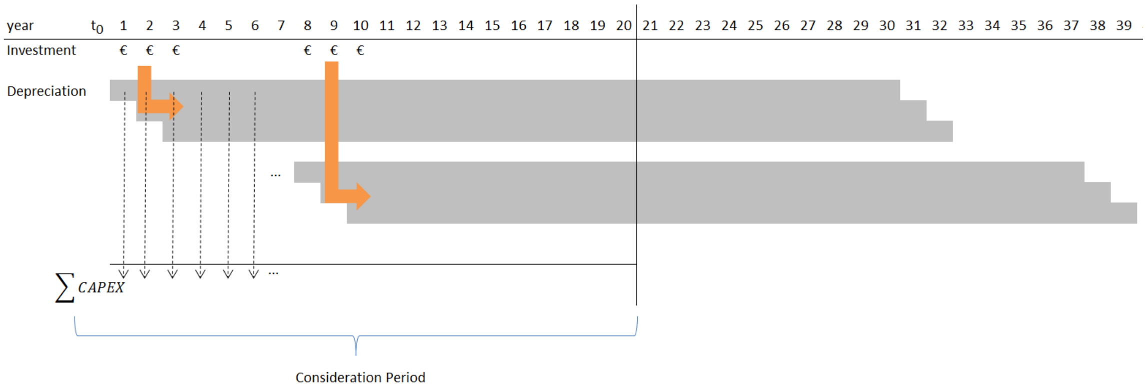
$$A_1 = \frac{I}{\left[\begin{array}{l} \frac{1}{(1+i)} + \frac{(1+g_2)(1+\Delta \mathrm{q}_1)}{(1+i)^2} + \frac{(1+g_2)(1+g_3)(1+\Delta \mathrm{q}_1)(1+\Delta \mathrm{q}_2)}{(1+i)^3} + \ldots \\ + \frac{(1+g_2)\ldots(1+g_n)(1+\Delta \mathrm{q}_1)\ldots(1+\Delta \mathrm{q}_n)}{(1+i)^n} \end{array} \right]} \qquad (7)$$

Following this the annual CAPEX may be deducted by simply multiplying A1 by the annual level parameters (the numerators in the brackets of equations (1) to (6).

The model tracks initial investment in an asset in each year between t_0 and year 20. This investment is renewed within the 20 year period if required (i.e. if its lifetime is shorter than the remaining years until year 20) and all assets will be depreciated over their complete lifetime. This means that long-living assets such as ducts are depreciated until e.g. year 59 (e.g. in the case of investment occurring on year 20 with a lifetime of 40 years). Otherwise, all investment would be completely depreciated by year 20 which would put an unjustified burden on the customers of years 1 to 20 (i.e. increase the price per line).

For years beyond year 20 all cost-relevant inputs (e.g. WACC, demand and price trend) are frozen at the level of year 20.[44] When the total CAPEX in each year has been calculated the determination of CAPEX per line is conducted solely for the years 1 to 20 which are the consideration period for this project. See Figure 5-17 for an example with an asset lifetime of 30 years and investments occurring in 6 years (years 1 to 3 and 8 to 9).

Figure 5-17: Tracking investment and depreciation



Indirect investments will be transferred into annual cost in the same manner as direct investments, considering the interest rate, the lifetimes and the price changes of each asset group.

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[44] Clearly, it is extremely difficult to forecast e.g. demand for the next 60 years so keeping inputs constant is the next best alternative.

5.4.3 WACC

The weighted average cost of capital (WACC) reflects the interest rate an operator has to achieve in order to cover costs of capital and to earn market specific profits from the undertaken network deployment. The WACC should also consider the risk a specific investment has, e.g. the investment in a fibre based access network. In the cost model the WACC is an input value that could be specified for each network element group individually. With regard to the WACC it seems to be more reasonable to keep one level for all network elements in question. However, a differentiation in the WACC level by the considered service (copper based, fibre based local loop) is plausible and will be optionally applied by the model[45].

The WACC level depends on the phase of the market such that in an emerging market phase where a new product is introduced and in a maturity stage where the product is already established different interest rate levels could exist. The WACC typically differs from country to country, reflecting the individual market conditions and the market position an incumbent has in its home market[46].

Generally, in the introduction stage, the WACC level is higher due to the number of risks that come along with the uncertainness. Investors will only finance the fibre roll-out when the offered interest rate incorporates the unsureness of the project outcome. In case of a copper network where the market had already accepted the product, the risk is remarkably lower and so the interest rate. We suggest to consider a higher WACC level for networks based on fibre compared to those based on copper.

According to the EU Recommendation (see footnote) the WACC for copper and ducts may be lower than the WACC for the fibre specific investments, thus the risk premium only should be applied to the fibre cables, splices, branches and ODFs. WIK uses the WACC levels that will be provided by CMT (WACC: 10,48%, WACC premium 4,81%).

5.4.4 CAPEX at different network deployment forms

The derivation of Capex allows CMT to consider different stages of network deployment (pure copper, pure fibre and overlay) coupled with different stereotyped service demand profiles for copper and fibre for groups of MDF areas within a given consideration period of 20 years.

Table 5-3 gives an overview about the main network deployment features accounted for in the Capex derivation (table represents characteristic examples, and cannot be

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[45] EU Recommendation on regulated access to Next Generation Networks (NGA), C(2010)6223 from September 20th, 2010, allows a risk premium for FTTx deployments above the pure copper level, taking into account uncertainties of the investment. The premium may be higher for FTTH than for FTTC. and may be lowered with decreasing uncertainties.

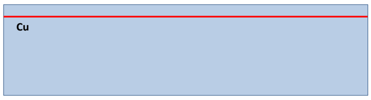
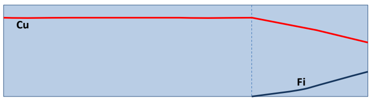
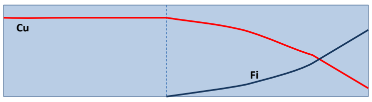
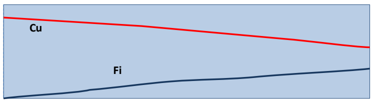
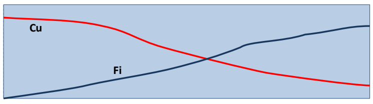
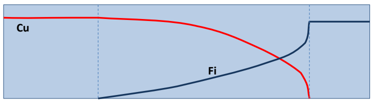
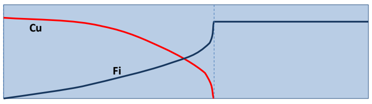
[46] For 2009 WIK research resulted in copper ULL WACC for AT: 10.02%; DE: 7.19%; FR: 10.7%; NL: 7.1%; SE: 9.1%; UK: 10.6%; ES: 10.8%

considered exhaustive). The model permits to parameterize each MDF area individually.

Further, there is an expectation about the process of deployment of fibre within the consideration period of 20 years. Some service areas are already pure fibre areas (fibre only, case 8, not yet at first model application in year 2012)), others are most unlikely to be ever deployed with fibre (pure copper, case 1). In the remaining service areas fibre lines will be deployed together with copper lines in an overlay manner (overlay, cases 2 - 7). To consider the expectations about network deployment in the 20 years consideration period a classification of the service areas in pure fibre, pure copper and overlay deployment is used as core input to the model. For each service area the model computes investment values for copper only, fibre only and overlay deployment.

For each service area (MDF/ ODF area) a maximum fibre demand D_{Fl} has been considered that describes the upper limit of fibre lines that at most is deployed in the consideration period. For copper this maximum demand value D_{Cu} has been set to the current demand for copper lines. Since copper line demand can be expected to decline the current line demand is likely to be the maximum value. The consideration of this is done during demand distribution at an early stage of the data preparation and reflects the maximum possible deployment of lines as expected by the regulator.

