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An Implementation of Adaptable "Bottom-up" Model for Calculating Interconnection Costs

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Abstract – **In this paper we present the results of implementation of adaptable "bottom-up" model for calculating interconnection costs build on the long-term incremental costs methodology. This cost model is suggested to be very convenient for implementation in transition countries. The model needs numerous input parameters for calculation interconnection costs but it can be tested without infrastructure parameters.**

Keywords – **adaptable bottom-up model, interconnection costs**

I. Introduction

Various cost allocation methodologies have been proposed for interconnection. Some are based on the operator's accounting and involve allocating historical costs to different services according to criteria prescribed by the regulators. Others estimate costs by reconstituting the networks on the basis of currently available technologies. The latter is generally regarded as the most appropriate one for estimating services interconnection costs. Long Run Incremental Cost (LRIC) methodology estimates the costs incurred, while offering a sub-set of services. The costs considered are those that would be avoided if these services were not offered. For estimating the cost of the interconnection services, the selected increment comprises network elements belonging to the core network, i.e., those shared among all the network's users, excluding network elements contributed to end users.

In this paper we suggest the adaptable *bottom-up* model for calculating interconnection costs as very convenient for implementation in transition countries. Also we proposed mathematical models for calculating demand for PSTN and leased lines services, switching and transmision elements.

The paper is organized in the following way. In Section 2 we briefly discuss the cost determination methodology. In Section 3 LRIC model is presented. Modeling principles are described in Section 4 and model structure is given in Section 5. An example of test results is given in Section 6. Conclusion remarks are given in Section 7.

II. Cost Determination Methodologies

For telecommunication operators, determining the cost attained to produce a specific service is a delicate and complex task. Therefore, this section defines some of the cost concepts used in telecommunication industry [1].

Direct costs or directly attributable costs are expenses that are incurred when producing a specific service or a series of services or products. They can be fixed or variable. Fixed costs represent the proportion of the organization's expenses that does not depend on, or vary with the activity of the organization, and variable costs are closely related to the level and the development of the organization's production and marketing operations. The difference between fixed and variable costs is time related. Generally, fixed costs are long term oriented. Conversely, variable costs are directly related to the day to day operations of the organization, hence, short-term oriented. However, in the long run, even fixed costs are variables. It is therefore possible to reconcile cost accounting analysis to the economic analysis. *Joint costs* are generated by a family of services or products. From economic point of view, joint costs are costs incurred in fixed proportions every time a service or a product belonging to the same family is produced by the organization. *Common costs* are shared by all the services or products of the company. The sum of the fixed costs, the variable costs, the joint costs and the common costs gives the total production cost or global cost. The global cost or total production cost is directly related to the production volume. Two fundamental cost concepts yield from this definition: the average cost and the marginal cost. *Average cost* is the unit cost obtained by dividing the total cost by the number of units produced. *Marginal cost* is the total cost variation resulting from a variation of the organization's production. Marginal cost is defined as the *incremental cost* resulting from the production of an additional unit. *Historical cost* is the cost value entered in the organization's books. Contrary to historical cost, *forward looking long-term* cost relies on the best available technologies, assuming that the organization's production cycle is globally at optimum.

There are several methodologies in regard to allocation of joint and common costs:

1. The Fully Distributed Costs method (FDC);
2. The Efficient Component Pricing Rule (ECPR) method;
3. The Ramsey-Boiteux and Laffont-Tirole methodology, which rely on demand-price elasticity;
4. Long-term incremental costs methodology.

The cost model analyzed here is relied on the long-term incremental costs methodology.

III. The LRIC Concept

There are two families of LRIC models: *top down* LRIC and *bottom up* LRIC. *Top down* LRIC is essentially an activity based costing methodology. *Top down* LRIC models derive incremental costs by summing up the costs that can be directly attributed to the service, and adding a mark up that covers a proportion of joint and common costs. The mark up is determined with the help of arbitrary distribution keys. Therefore, the resulting cost is more backward oriented than forward looking. *Bottom-up* LRIC is a methodology for determining forward looking service cost. The methodology involves simulating the cost incurred by an efficiently

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operated network, using best available technology, to provide the service. *Bottom-up* LRIC models are highly recommended for regulatory decisions.

