COST MODEL FOR THE FIXED TELECOMMUNICATIONS NETWORK

Hybrid Cost Proxy Model - PORTUGAL

17 November 2000

INDEX

1. INTRODUCTION 3

2. HYBRID COST PROXY MODEL 6

2.1 MODULES OF THE HYBRID COST PROXY MODEL 6

2.1.1 Access 6

Customer Location Module 7

Loop Design Algorithms 7

2.1.2 Interconnection 8

2.2 HCPM – PORTUGUESE EDITION 8

2.2.1 Access 8

2.2.2 Interconnection 10

3. INPUTS 11

3.1 INFORMATION SOURCES 11

3.2 INFORMATION PROCESSING DIFFICULTIES 12

3.2.1 Access 12

3.2.2 Interconnection 13

3.3 OTHER INPUTS 13

4. OUTPUTS 14

4.1 NETWORK COSTS 14

4.2 NON-NETWORK COSTS 15

4.3 UNIVERSAL SERVICE 16

5. CONCLUSION 17

1. INTRODUCTION

The present document aims to provide an overview of the work developed by a Project Group of the Instituto das Comunicações de Portugal (ICP), created as an engineering process economic cost model (bottom-up) to calculate the long-term costs that an efficient entrant – constrained by the current locations of exchange nodes of the historic operator of the fixed telephone network in Portugal – would bear if it decided to satisfy the entire present demand for telecommunications switched services and leased lines.

The services' price-cost orientation, the interconnection between rival networks and the obligation to provide telecommunications Universal Service constitute critical issues in which the regulatory authority must be particularly skilled.

In order to give correct signals to promote efficient new market entrants, and suitable investment and innovation levels, the regulatory authority must base its decisions on **forward-looking economic costs**. This is because the accounting costs presented by the incumbent operator are historic costs that, by definition, will not be borne by new entrants. New entrants will decide upon the basis of current costs. Thus in addition to the information produced by accounting models, the regulatory authority needs additional information in order to calculate forward-looking economic costs.

The cost methodology that supplies correct signals to increasingly competitive markets is the **engineering process approach**, because it enables an exact spatial configuration of the latest infrastructure-related elements of the network (evaluated at current prices) needed in order to satisfy demand levels as established by user inputs. In this manner it is possible to determine the minimum forward-looking economic costs of the services identified for this purpose, using the appropriate combination of network elements. At the same time, this approach ensures that sufficient network facilities are deployed in order to satisfy demand at the quality of service specified by the model inputs.

In order to estimate the cost of infrastructures required for the production of telecommunications services, long-term engineering process economic models combine the engineering process of production of services with optimisation routines, incorporating the engineering standards and practises used by telecommunications companies when they plan their telecommunications networks.

The cost-output relationship is derived from an optimising behaviour: the minimum production cost is determined for various output levels given the prices of inputs, engineering constraints and the production function.

There are essentially two approaches to the economic costing of the engineering process of telecommunications networks – the **scorched earth or green field** approach; and the **scorched node** approach. Models using the first approach handle all inputs as variables, including the number and location of exchanges. Models using the second approach assume that the location and number of exchanges are fixed. The rigidity of input may be used in order to assess the degree of historic inefficiency associated with the growth of networks.

The scorched node approach has generally been preferred by incumbent historic operators and regulatory authorities. Until now, most engineering process economic models used by incumbent operators have not considered the objective of optimisation of the location of exchanges, as a new entrant would do. For example, when a telephone company calculates the incremental cost of a client's access circuit, it does not try to determine the cost-minimising location of the exchange. Instead, it assumes that the current location is the optimal solution. In other words, these models assume that the current location is the best solution for minimising long-term costs.

The current location of exchanges may or not be optimal. It is only possible to establish a definite conclusion as to whether the current location is efficient by comparing the present discounted value of the costs of alternative locations. This procedure is consistent with the economic principle that over the long term all inputs are variables.

The key reason that determined the choice of the Hybrid Cost Proxy Model (HCPM) as the model for costing the Portuguese telephone network was the specific manner in which this approach models the access network. Based upon the location of clients, the model uses spatial aggregation algorithms and selects the minimum cost path that connects clients to the exchange.