Table 5-3: Economic depreciation and demand evolution*

	CAPEX		**ECONOMIC DEPRECIATION**	
Case	Network considered for CAPEX calculation	Service demand considered for CAPEX calculation	Cost annualization	Service demand evolution taken into account to perform economic depreciation
1	Copper network	Dcu	Only copper costs are distributed	
2	Overlay	Dcu + 20% Dfi	Both copper and fiber costs are distributed	
3	Overlay	Dcu + 80% Dfi	Both copper and fiber costs are distributed	
4	Overlay	Dcu + 30% Dfi	Both copper and fiber costs are distributed	
5	Overlay	Dcu + 80% Dfi	Both copper and fiber costs are distributed	
6	Overlay	Dcu + Dfi	Both copper and fiber costs are distributed	
7	Overlay	Dcu + Dfi	Both copper and fiber costs are distributed	
8	Fiber network	Dfi	Only fiber costs are distributed	

*Source: CMT

Thus the demand had been determined in a per service area way, describing D_{CU} and D_{FI} in the copper respectively fibre only cases and D_{CU} and D_{FI} with its increasing slope over 20 years in the copper/ fibre overlay case. This is a large effort if done individually per MDF/ ODF area, hence another option could be to group areas with similar expected development (same share of penetration in relation to the total MDF/ODF homes, the potential market) to clusters for which these details are described in common. By this way we would get clusters describing copper only, fibre only or copper/ fibre overlay deployment. At least for the latter MDF/ ODF areas we received different fibre roll out start points and final total fibre demand, as described in Table 5-3, cases 2 to 7. The exact values have been agreed between CMT and WIK upon market input and expert estimations, if market input was not available.

1. Copper only (case 1)

In the case of copper only the model only considers the efficient demand of ducts and copper cables to serve the area according to the maximum demand in the consideration period, D_{CU}, which we expect to exist at the beginning of the consideration period due to typically declining copper access line demand. The model keeps that demand constant over the consideration period since a declining demand approach for determining the appropriate wholesale price would result in increasing prices, when economic depreciation is applied, and is not conform to economic theory. A bottom-up LRIC approach may only be applied as long as the demand is increasing or at least constant over time, since the method emulates a competitive market price, what an alternative operator would be willing to pay - nothing more than producing the assets by its own in an efficient manner at current cost and state of the art methods and technologies. For declining demand nobody would construct a new network, thus the price determination at constant D_{CU} is the upper acceptable limit at all. A bottom line may be the short run incremental cost (SRIC) just required to operate the copper network. The opportunity cost in general describe the valuation by demanders of the types and volumes of services that could be produced by the existing and estimated future capacity, thus describing a valuation in the band between LRIC and SRIC. Historic cost may result to a valuation within this band, but includes inefficiencies and thus may utmost be a valuation proxy[47].

For the copper only case we recommend to apply the FL-LRIC costing approach at current cost, supported by the SRIC approach in order to determine a base line as described in section 3.1. We believe the historic cost approach not to be applicable, but technically it may be computed by the model, exchanging the current cost values by historic ones, derived from the incumbent’s accounts.

Nevertheless, appropriately parameterized the model can also calculate economic depreciation with declining demand, because this feature is generally implemented and has not been switched off due to the explicit demand of CMT.

2. Fibre only (case 8)

Fibre only describes the situation where the fibre access network is deployed already and all customers are using this service from year 1 on, e.g. in new deployment areas or already completely migrated areas. The model only considers the efficient demand of ducts and fibre cables according to the maximum demand of fibre access lines in the consideration period, D_{FI}. In the fibre only case we assume this demand is already achieved. Thus in order to parameterize the demand for the economic depreciation the growth rate will be zero.

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[47] For a detailed discussion see:
Hoernig, Steffen; Jay, Stephan; Neu, Werner; Neumann, Karl-Heinz; Plueckebaum, Thomas; Vogelsang, Ingo: Wholesale prices, NGA take up and competition, Bad Honnef, April 2011

In completely migrated areas there still may exist old copper cables or copper ducts, which are not required for the efficiently designed fibre access network. Those copper related assets are sunken investment and will not be considered any longer for wholesale access price determination, because they are of no use any longer.

For the fibre only approach we recommend to apply the FL-LRIC costing approach at current cost, as it is standard for regulatory cost determination in constant or emerging markets.

3. Copper/ fibre overlay (case 2 - 7)

In the copper fibre overlay cases we assume that a sufficient amount of ducts already exists at the beginning of the consideration period, which allows to efficiently deploy copper and fibre access lines within the consideration period. According to CMT this reflects the current situation in Spain for a large extent of service areas where fibre will be deployed within the consideration period. If there are additional ducts available which are not required for the copper and fibre overlay deployment and an appropriate operational and technical spare those additional ducts will remain out of consideration.

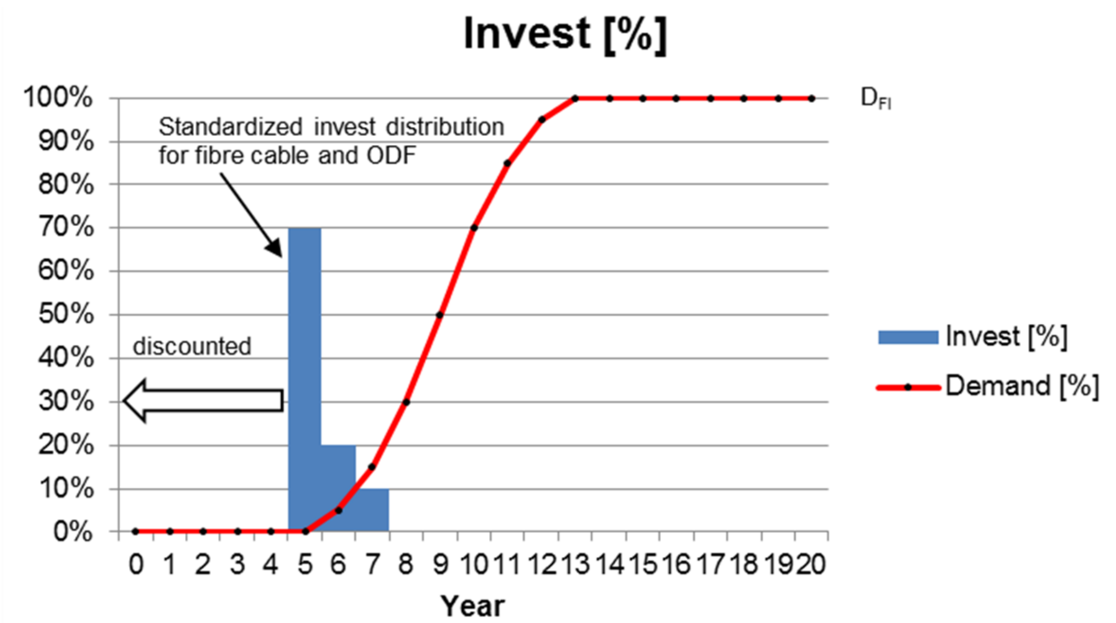
The initial copper access line demand D_{CU} and its appropriate share of civil infrastructure (subducts, space in chambres, MDF, …) determine an upper copper access line price limit as described in the copper only case. Decreasing demand will be ignored for the same reasons already mentioned above. If, like in case 6 or 7 the copper demand falls to zero the copper related investment is sunk, because without further use. The duct cost will not be transferred to the cost of fibre.

The maximum fibre demand D_{FI} determines the network dimensioning for the fibre access network share of the total civil infrastructure. The fibre demand will typically increase up to the end of the consideration period. Economic depreciation is an appropriate tool of choice to determine the wholesale price taking into account future demand, thus lowering the initially high cost per line in the early market entry.

The model only dimensions the fibre access demand up to the maximum value achieved in the consideration period (e.g 20% D_{FI} in case 2, 30% D_{FI} in case 4 and 80% D_{FI} in cases 3 and 5), since the ongoing development (beyond 20 years from now) then is out of the consideration period and may be considered in later years. If the fibre demand achieves its maximum value (D_{FI}) already before the end of the consideration period (cases 6 and 7) the demand development of the economic depreciation applied in the overlay case does not stop at the year where the maximum is achieved but takes the demand of the total consideration period into account. This is justified as a forecast and price determination instrument as long as there still is an overlay situation. In later situations, where there is de facto fibre only, this latter method has to be applied according to economic theory[48].