The LRIC methodology takes in account fixed costs caused by the provision of interconnection services, but does not take in account the common costs, which do not vary proportionately with the provision of interconnection services. In practice, the implementation of LRIC models requires a systematic assessment of demand and cost evolutions, as well as the interdependencies that may result. A systematic analysis of network elements load factors is also critical to accurately size the resources needed to convey the incremental traffic. In other words, the LRIC methodology enables the cost determination to be based on forward looking costs, and not on historical costs [2, 3].

The incremental costs of a service somehow represent the cost savings, which result from not implementing that service. The long-run concept involves taking the costs incurred in a long-term perspective. In the long run, production fixed costs can be considered as being variable costs. The long-run incremental costs of a service therefore represent all of the costs that could be avoided if that service were not implemented. Hence, the incremental costs include all the costs directly attributable to service, whether they are variable or fixed.

A telecommunications operator generally offers a wide range of services, whether to its subscribers or to other operators. These services have been traditionally classified according to their commercial nature. However, another service classification approach is based on the use of network elements. In general, there are three major categories of network elements:

- Elements, which are dedicated to end users. These elements are generally found in a local loop network or access network, and include subscriber's connection line to the switch;
- Elements, which are shared among users. These network elements are allocated temporarily to a subscriber and are generally found in the core telephony network.
- Elements shared by users, but used for the provision of complementary or supplementary services.

The services discussed above can be labeled as: access services, for services dedicated to each user, transport services, for services shared among network's users and offered by the core network functions and value added services, for shared services offered by intelligent functions of the network.

The incremental cost methodology distinguishes directly attributable from no attributable costs. It involves ascertaining, whether or not the production cost of "horizontal" service is increased, whenever a "vertical" service is added to the basket of other services produced [7].

The provision of interconnection services does not modify the retail sales service and it does not modify the access service, because the capacity implemented and its maintenance does not have to be adjusted to bear the flow of this additional traffic. In contrast, transport services are affected by the traffic resulting from interconnection services. The increment costs, to be considered for the calculation of interconnection services costs, comprises the core network and excludes the access network's elements which are dedicated to users [8].

IV. Modelling Principles

The LRIC method adopts a long run approach. The reconstruction of all networks elements is assumed during one year, and includes the increment costs. Selecting a forward-looking approach means considering both the best technologies available and their current costs. The model simulates a network that, at a given production level, minimizes the total cost by using best available technologies.

The model has to determine unit interconnection costs. It is, therefore, necessary to select metrics. Traditionally, the traffic flow through the core network is measured in minutes. The cumulated duration of calls, measured in minutes, is considered to be the important parameter in determining costs [4].

However, some interconnection prices and some cost models also take in account the number of calls. In practice, network elements also handle the following non-invoiced periods: the call set-up time, the closing time, and the time spent in handling unsuccessful calls. The sizing of some network elements therefore depends on the number of calls conveyed. This is particularly relevant for switching elements that have to handle call attempts. The number of calls essentially continues to determine the cost incurred by the temporal occupation of non invoiced network elements (waiting time and unanswered calls). The cost per minute is by convention, the representative unit cost.

To sum up, the model re-constructs the costs of the network at two levels. At the level of nodes (switching elements), investment costs are structured in fixed and variable components according to BHE (business hour Erlangs transformed into 2 Mbps) and to the number of subscribers, respectively. At the level of links, calculations are done at two sub-levels:

- Transmission level - at which electronic transmission equipment (mainly on SDH rings) are designed and sized;
- Infrastructure level - at which the link substratum is designed.

The links are sized by the traffic at peak times expressed in capacity (Mbps) and are sized to handle the switched telephone network traffic, as well as leased lines bandwidth. Assumptions regarding the sharing of certain elements of basic infrastructure with other networks subsequently allow for the sharing of costs, which are not fully borne by the core network.