HCPM is a typical static long-term engineering process cost model. As a static model, the HCPM is particularly well suited for calculating the cost of services, given that its information requirements have fewer constraints and require less speculation in terms of price levels and future demand levels. The model currently operates only in the scorched node mode and was constructed in the two typical stages of an engineering process. First, identification is made of the engineering process stages used in order to design telecommunications networks. The engineering procedures are then reduced to mathematical relationships. This reduction is the core of an engineering process model; engineering functions are expressed as a series of economic equations. The HCPM multiplies the physical quantities of the network elements by their current prices, for all network components – access circuits, exchanges and interconnection circuits – after having calculated the infrastructure and equipment requirements needed in order to satisfy a specific demand level (measured by number of clients and projected traffic). Finally, using suitable algorithms in order to spatially aggregate clients in the access network and exchanges in interconnection rings, the model seeks the combination of technologies that will minimise annual production costs, equivalent to minimising the present value of capital, after maintenance costs and taxes.

Through repeated simulations of cost-output relations, the model favours the development of information formats that makes it possible to measure the impact of varied output levels on production costs for various services. For example, the model is able to compute incremental costs by simulating an increase in the demand level for local calls, measured in minutes of traffic generated.

2. HYBRID COST PROXY MODEL

This section provides a summary of the original version of the Hybrid Cost Proxy Model[1], while also outlining the specific aspects that result from applying the model to the Portuguese context.

2.1 MODULES OF THE HYBRID COST PROXY MODEL

The Hybrid Cost Proxy Model was designed considering the access network and the interconnection network as two distinct activities, independently of the existence of sharing of certain infrastructures and consequent sharing of costs.

The optimisation of each network takes place separately, by recourse to distinct programming models. In the access network, the *customer location module* and *loop design module* are the programmes responsible for the design of the feeder and distribution network. In the interconnection network, the *interoffice cluster* and *interoffice design module* ensure complete connectivity between network nodes.

This section starts with the optimisation stages of the access network, followed by the optimising routines for the interconnection network.

2.1.1 ACCESS

The access network guarantees the connection of each client to the exchange in his Wirecenter, through a dedicated circuit. The HCPM model optimises this connection via two modules: the *Customer Location Module* and *Loop Design Module.*

---

[1] Background documentation concerning the HCPM model, may be found in the site: www.fcc.gov/ccb/apd/hcpm/.

Customer Location Module

On the basis of the geographic location of fixed telephone network clients in a specific wirecenter, the *Customer Location Module*, via the *Cluster Algorithm* selected by the user[2], starts to group clients into *clusters*, in accordance with engineering constraints.

The centroid of each *cluster* corresponds to a Serving Area Interface (SAI), responsible for connecting the feeder network to the distribution network. The size of each Serving Area (SA), determined by the set of clients connected to each SAI, depends not only on the number of lines, in accordance with the capacity of the Serving Area Interface, but also on the maximum distance permitted to the exchange. This maximum distance determinates the capacity of the copper portion of the local loop to provide access to advanced services using xDSL technology.

Once the clusters or Serving Areas have been defined, it is necessary to transfer the information so as to be read by a *Loop Design Module*. As a result, a grid is superimposed over each Cluster and the location of customers is indicated on a microgrid.

Loop Design Algorithms

After the identification of the inhabited cells by the *Customer Location Module*, the *Loop Design Module* efficiently designs the distribution and feeder networks.

When designing the feeder network, that connects the Serving Area Interfaces to the exchange of the chosen Wirecenter, an algorithm is used based upon the *Minimum Cost Spanning Tree* algorithm.

The distribution network which links the inhabited cells to the nearest concentration point, SAI, is constructed on the basis of two algorithms: the *Minimum Cost Spanning Tree* algorithm and the *Prim Modified* algorithm, responsible for connecting the distribution network to the populated micro cells.

---

[2] The authors of the model recommend the *Divisive* algorithm that attempts to create a minimum number of *clusters* for each area, in order to minimise costs.

2.1.2 INTERCONNECTION

The design and calculation of interconnection costs is achieved via two modules: the *Interoffice Clustering Module* and the *Interoffice Design Module*.

The *Interoffice Clustering Module* uses cluster analysis in order to determine groupings of exchanges in a ring hierarchy, so as to guarantee perfect connectivity between all network nodes.

The *Interoffice Design Module*, executed after the clustering of exchanges, is responsible for switching the interconnection routes and for determining investment in fiber cables, structures and the capacity of terminal equipment.