In the overlay cases the ducts already exist in the beginning of the consideration period - otherwise an overlay consideration would not be justifiable, since later duct deployment for fibre cannot profit from common construction with copper and is a fibre only case. The fibre cable deployment and the according investment can start later, as described in cases 2, 3 and 6 of Table 5-3 above. The investment may be distributed over a period of time in such a manner, that it is installed with a sufficient time gap before the demand has to be connected (sales lead time, sales lag). This is realized by a standardized invest distribution for the investment of fibre cables in all segments and the ODF (Figure 5-18). This investment is discounted to a net present value in year 0 and then is treated as an investment of year 0 in our model computation. The duct infrastructure for fibre already exists in year 0 and the required investment is treated that way. Thus both, the duct investment and the discounted fibre investment, can be depreciated in a common manner. For the whole consideration period the investment for ducts dedicated for fibre is considered as fibre network cost, even if at the beginning of the consideration period the ducts are unused.

Figure 5-18: Progressive capex imputation



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[48] What is the competitive market price? What would the alternative operator be willing to pay utmost? …

The shares of the standardized 3-year invest distribution shown in the previous figure (70%, 20% and 10%) are an illustrative example, and are actually incorporated as input parameters in the model.

We recommend the copper prices in the copper fibre overlay case to be determined by the FL_LRIC costing approach at current cost, added by a SRIC base line (see section 3.1). For the fibre assets we also recommend the FL-LRIC costing approach at current cost, and due to the increasing demand over time the economic depreciation should be applied, alternatively the tilted annuity could be used also.

The cost model would also allow to be fed with historic cost for the copper assets and the civil infrastructure, both for copper and fibre, but we do not recommend applying this. Dividing the copper and fibre ducts and using historic cost for the copper ducts and current cost for the fibre ducts is not justifiable since they are commonly constructed at the same time and use the same spares. Applying SRIC for the copper civil infrastructure in the context of the copper baseline calculation is driven by the fact that this relates to the opportunity cost for these assets once copper demand is declining

5.4.5 Wholesale provision cost

Wholesale costs as part of the relevant network service cost could be considered as relevant as regards to the provision of the unbundled local loop and therefore should be included to the specific cost of the service. Positions such as billing, sales, documentation and customer care (for the relation incumbent - other licensed operator) are parts of the wholesale cost. Wholesale cost will be considered as investment value into the wholesale system which is reinvested and capitalized according to the number of new (=additional) lines provided each year accounting for churn. It will be considered as a one-shot payment at the moment when the operator is provided one line and does not impact the monthly line rental.

Since that such values have not provided by the operators, WIK and CMT referred to information from their benchmark database.

5.4.6 Common Cost

Common costs are expenses assigned to positions which could not be directly allocated to a specific network service, but are needed in order to let the whole network operate successfully as well as for other working processes of the company. Common costs are expenses such as management, administration, human resources and strategy & research (overheads). The costs are considered in the model by an input parameter which will be applied as a mark-up to the sum of total CAPEX (direct and indirect cost) and OPEX. Thus the model allows to calculate the LRIC (without common cost) and LRIC+ (including common cost). The latter will be used during the on-going modeling process. WIK proposes to use a common cost mark-up of 10% based on many WIK benchmark values and which has been used in numerous project. The former project parties and operator agreed on that level.

5.4.7 Cost per access line

The cost per access line is determined on a monthly basis for both fibre based and copper based realisations. The cost based monthly rate is considered as the sum of direct and indirect cost, OPEX, common cost and wholesale cost. The aggregation includes all service areas (MDF/ ODF) regarded to be relevant which could be all service areas or any subset of it. The sum of the MDF specific cost is the total access line cost on a yearly basis. In a final step, total access line costs are divided by the number of active access lines of the considered service areas and by 12 month leading to monthly access line cost. The cost unit is the active line which will also have to carry the cost of technical and economic spare capacities.[49]

5.5 MDF aggregation

The model calculates all results, the interim values as well as the LLU cost per month, in an aggregation of MDF, e.g. per province or on a national level, but in principle allows a per MDF/ODF area granularity. It depends on the degree of aggregation of the inputs into module 3 of the Excel modules. This degree of detail allows to combine the results per MDF in a wide variety of ways, not only as a national LLU average (or national total investment) over all MDFs, but as values for groups of MDF grouped e.g. according to customer density (a typical approach) or other criteria.

Since the model allows calculating three deployment forms, copper only, copper/ fibre overlay and fibre only (fibre with P2P and P2MP/ GPON) one also can combine the values per MDF according to the different deployment forms.

5.6 Structure of model results

The model outcome is mainly based on investment values that are provided in detail for all relevant network elements such as cable investment in duct deployment, directly burried deployment and aerial deployment, trench investment in duct deployment and directly buried deployment, investment in poles in case of aerial deployment etc. The detailed overview is given separately for copper deployment and for fibre deployment and is differentiated by network segment (Inhouse, Building access, distribution cable segment, feeder cable segment, chambers etc.).

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[49] In section 5.1.9 the two types of spares are explained in more detail.

In detail, the model output provides information about

- Direct investment
- Indirect investment
- OPEX on direct investment
- OPEX on indirect investment
- CAPEX (direct investment)
- CAPEX (indirect investment)
- Sum of OPEX, CAPEX

The financial values above are being provided for each of the following position:

- Building drop box, Inhouse
- Distribution cable segment, discriminating among at least the following:
    - buried – trenches
    - buried – cables
    - duct – ducts
    - duct – cables
    - aerial – poles
    - aerial – cables
    - sleeves
    - manholes
- chambers
- Feeder cable segment, discriminating at least among the following:
    - buried – trenches
    - buried – cables
    - duct – ducts

  - duct – cables
  - sleeves
  - manholes
- MDF/ODF

The bullet positions are provided for fibre and copper separately.

The output indicates the resulting total LLU price and its major cost group shares per LLU. It is an aggregation either over all MDF or over any subset of MDF. Alternatively LLU prices could be indicated on an MDF level (as explained in section 5.5).

In detail the output provides the following cost overview for copper-LLU, fibre-LLU, bitstream over copper, bitstream over fibre, and civil works rental:

- CAPEX
- OPEX
- Common cost
- Total cost (sum over the previous positions)

Results can be provided by means of any kind of MDF/ODF aggregation (e.g. specific areas, specific urban densities, copper ULL areas, etc.).

6 Model evolution

The cost calculation as described in section 5.4.4 with its long term forecast of copper and fibre demand, up to the point, when copper is completely substituted, requires a demand development over the whole consideration period. The model requires this data for each of the MDF areas, or for groups of MDF areas. The next section (6.1) describes how this forecast has been derived and agreed by CMT and WIK.

Since all computation of the model based on today’s data is a snapshot of how the situation is estimated today, in today’s situation (streets, houses, population, …) we in the second section (6.2) describe additional methods for estimation of the future development by interpreting and combining model results.