The model is easy to use, and request information that regulators or operators can easily find. However, there remain some limitations. First, the model is designed for "small" networks which do not yet implement complex transit functions or routing algorithms. Second, the model does not seek full optimization when re-building the transmission network. More specifically, the model does not optimize the nodes, as the current network topology is kept unchanged. Third, it does not provide a detailed modeling of the cables and duct networks, although it discriminates among different types of geography (urban, suburban, and rural) or nature of the trenches (wrapped, ducted, and buried). Such a module could be developed by each regulator, although nodes location optimization may not be critical at current stage of telecommunications network development in developing countries. The proposed cost model provides accurate cost proxy estimates when applied to networks with less than 1.5 million main lines, and when the incumbent's network topology (number and location of nodes) is optimized or close. The lower bound will correspond to a configuration of a fully optimized network (nodes and links), while the upper bound will correspond to a partially optimized network (only links are optimized).

V. Model Structure

In general, the model requires the entry of substantial amount of information characterizing the networks which are interconnecting (topology, architecture principles and rules, traffic matrix and patterns, costs elements, etc.). To palliate the frequent gaps in the information systems, the model proposes default values that the user could consider if needed. This applies mainly to the routing factors that are rarely documented in most countries. The logic of the model is: [5]

1. The main input elements of network are nodes and links;
2. Each service uses these elements in different proportions. The routing factors represent the average number of times a given element is used by the service considered. The model then calculates the total load supported for each network element;
3. The model calculates the size of network elements (transmission elements) within the framework of the selected topology;
4. The model adds up all corresponding network element costs and calculates the per minute cost for each network element;
5. The model calculates the interconnection costs on the basis of the routing factors.

The network conveys interconnection service according to the extent and complexity of the service. The model calculates the investment cost, and also the cost of operation and maintenance incurred by network elements. These costs are distributed over four components: investment, operating, attributable and common costs.

Common costs are expressed as a percentage of the attributable costs. The attributable costs are the costs directly caused by the interconnection service and would have been avoided by the provider. They consist of operating and investment costs. The operating costs are composed of two terms: maintenance and operating cost related to the network element (spare parts, equipment section of preventive and corrective maintenance, energy consumed, etc.) and staff costs related to operation and maintenance activities. The staff cost is distributed among different network elements according to parameters specified by the user. The investment costs are calculated considering the estimated volume of traffic to be handled by each network element at peak hour. The size of each network element is accordingly derived using engineering procedures. For each network element, the model calculates the investment cost incurred and generates an investment annuity. Operating and non attributable costs are then allocated to it to obtain a global cost per minute for each element. For each service, relevant costs per minute for network element are added up to obtain the interconnection cost. The latter value is adjusted using the gradient of retail prices to derive the interconnection rate.

The model calculates the interconnection costs over:

- Switching elements are considered to be the nodes. Their investment costs include a fixed component and a variable one which depends on the switching system BHE and the number of subscribers connected.
- The links connecting the different network's nodes. The model differentiates the infrastructure and transmission layers:
  - The transmission layer enables the user to design the electronic transmission equipment by choosing and sizing the capacity of the most appropriate technology to be rolled out (SDH rings, PDH technology, etc);
  - The infrastructure layer enables the determination of the links' substratum or the physical elements that will support the transmission link.

The links are sized by the traffic carried at peak hour expressed in Mbit/s. The transmission links size is determined, to enable normal flow of traffic expected from switching centers and leased lines connected to them. Certain infrastructure elements are shared by different categories of traffic; this is particularly applicable to SDH rings in the access network. The model enables such costs to be shared. For example, SDH rings in the access network will be used to carry core network traffic flow and the access network traffic.

VI. Example

We tested the previously described model on hypothetical local network. Input parameters of the model are:

1. **Node and subscriber line informations** (3 tandem switches, 15 local switches, 30 remote concentrator units);

2. **Traffic informations** (number of minutes and number of successful calls in local, long distance, international, calls to/from mobiles, interconnection, number of leased lines and others). We used recommended values for traffic statistic of successful and unsuccessful calls.