2.2 HCPM – PORTUGUESE EDITION

This section describes the specific modifications resulting from adapting the model to Portugal.

An assumption has been made that in terms of exchange equipment only the Line Cards and Main Distribution Frame pertain to the access network, and the rest is attributed to the interconnection network.

2.2.1 ACCESS

In the design of the access network in Portugal, as previously occurred in the United States, the algorithms mentioned in the previous point were used, including the Divisive algorithm for the *Cluster* programme of the *Customer Location Module*.

The HCPM is an exacting model in terms of information concerning the demand for access lines and its geographic location. In addition to the exact locations of all subscriber lines in the exchange, the model is capable of utilising exhaustive geological and altimetric information of the terrain.

In Portugal, the *Instituto Nacional de Estatística* (INE) do not provide *census block data*[3] information with the level of detail required by the model. As a result, the authors of the HCPM model designed auxiliary calculation programmes, that on the basis of information existing in Portugal, attribute lines to geographic locations, taking into consideration the demographic characteristics of the region in which the subscriber's line is located. The geological and altimetric characteristics of the terrain are also considered within each region.

These programmes are responsible for generating the base inputs of the HCPM model, based upon the information collected. The optimisation routines will be applied on these inputs.

The Portuguese edition extends the scorched node notion in order to include the area of influence of each PT exchange node. In other words, the model is constrained to use the current boundaries of the wirecenters of the historic operator.

The wirecenters correspond to the geographic coverage area of a specific exchange that in the Portuguese approach may be local or remote.

The exchanges classified as "Mixed" by the historic operator were unbundled into two network nodes, a Tandem and a Local node. The Tandem node, because it is considered not to have subscriber lines connected, is only used in the design of the interconnection network, and does not constitute a Wirecenter.

A second specific feature of the application of the HCPM model to the design of the access network in Portugal is the manner in which the Universal Service is calculated. On the basis of optimisation routines described for access and through the introduction of a *benchmark* corresponding to the return value required per line, the model determines the incremental cost of the subsidised lines in each wirecenter.

---

[3] Census databases used in the United States that contain diverse information, in particular the number and location of telephones per household.

2.2.2 INTERCONNECTION

The design of the interconnection network by the HCPM model is a function that has been added since the original version. The original version only took account of the design of the access network.

The model was applied to Portugal in accordance with the algorithms described in the previous section. For this purpose it was necessary to collect and process data concerning the exchange nodes of the historic operator (location, lines, peak traffic etc). The model's optimisation routines were then applied to this data.

The scorched node restriction at the level of the location of the exchange nodes of the historic operator do not, however, apply to the equipment in these locations. As a result, the switching equipment in each location may be substituted by more efficient equipment, as a result of the optimisation adopted by the model.

In this manner, the identification of the number and location of current wirecenters is the first step in the application of the optimisation procedure.

The model determines the interconnection rings and equipment in accordance with engineering parameters and cost minimisation routines, while ignoring the type of equipment in each location, and using a SDH technology with a topology of three levels (remote, local and tandem).

It should be noted, nonetheless, that the model enables routines to be applied to the current network configuration. For this purpose, it is sufficient to indicate the hierarchic relations between exchanges.

In this manner the Portuguese interconnection network will be the first to be conceived by HCPM, subject to the restriction in terms of number and location of the historic operator' nodes.

3. INPUTS

In order to apply the Hybrid Cost Proxy Model (HCPM) in Portugal it was necessary to extensively collect and systematically process a great deal of information: demographic, geographic, geological, altimetric and cartographic.

The reliability of the model's results depends not only on the engineering parameters and economic principles, which are integrated or used in model optimisation routines. It also depends upon a calculated detail related to customer location and terrain characteristics.

With the objective of developing an optimal telecommunications network based on Portugal Telecom (PT) switching nodes, a precise and separable database was compiled, identifying, wherever possible, the customer and his particular characteristics.

In this section the information sources are identified and some of the difficulties in processing information according to the model's requirements are described.

It should be noted that imprecise input values, due to the quality of available information, might imply less accuracy on output costs.