6.1 Evolution of FTTH Services (2010 - 2030)

6.1.1 Design Criteria

The estimation of the evolution of both FTTH coverage (passed homes) and FTTH service demand (connected homes)[50] along 20 years is carried out in the model through the steps represented in the following figure:

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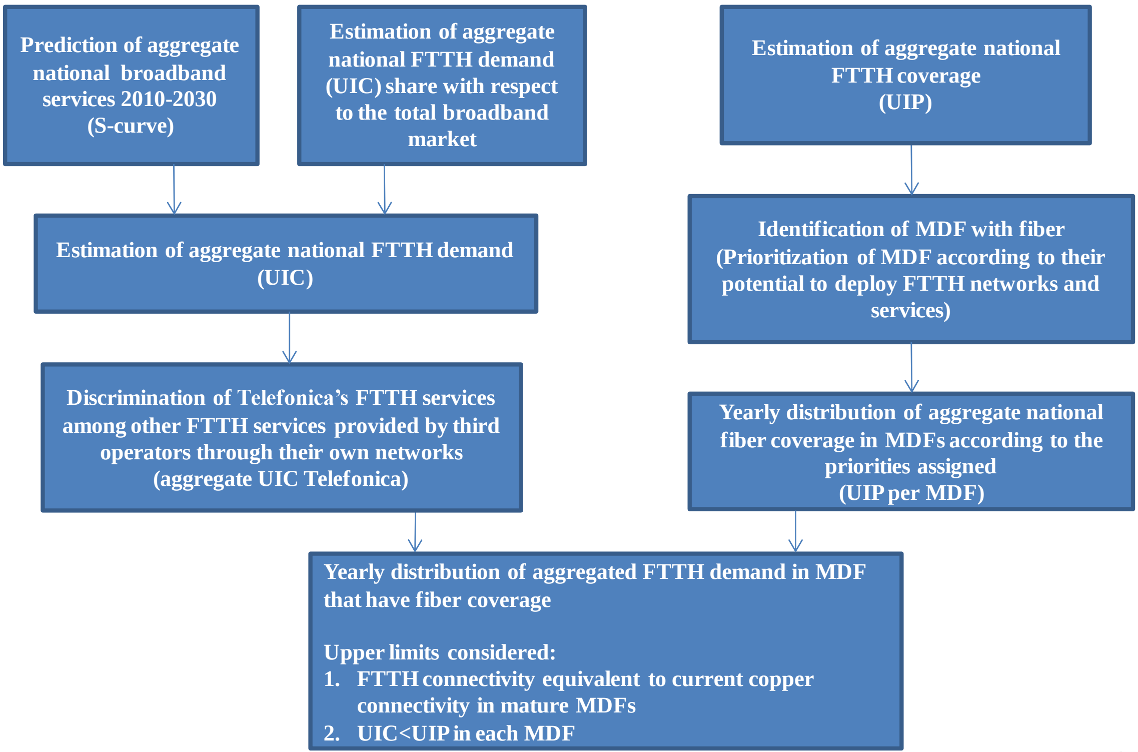
[50] UI: homes and business locations (*unidades inmobiliarias*); UIP: homes (and business locations) passed; UIC: homes (and business locations) connected.

Figure 6-1: FTTH forecast process for Spain



Source: CMT

6.1.1.1 Estimation of aggregate national FTTH coverage (2010-2030)

The coverage is determined by the share of Real Estate Units Passed with fiber (UIP). This is calculated from the following data:

- Current data about FTTH deployment (number of UIP).
- Telefónica's yearly UIP estimates up to 2015.

6.1.1.2 Identification of MDF with fiber (MDF prioritization)

We assume that priority and speed of fibre roll out is mainly driven by the investing operator's profitability. Profitability is on the one hand determined by the cost per customer, on the other hand by fast service take up and by high willingness to pay. Thus socio-economic criteria are used to quantify the probability that the current Telefónica's MDF have to develop FTTH services to a greater or lesser extent throughout the period of 20 years covered in the cost model for access network in Spain. Some of the criteria that increase the profitability potential of MDF are the density of population (high density - low cost), employment levels (active population) and share of individuals with high level education (fast acceptance and high willingness to pay). Such information has been accessed through the National Statistics Institute (INE).

Additionally the model considers the following parameters to determine a realistic MDF prioritization:

- Current level of fiber deployment in each MDF according to figures provided by Telefónica.
- Degree of competition in broadband services that exists in each area, which is determined by identifying the MDF where the number of unbundled lines is significant (higher than 1000 lines), in combination with those areas where cable operators are present. It has been observed notable coincidence of both competition indicators given that 80% of cable lines are located in those areas with high ULL competition.

Both situations - high levels of deployment of fiber optic and broadband competition - show the greatest potential to develop FTTH services in the short or medium term. As a result of the analysis different priorities are assigned to each of the 6535 Telefónica MDF areas, to which the current remote nodes deployed are added (over 6000 small areas). These areas are arranged according to the priorities assigned in order to distribute national FTTH coverage among them in a way that the highest priority areas are served first.

6.1.1.3 Yearly distribution of aggregate national FTTH coverage among MDF areas

Aggregate national FTTH coverage values are annually distributed among Telefónica's MDF to a greater or lesser extent depending on the priorities assigned to them: in areas of high priority as are those with significant levels of competition, the penetration of services over FTTH is fast, while in low priority areas such as rural areas with limited competition, the evolution is slower and may even be zero over the whole considered period.

This distribution of aggregated annual growth between different network MDFs is performed first by assigning additional shares of FTTH network and service penetration in MDF areas that already have fiber deployed, and secondly by distributing the remaining aggregate growth - not assigned to the first - among new MDF areas that are activated with the objective to absorb this remaining demand. This process is repeated annually until the end of the period. Current data of FTTH deployment per MDF and yearly growth rates in both fiber and non-fiber areas are input parameters.

The maximum coverage share achievable in every MDF is the total number or Real Estate Units located (UI) in its influence area. When the fiber coverage share approaches 80% of the real estate units in that area an efficient operator makes its best efforts to speed up as far as possible fiber deployment and migration of all users to the new services over fiber so that it can be able to close the copper MDF, thus avoiding to suffer the extra-cost caused by operating two networks in parallel. Therefore, when such threshold is achieved (80%) fiber deployment trend is accelerated thus quickly increasing coverage shares until the maximum coverage is reached (100% of Real Estates passed in the area).

6.1.1.4 Projection of aggregate national broadband services (2010-2030)

Predictions are made for future deployment -until 2030 - of broadband services provided over NGA networks. The following studies and references are considered to determine a trend throughout 20 years by using a logistic function (S-curve). This function is normally used to predict broadband service demand and can be calibrated with historical data:

- Historical data about broadband deployment in Spain.
- Market Development up to 2020 as determined in the bottom-up LRIC model for wholesale services (Frontier, 2011).
- Objectives outlined in the Digital Agenda published by the EC[51].

6.1.1.5 Estimation of aggregate national FTTH demand (2010-2030)

Considering that broadband services can presumably be provided through different network technologies - FTTH, VDSL2, VDSL2 Vectoring, HFC, or radio HSPA/LTE - that will coexist and evolve over the considered period, it is determined the share of deployment that exclusively corresponds to FTTH networks. Thus, it is estimated the aggregate national FTTH demand share with respect to the total broadband market. The following sources are considered to determine the future trend until 2030:

- CMT quarterly reports evidence exponential growth since 2009 in the fibre marked share with respect broadband market.
- Market forecast up to 2020 as determined in the bottom-up LRIC model for wholesale services (Frontier, 2011).

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[51] As stated in the Digital Agenda, in 2020 50% of European households will have broadband services at speeds equal to or higher than 100Mbps.

Such references, together with the number of national broadband services determined in the previous step, permit to identify the aggregate national FTTH demand in terms of Real Estate Units Connected with fiber (UIC).

6.1.1.6 Discrimination of Telefónica's FTTH services

It is determined and excluded the share corresponding to operators different from Telefónica that will provide services over their own FTTH access networks. Therefore aggregate national FTTH demand (UIC) exclusively corresponding to Telefónica up to 2030 is obtained.

6.1.1.7 Yearly distribution of aggregate national FTTH demand in MDFs

Aggregate national FTTH demand values are annually distributed among Telefónica's MDF that have fiber coverage in order to determine the number of fiber access lines per MDF area.

In every MDF the increase of fiber services occurs for two reasons: first due to the increase in the number of Real State Units covered with fiber (given that a share of them will demand fiber services), and secondly due to the increase of service demand in those Real State Units already covered with fiber in previous years.

In addition the model considers the following control measures in order to avoid that service demand exceeds natural upper limits:

- In every MDF, FTTH service growth is limited thus avoiding that it exceeds the current number of copper active access lines. That is, the maximum penetration of FTTH services per MDF in 2030 is estimated equivalent to the current penetration of active copper access lines, under the premise that the modeled operator (Telefónica) will maintain in the future a degree of FTTH connectivity equivalent to the current copper connectivity. This criteria assumes that over the next 20 years an increase in global connectivity will occur driven by an increase of the Spanish population (based on figures published by the INE) and by the widespread deployment of Information Society Services.

Under this assumption the model predicts the future development of broadband services and distributes it among the various access technologies mentioned above, considering also a share corresponding to operators different from Telefónica that will provide services over their own FTTH access networks. The projections made in the model allow us to conclude that demand for broadband services in 2030 is broad enough to model at that time a degree of Telefónica´s FTTH connectivity - in those MDF where FTTH network deployment is mature enough to end with the total replacement of copper access by fiber access - that is equivalent to existing Telefónica´s active copper accesses. These assumptions include, that not necessarily all broadband access lines provided by Telefónica only serve Telefónica's retail and business customers, but also are used as wholesale products offered to competitors.

- On the other hand the model continuously monitors that the amount of FTTH demand per MDF area remains below the FTTH coverage.

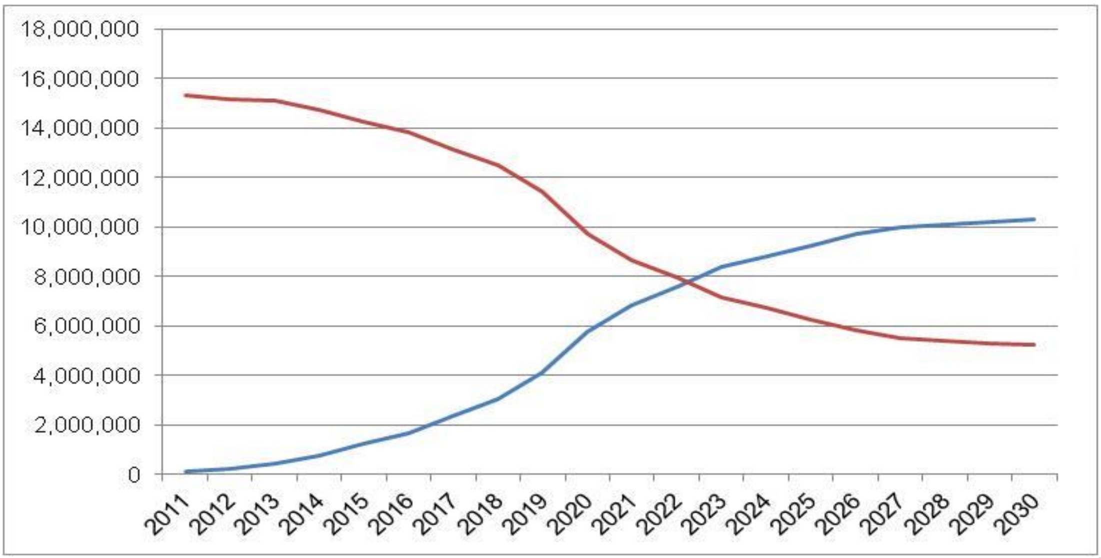
6.1.2 Annual aggregate figures: Real Estate Units Connected and Passed

The graph below shows the aggregated demand of FTTH services (over all MDF/ODF locations). The values are presented in terms of Real Estate Units Connected (UIC), which includes both business locations and homes connected.

Table 6-1: Homes (and business locations) connected

Year	UIC	% over current active copper lines
2011	167K	1%
2020	6M	38%
2030	10.2M	66%

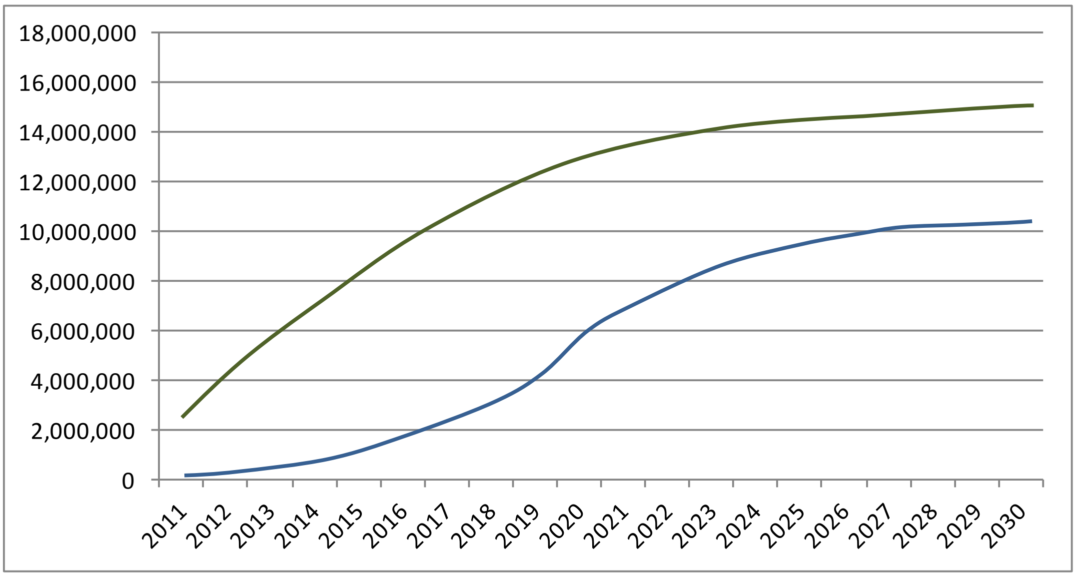
Figure 6-2: Homes (and business units) connected, absolute value forecast



Source: CMT

The chart below shows (in blue) the Passed Real Estate Units (UIP, including homes and business locations) compared to the Connected Real Estate Units (UIC):

Figure 6-3: Homes passed and homes connected (absolute values)



Source: CMT

6.1.3 Evolution of FTTH services in each MDF area

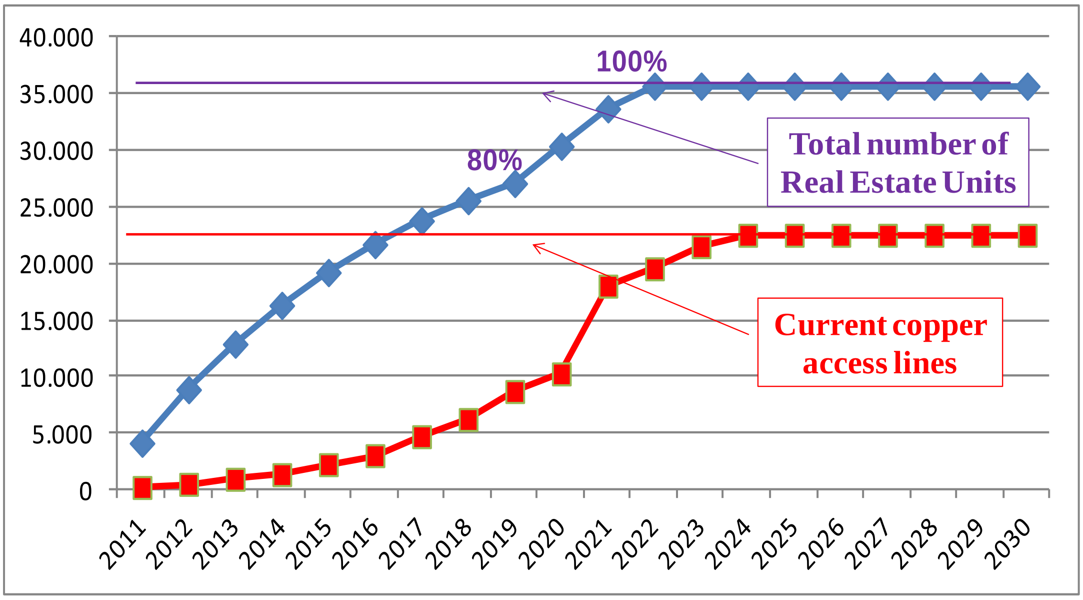
As a result of the MDF areas prioritization process and the aggregate demand estimation described in the previous section, the various Telefónica's MDF suffer greater or lesser allocation of services over FTTH throughout the period. Each MDF is represented until 2030 by a curve of FTTH network deployment (UIP) and a curve of penetration of services provided over these networks (UIC). The evolution curves reflect the potential of each area MDF and show, among other things, the following parameters:

- Date when the implementation of FTTH services starts in each MDF area. As reflected by currently available figures about FTTH service deployment, some MDF already show a certain level of development, while others will start in coming years and some others will not start fiber services for the entire period.
- Speed or intensity of development of networks and services (annual values of homes passed and homes connected in each MDF area).
- Eventually, the closing year of the MDF. During the course of 20-year period considered, the introduction of FTTH services will be consolidated in a number of

MDF areas, which will reach a situation of total replacement of copper access by fiber, thereby closing the MDF placed in those areas.