3.1 INFORMATION SOURCES

Bearing in mind the requirements in terms of the separate nature and diversity of data, information was collected from the following institutions:

- Information on network topology granted by Portugal Telecom (PT):
    - Local Telephone Networks Map drawn up by DGN/DSG, at a scale 1:500.000, identifying the local networks constituting each Network Group;
    - Switches database, indicating the switch's identification code, its geographic location, the type, the number of residential, business and ISDN lines associated to it, etc. for the year 1998.
- Information on traffic billed by PT in 1998 per type of call;

- Military Maps on paper and in digital format of the *Instituto Geográfico do Exército* (IGE), highlighting information related to the buildings and to the digital model of the land with a grid spacing of 200 metres, (scales 1:25.000 and 1:250.000 respectively);
- Demographic data per *Freguesia*[4] from the *Instituto Nacional de Estatística* (INE) regarding the Censuses of 91 and Enterprises per *Concelho*[5] in 1997;
- *Freguesias* Digital Map granted by the *Direcção Geral do Ambiente (DGA)* for the year 1999;
- Geological Soil Type Maps from the *Instituto Geológico e Mineiro (IGM)*, currently being produced;
- Proper Geographic Information System software that contains information related to the location of ports, airports, beaches, places, etc.

Finally, whenever necessary, the National Telephone Directories and Portugal Telecom's national Enquiry Service (118) on the Internet, were consulted.

3.2 INFORMATION PROCESSING DIFFICULTIES

3.2.1 ACCESS

Based on the wirecenters of the historic operator, files were created for the access network that, for each location, identified information regarding the customer, such as: the number of lines and data related to the terrain and altimetry.

In the absence of census block data, that would clearly identify subscriber line demand, it was necessary in each wirecenter to attribute subscriber lines to the buildings included in the charts of the IGE.

In this process, the *Freguesias* map from the DGA, the list of PT switches, the Digitised Maps of the Wirecenters and the demographic information of the INE were all information sources used to create the desired databases.

---

[4] Portuguese administrative division.
[5] Portuguese administrative division. A *concelho* groups one or more *freguesias*.

Once this information had been processed, it was compiled by a programme especially developed for the purpose by the creators of the model. This programme, which attributes subscriber lines to the buildings, runs according to two alternatives: (i) it either attributes lines to switches based on the minimum distance in relation to the switch; (ii) or it attributes lines to a previously identified switch which also constitutes a Wirecenter of the historic operator.

It should be noted that Alternative (ii) has advantages over Alternative (i). Although Alternative (i) dispenses the digitisation and geocoding of PT's Wirecenters, thus speeding up the file generating process, Alternative (ii) has the ability to almost exactly reproduce the bord ers of PT Wirecenters. Thus, there is correspondence among the data granted by PT, in terms of the subscriber lines per switch and the total number of lines effectively attributed to the buildings in that Wirecenter.

Faced with the absence of census block data , ICP adopted the second alternative.

3.2.2 INTERCONNECTION

With regard to interconnection, the model requires a file that includes the following per switch: latitude and longitude co-ordinates, subscriber lines, peak traffic, peak interconnection traffic and leased lines. This file was created based on information provided by Portugal Telecom.

3.3 OTHER INPUTS

In addition to the switch file for interconnection and the access files, the model also requires a set of inputs related to engineering parameters and input prices.

The contributions of operators with regard to engineering parameters and input prices will be appreciated and of great interest.

4. OUTPUTS

After carrying out the access, interconnection and universal service modules, the HCPM model establishes a diversified set of separate costs per element of the fixed telecommunications network. These network costs are attributed in function of the services seen as representative of the services supplied/demanded in the market.

Apart from the costs calculated by the model, there are other costs which are not subject to engineering modelling and which must be taken into account in a cost establishing process. These costs include non-network costs such as billing, commercialisation and sales, etc.

This section describes how the service cost design was conceived, including the universal service; it identifies the services deemed relevant; it describes the criteria and approaches adopted in attributing network costs; the way in which non-network costs were imputed; and it describes an alternative for setting the percentage of the cost of labour in the total cost.

4.1 NETWORK COSTS

As the model calculates costs per network element, it is necessary to attribute these to the relevant services, which in this case are close to the current tariff system of the historic operator.

The *Routing Factors*[6] seek to reflect the average combination of network elements used in the production of a service. Thus, 19 combinations of network elements were identified according to the types of calls considered.

One identified 8 service groups, Local Access, Calls among network customers, International Calls, Public Payphones, Internet, Incoming Interconnection, Outgoing Interconnection and Transit Interconnection, totalling 23 services.