The following figure shows an example of rapid deployment of services in a high priority MDF, where the total replacement of copper by fiber access lines occurs (MDF close-up):

Figure 6-4: Homes passed and homes connected in a high priority MDF



UIP (blue) and UIC (red) absolute values

Source: CMT

As explained before, when the fiber coverage share (UIP, in blue) approaches the 80% threshold in the MDF area, an efficient operator makes his best efforts to speed up as far as possible fiber deployment and migration of all users to the new services over fiber so that he can be able to close the MDF, thus avoiding to suffer the extra-cost caused by operating two networks in parallel.

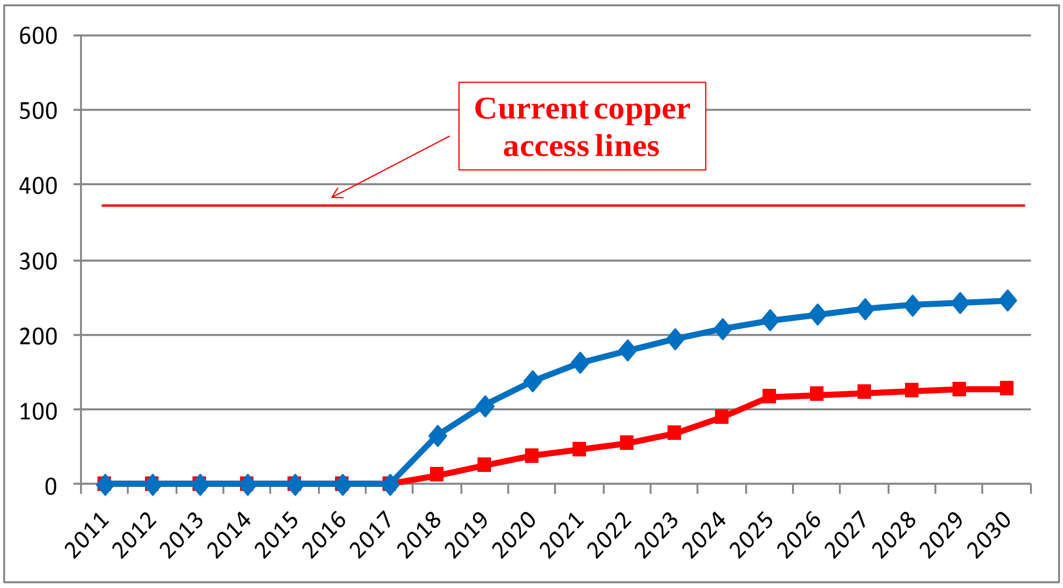
Such acceleration of the trend continues for a period of approximately 5 years, which is consistent with the period of notice - specified in the Spanish regulation - after which Telefónica is allowed to dismantle the MDF and the copper network. This accelerating trend is achieved by the following procedures:

- Enhancing fiber deployment (UIP) efforts in order to guarantee coverage to all users who are in the access area of the MDF. As a result, in the example above, all households are passed in year 2023.

- Promotion of commercial efforts in order to complete the migration of all users that are still connected to copper access, before the referred period of 5 years ends. After this period every copper access disappears, and all users are connected by fiber.

The figure below, on the other hand, reflects the deployment of FTTH networks and services in an MDF whose potential is considered low as a result of the application of the design criteria described above:

Figure 6-5: Homes passed and homes connected in low potential MDF



UIP (blue) and UIC (red) absolute values

Source: CMT

In cases like the one shown in the figure above the penetration of the fiber network (UIP) progresses slowly, and after the period of 20 years is well below the full MDF area coverage. Similarly, services provided over fiber reach only a small percentage of current active copper lines. The magnitude of this percentage is given by the fiber deployment potential specifically assigned to each MDF area.

6.1.4 Status of implementation of fiber services in 2030

The following table summarizes the situation at the end of the period of 20 years considered:

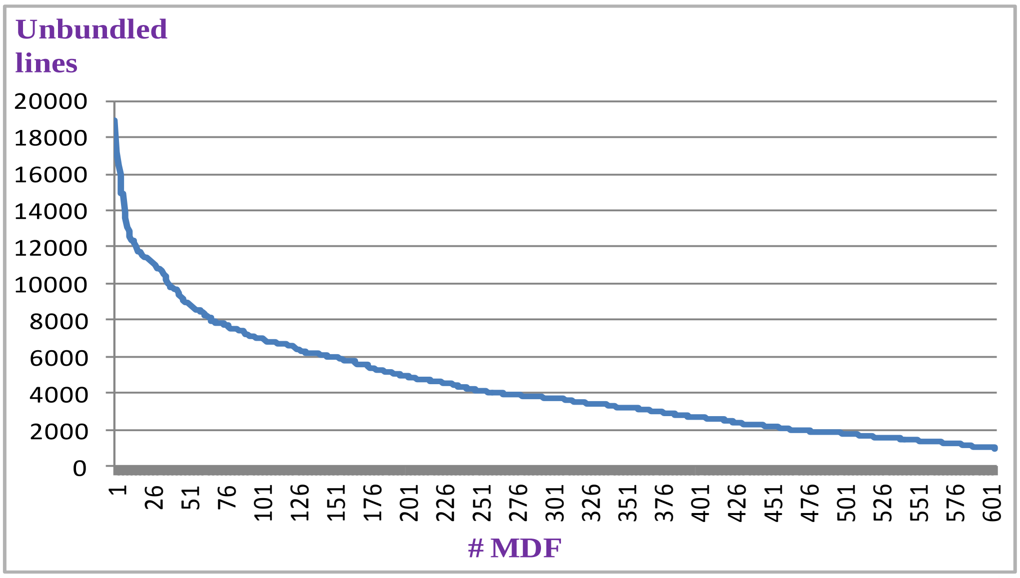
Table 6-2: Demand estimated for 2030

General		Comments
Number of UIC	10.2M	51% of all households
Number of UIP	15.0M	75% of all households
Share UIC/UIP	68%	
Number of MDF areas with fibre	1.591	Out of 6500
Number of MDF areas without copper (closed MDF)	870	
Number of MDF areas where copper and fibre coexist	721	

6.1.5 MDF with operators currently collocated

The following figure shows MDF arranged according to their number of current unbundled lines.

Figure 6-6: MDF with collocated operators (rented pairs > 1000)



Source: CMT

There is a total amount of 606 MDF where the number of lines rented to alternative operators is greater than 1000. Such MDF are included in the group of 870 MDF where the model foresees the complete replacement of copper access by fiber access -and therefore the closure of the copper MDF- in 2030.

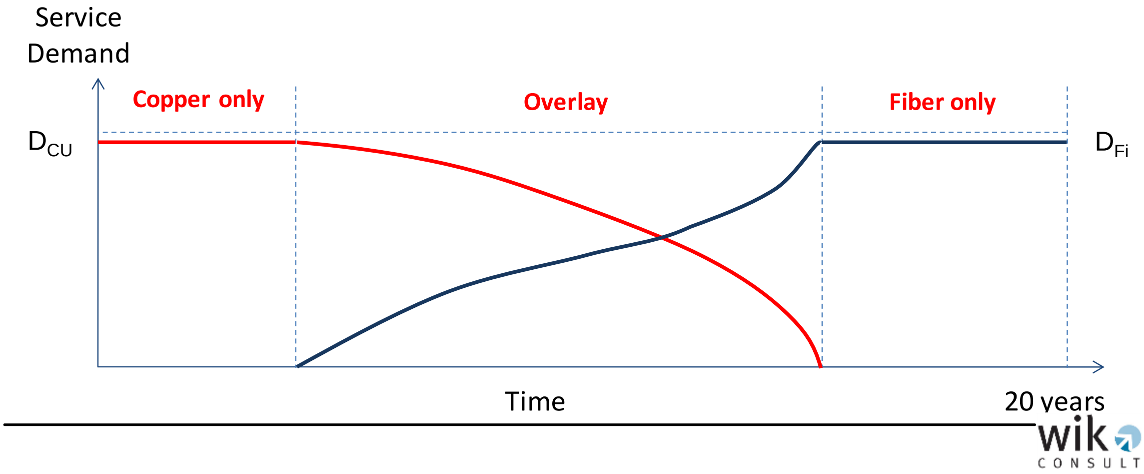
6.2 Interpretation and combination of model results

The model results per deployment form and per MDF/ODF area allow to combine the results in different manners, thus allowing to describe a glide path of copper - fibre migration as a combination of efficient snapshots of MDFs, some in pure copper, some in copper/ fibre overlay and the rest of MDFs in fibre only technology. The share of these may vary over time.

In order to determine which MDF to be calculated in which deployment form one may choose the subscriber density as criterion, or one can base on the sociodemographic data which is available as census information per census area for Spain[52]. Assuming that there exists a rule to describe the end customer fibre affinity by the sociodemographic data given one may determine the MDF areas being deployed with fibre access networks in a ranked order, thus also allowing to describe a migration path by combining the MDF results in a manner described by these sociodemographic data.

Besides the option to combine MDF areas in their specific deployment form the economic depreciation approach chosen also allows to model the overlay situation in more detail, using the different growth values per year for fibre up to the final fibre demand D_{Fi} (Figure 6-7, see also Table 5-3 for variations). The initial copper demand D_{CU} and the final fibre demand will be used to dimension the required civil infrastructure. The cost shares assignable to each of these infrastructures will be assigned appropriately according to the duct space consumed.

Figure 6-7: Overlay network evolution



Source: CMT 2011

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[52] Such data will not be used in the actual modelling process, except being used to qualify the cadastral information used.

The economic depreciation then will allow for increasing markets to allocate the fibre cost according to the integrated demand of fibre access lines of the whole period (20 years) in a homogenous manner.

Thus the evolution of the access network may be described by a snapshot combination of pure copper MDFs, for which a fibre roll out is not yet concretely planned or will not take place in the consideration period (of 20 years), copper/ fibre overlay MDFs with their specific demand evolution and pure fibre MDFs, which are already deployed yet or where copper will be switched off at the snapshot point of time.

Network topology will evolve in the future due to the construction of additional buildings, streets, civil works, etc. Also ODF status will change, being fibre more intensively deployed in some of them, and more conservatively in others. Also the change from several copper/ fibre overlay MDF/ ODF to one new fibre only ODF or the additional deployment of remote nodes initiates the reconsideration of a new efficient network structure. Such situations will require to recalculate CAPEX in some zones, what CMT could carry out by running the planning and evaluation algorithms provided by WIK.

7 Summary

The model is a flexible tool allowing to calculate the cost of copper only, fibre only and also combined copper/ fibre overlay access networks at a per MDF/ ODF access area granularity. For fibre two topologies are considered, either Point-to-Point (P2P) or Point-to-Multipoint (P2MP). Combinations of the results of the different deployment forms on the one hand and the implementation of the economic depreciation with individual growth values per period in the network overlay situation on the other hand also allows for differentiated and detailed network evolution considerations.

The model is based on detailed geographic information on streets, residential and business buildings and their use and allows deriving a very exact demand estimation in its spatial distribution.

Network optimization tools allow modeling the deployment of an efficient access network from the end customer locations to the MDF/ODFs, which are taken as scorched nodes, in each of the technologies and mentioned above. The MDF/ODF access areas are delineated in an efficient manner, independently of existing network inefficiencies. Also the distribution access areas are delineated according to efficiency criteria. The path for distribution and feeder network are planned as cost optimal trees, consisting of the demand adapted and optimized network elements, e.g. cables, ducts, manholes etc. It also optimizes costs if the network segment would be more efficiently deployed on one or two sides of a street, driven by the concrete demand situation of a given street segment and by costs.

The resulting cost per access line and type are computed for the aggregation level chosen by the user (single MDFs or multiple MDF up to national level) and therefore may be combined in different manners to average values, like regional or national averages or to averages for groups, which may be defined by other criteria.

This cost includes all relevant aspects, besides the required direct investments also the indirectly attributable investments, operational expenditures related to the access network, wholesale cost, interest fees and an appropriate share of common cost.

ANNEX 1. MODULE 3 DESCRITION

The module consists of the following spreadsheets.

Overview of module 3 spreadsheets

Sheet	Content
fi_summary	Summary of monthly CAPEX, OPEX and price per fibre line. Also controls the tilt factor for the tilted annuity
fi_annuity(linear)	CAPEX and OPEX based on simple annuity
fi_tilted_annuity	CAPEX and OPEX based on tilted annuity
fi_econ_depr	CAPEX and OPEX based on economic depreciation according to detailed demand forecast by CMT
fi_OPEX	fibre OPEX determination (without annualisation)
cu_summary	Summary of monthly CAPEX, OPEX and price per copper line. Also controls the tilt factor for the tilted annuity
cu_annuity(linear)	CAPEX and OPEX based on simple annuity with constant demand at level of year 1
cu_tilted_annuity	CAPEX and OPEX based on tilted annuity with decreasing demand (sunk cost of MDF without demand are removed). Tilt factor is defined here, too.
cu_econ_depr	CAPEX and OPEX based on economic depreciation according to detailed demand forecast by CMT (sunk cost of MDF without demand are removed)
cu_OPEX	copper OPEX determination (without annualisation)
ws_duct_summary	Summary of monthly CAPEX, OPEX and price per sub-duct meter. Also controls the tilt factor for the tilted annuity
ws_duct_annuity	CAPEX and OPEX based on simple annuity
ws_duct_tilted_annuity	CAPEX and OPEX based on tilted annuity
ws_duct_econ_depr	CAPEX and OPEX based on economic depreciation according to detailed demand forecast by CMT
ws_duct_OPEX	fibre OPEX determination (without annualisation)
fi_invest_renewals_NPV	determination of total fibre investment and reinvestment in each year according to roll-out
cu_invest_renewals_NPV	determination of total copper investment in t0 and later reinvestment
ws_duct_invest_renewals_NPV	determination of total duct investment in t0 and later reinvestment
ws_duct_MDF_invest	fibre investment per MDF
cu_MDF_invest	copper investment per MDF
cu_MDF_invest	wholesale duct investment per MDF
fi_one time invest	determination of fibre one-time investment per new line (wholesale system and selected other positions); independent from monthly rental calculation
cu_one time invest	determination of copper one-time investment per new line (wholesale system and selected other positions); independent from monthly rental calculation
Inp_Asset_Types	Defines assets, lifetimes, price trends and network specific WACC for fibre and copper
Inp_Indirect_Inv	Defines mark-ups for determining indirect investments
Inp_OPEX	Defines mark-ups for determining OPEX

Sheet	Content
Inp_other	defines further input parameters
Inp_Transposed	re-organized inputs to ease model setup and analysis
Module2_outputs	Output from the Investment tool (module 2): primarily investment for each asset type per MDF to build the network once at year 1 prices. (all quantities are shown in module 2)
fi_demand	fibre demand forecast by CMT (considering only those MDF for which the previous Modules have run)
cu_demand	copper demand forecast by CMT (considering only those MDF for which the previous Modules have run)
ws_duct_demand	wholesale subduct take-up rate forecast by CMT (considering only those MDF for which the previous Modules have run)
fi_demand_all_MDF	fibre demand forecast by CMT (full forecast for all MDF)
cu_demand_all_MDF	copper demand forecast by CMT (full forecast for all MDF)
ws_duct_demand_all_MDF	wholesale duct take-up rate forecast by CMT (full forecast for all MDF)

Most sheets are fully dedicated to one technology which is indicated by the prefix "cu_" for copper, "fi_" for fibre and "ws_duct_" for wholesale ducts. Because the sheets themselves are very similar they are also referred to e.g. as xx_summary meaning that cu_summary, fi_summary and ws_duct_summary are addressed in the respective explanations.