---

[6] Note that the original HCPM documentation published by the US FCC uses a similar term to describe a quite different concept; however, in this section we use this terminology according to the convention of the European Union.

Therefore, network costs per service are established based on defined Routing Factors, the traffic volumes billed in 1998 or the number of access lines for the end of 1998 and, naturally, based on the model optimisation results per network element, for the whole country.

Four approaches were considered for network costs attribution: Standalone Cost (SAC), Total Service Long Run Incremental Cost (TSLRIC), Long Run Average Incremental Cost (LRAIC) and Long Run Incremental Cost (LRIC).

For this purpose, 3 service groups were identified, including the services mentioned previously: Access, Traffic and Leased Lines.

It should be noted that the leased lines were only included so as to share the interconnection and access costs, as they are not sufficiently separate to alow for autonomous cost.

The HCPM, as well as other prospective engineering models, does not allow one to directly extract the values for labour included in the model's results. However, efforts were made aimed at ascertaining the magnitude of labour expenses included in the access, switching and transmission costs.

With the objective of calculating labour costs, with regard to the network, the model was carried out by considering that maintenance and running costs equalled zero and, later, by also withdrawing from the investment a percentage of the cost for equipment, cables and infrastructures of the exterior network.

4.2 NON-NETWORK COSTS

When establishing the costs of services, one must add non-network costs to the network costs, for example, billing, commercialisation and sales, revenue to the State, etc.

The non-network costs may be apportioned in multiple ways. For example, they may be distributed proportionally to network cost values. Alternatively, one could add the network and non-network sensitive costs and distribute the non-sensitive (network and non-network) proportionally.

The non-network costs resulting from the analytical accounting of Portugal Telecom can eventually be used.

4.3 UNIVERSAL SERVICE

The programme developed in order to calculate th e Portuguese Universal Service cost is based on a certain *benchmark*, which is defined by the user and which corresponds to the expected return per line over a one-year period. Once the *benchmark* has been defined, the programme calculates the cost of lines in successively smaller-ranging areas, starting from the largest radius demarcating an area, via successive repetitions. The process is complete when the average cost of the lines in an area defined by a certain radius (the minimum radius), is equal to the *benchmark* value. Thus, is obtained the access cost of the furthest lines that an efficient enterprise, not subject to the obligation of providing the Universal Service, would not provide.

Contributions from operators regarding the *benchmark* value will be greatly appreciated, with special attention given to its calculation formula.

5. CONCLUSION

The HCPM model presented here describes the production function of the telecommunications services produced on the fixed Portuguese telecommunications network. It incorporates optimising routines for equipment in the switching nodes and for its interconnection in rings, which is an innovation among the current bottom-up models, and within the possible technologies it chooses the minimal cost technology.

In order to best deal with the imprecise nature of the available Portuguese information, namely the uncertainty regarding customer location, the original HCPM version was altered, by adding new programmes and modifying others.

The Portuguese interconnection network is the first to be modelled by HCPM. In fact, up until now, the HCPM had only been used to calculated access costs and the cost of universal service in networks of the United Sates of America.

The model's output was designed so as to reflect the Portuguese reality, namely so as to determine the network usage costs. Three service groups were defined: Access, Leased Lines and Traffic. The latter was broken down, via Routing Factors, into typical services of the historic operator, for which one defined the Standalone Cost (SAC), the Total Service Long Run Incremental Cost (TSLRIC), the Long Run Average Incremental Cost (LRAIC) and the Long Run Incremental Cost (LRIC). In this way, the model allows one to determine the operator's degree of tariff orientation regarding costs, irrespective of the relevant regulation cost. The model is also a powerful simulation tool, by changing the input value or the engineering constraints, and is thus suitable for research work. It is a model with limitations, the greatest of which is the long-term static approach it assumes; it does not account for the transition dynamics of the historic network. Currently, no engineering model can deal with the dynamic aspects of network transition. It is a model in process, i.e. it is never complete. For instance, with minor alterations, it can model the interconnection network of archipelagos like the Azores, or it can model cellular networks or even incorporate *first best* optimising routines.

The most likely prospect is that it will evolve in order to shape the costs of these realities. The model can therefore evolve in two distinct directions: (1) cost modelling with more precise information; (2) cost modelling using new optimisation routines and algorithms.

Latest update: 07.02.2006
Published: 04.02.2002
Author: anacom