Almost all input parameters are defined in the yellow Inp_xxx sheets. There are less than a handful of parameters that are located elsewhere, typically in order to immediately analyse the impact on results (the tilt factor for the tilted annuity and the common cost mark-up which are configured on the xx_summary page and some parameters for the one-time investment calculation which are located directly on the respective one time invest sheets).

Colour coding indicates sheets with a related theme. In principal one may distinguish 4 different categories

- Summary and annualisation sheets (red for fibre, blue for copper, green for wholesale ducts)
- Investment sheets (grey)
- One-time investment sheets (rose)
- Inputs (yellow)

All sheets are explained in the following subsections.

Summary (xx_summary)

The summary sheets (fi_summary, cu_summary, ws_duct_summary) sheets show the final results of all of the modelling process for the currently considered set of MDF. Ultimately, the user will always want to return to these sheets to check the impact of any changes. The sheets aggregate results from different depreciation approaches and provide the following information for each year in the 20 year time frame:

- Monthly CAPEX
- Monthly CAPEX per line
- Monthly OPEX
- Monthly OPEX per line
- Monthly Common Cost per line
- Total Cost per line

Diagrams at the bottom of the sheet visualise important results. The only controllable input parameters on this sheet are the mark-up for common cost and the tilt factor for the tilted annuity.

cu_summary also shows Short Run Incremental Cost (SRIC) as an alternative price point for the copper network.

Annualisation sheets

There is one sheet for each of the three depreciation options of annuity (xx_annuity(linear)), tilted annuity (xx_tilted_annuity) and economic depreciation (xx_econ_depr). The primary function of each sheet is to develop annual and ultimately monthly CAPEX from the Net Present Value of investment (determined in xx_invest_renewals_NPV) for each asset. Depreciation is conducted individually for each asset and investment stream generated in each year.

In addition, the sheets apply the same annualisation scheme to the OPEX profile which is determined in xx_OPEX.

CAPEX, OPEX and Total Cost can be reviewed for each asset.

There are no input parameters on these sheets.

OPEX sheets (xx_OPEX)

These sheets determine the annual (and monthly) OPEX through mark-up factors on investment values.

For the copper network the calculation is conducted a second time for the case of decreasing demand leading to MDF closure and hence reduction of relevant OPEX.

There are no input parameters on these sheets.

Investment sheets

There are two types of investment sheets. xx_MDF_invest determines the indirect investment through mark-ups on the (direct) investment. In addition, the original investment values from module 2 can be altered through a factor (defined in the Inp_Asset_definition). Investment shown in this sheet is derived from module_2_outputs which holds the investment for building the network at year 1 prices without accounting for renewals or delayed timing of roll-out. The investments are still shown individually for all MDF and all assets.

There are no input parameters on these sheets.

The second set of sheets is xx_invest_renewals_NPV. In fi_ invest_renewals_NPV the fibre roll-out path is taken into consideration to shift the investment into the relevant year in the future if required. The sheet also determines renewals that occur within the 20 year time frame and ultimately provides a detailed investment profile and Net Present Value for each asset. In the copper case renewals are accounted for in the same way but the roll-out fully takes places in t0, i.e. the roll-out is not stretched over time; the same is applicable to wholesale ducts.

There are no input parameters on these sheets.

One-time investment sheets (xx_one-time_investment)

These sheets have two functions. The first one is to determine a one-time fee for wholesale connections based on the investment and renewals for the necessary wholesale system.

The second function is to show unit prices for selected inhouse network components that are also considered as one-time investment.

There are 2 controllable parameters on each page. First, the user can set the investment for the wholesale system. Second, the user can choose between an economic depreciation or a linear annualisation of CAPEX. In addition, the price trend of the wholesale system can be configured.

Input sheets

There are a total of 12 sheets which collect input parameters.

Inp_Asset_Type defines some of the most important parameters of cost determination. These are for each asset

- For copper, fibre and wholesale ducts
    - Economic lifetime
    - Price trend
- For copper and wholesale ducts
    - One WACC equally applicable to all asset
- For fibre assets
    - One WACC risk premium (added to the WACC level defined for copper assets) applicable to all eligible assets
    - Whether the asset shall be eligible for the WACC risk premium
    - Whether the roll-out path defines the timing of investment or whether the asset shall always be considered to be deployed at t0 (example: ducts for fibre are considered to be deployed together with the copper infrastructure at t0)

For the years 21 to 60 the value from year 20 is "frozen" and kept throughout all periods beyond the 20 year scope.

Inp_Indirect_Inv defines the mark-up factors to determine the level of indirect investment.

Inp_OPEX defines the mark-up factors to determine the OPEX.

Inp_Transposed is a simple transposition of rows and columns to ease model development and analysis. All values must be set at their respective original source (Inp_Asset_Type, Inp_Indirect_Inv or Inp_OPEX) and should never be changed on this sheet!

Module2_outputs is a sheet generated in Module 2. It contains the direct investment values for each asset, the number of lines and a few additional items. All information is provided MDF by MDF.

xx_demand defines the demand forecast for each currently considered MDF over 20 years. The fibre sheet also derives the roll-out timing from the fibre demand. The copper sheet derives the timing of MDF closure and the associated percentage of the total investment related to the closed MDF from the demand profile. This information is used to remove sunk cost in two of the copper depreciation scenarios (tilted annuity and economic depreciation).

xx_demand_all_MDF contains the demand forecast by CMT for all Spanish MDF. It is the basis for inserting the relevant MDF demand data into the xx_demand sheets.

Notes about the depreciation methods

There are some assumptions linked to the application of the different depreciation methods, especially for the copper network. They are shown in the following table:

Depreciation methods and connected assumptions on demand and asset price trend

	COPPER		**FIBRE**	
Depreciation method	**Demand**	**Asset price trends**	**Demand**	**Asset Price trends**
Simple, linear annuity	Constant through all the years, all MDFs remain in the calculation	Not considered	Increasing according to forecast (unless fibre only scenario is manually activated, then constant demand)	Not considered
Tilted annuity	Decreasing as forecast by CMT, MDF sunk cost removed	Considered (can be set to 0)		Considered (can be set to 0)
Economic depreciation				

Some conclusions follow from this:

1. When the copper only scenario is run, tilted annuity and economic depreciation should not be regarded because they rely on the demand forecast with decreasing demand which is inappropriate in the copper only scenario. If the user nevertheless wants to compute these options he will have to reset the copper demand forecast manually to be constant at the level of year 1 throughout all periods in order to observe meaningful results.
2. By setting the tilt factor to 0 the CMT can observe the effects of applying a linear CAPEX spread like the simple annuity to decreasing copper demand and accounting for sunk cost removal. The effect is – as expected – generally an increase in cost per line over the years. The severity of the increase is mitigated by removal of sunk cost when MDF have no more

subscribers. In its purest form this is visible when setting the asset price trend to zero.