Demand generated by the current number of billed calls can be expressed as:

$$D_c = \sum_n B_c \tag{1}$$

where: Dc - current demand measured in number of calls, n - number of PSTN services, Bc - number of billed calls.

Demand generated by current number of billed calls in minutes can therefore be expressed as:

$$D_m = \sum_n B_m + (B_c \cdot T_h) \tag{2}$$

where: D_m - current demand measured in minutes, n - number of PSTN services, B_m - number of billed minutes, B_c - number of billed calls, T_h - holding time in minutes.

Demand for leased lines is expressed in 64bit/s equivalents and is converted into Mbit for dimensioning transmission electronics. This can be expressed as:

$$D_L = (n/\psi) \cdot 2 \tag{3}$$

where: D_L - existing demand for leased lines in Mbit, n - number of 64kbit equivalent leased lines, ψ - number of 64 kbit channels in a 2 Mbit.

3. **Percentage of subscriber lines connected to network elements;**

4. **Establishing demand for switching elements** (we used recommended values for utilization level of switching nodes);

The total demand for the switching element measured in number of calls is expressed as:

$$T_{dcE} = \sum_{i}^{n} T_{dci} \cdot R_i \tag{4}$$

where: T_{dcE} - total demand for the switching element for all narrow band calls, n - all narrow-band services, R - routeing factor for switching element, i - narrow band call service,-T_{dc} - total demand (in calls) for narrow-band service.

The total demand for the switching element measured in minutes can be expressed as:

$$T_{dmE} = \sum_{i}^{n} T_{dmi} \cdot R_i \tag{5}$$

where: T_{dmE} - total demand for the switching element for all narrow band minutes, n - all narrow-band services, R - routeing factor for switching element, i - narrow band call service, T_{dm} - total demand (in minutes) for narrow-band service

5. **Establishing Demand for Transmission Elements-** Traffic (in minutes) making use of the transmission network is converted to BHE that are used to dimension the transmission network. BHEs have to be converted to Mbit as follows:

$$D_{SW} = BHE /(g * \psi / 2) \tag{6}$$

where: D_{SW} - existing demand for switched traffic in Mbit BHE - total switched traffic in BHE, g - circuit efficiency (or erlangs per circuit), ψ - number of 64 kbit/s channels in a 2Mbit;

The adjusted total demand for the transmission element expressed in Mbit is:

$$ATD_{TE} = TD_{TE} / f \tag{7}$$

Where ATD_{TE} - total (adjusted) Mbit at a transmission element; TD_{TE} - total demand for the transmission element in Mbit, f - percentage of capacity utilised;

Adaptive interconnection model is tested without infrastructure parameters and results are shown in Tables 1, 2.

Table 1. LRIC including common costs

	RCU	LS	TS
Equipment Costs (euros)			
network	966,019	2,279,909	986,340
non-network	47,010	110,950	53,977
total equipment costs	1,013,029	2,390,859	1,040,317
Operating Costs (euros)			
network	540,256	1,016,933	440,118
non-network	159,889	300,558	214,905
total operating costs	700,146	1,317,491	655,023
Total costs (inc working capital)	1,884,493	4,079,185	1,864,874
	RCU	LS	TS
Unit Cost	2.122774	8.436784	4.008328

Table 2. LRIC excluding common costs

	RCU	LS	TS
Equipment Costs (euros)			
network	666,481	1,807,705	986.340
non-network	47,010	110,950	53,977
total equipment costs	713,491	1,918,655	1,040,317
Operating Costs (euros)			
network	346,216	713,746	440,118
non-network	159,889	300,558	214,905
total operating costs	506,106	1,014,304	655,023
Total costs (inc working capital)	1,341,556	3,226,255	1,864,874
	RCU	LS	TS
Unit Cost	1,341,556	3,226,255	4.008328

It could be possible testing different network configuration (maximum number of nodes on a SDH ring is 16), with great range of input parameters.

VII. Conclusion

The analyzed cost model is a tool provided to regulators and operators to help them to determine economic oriented interconnection rates for terminating and departing traffic from, or to, fixed and mobile networks. It also ratifies crucial assumptions pertaining to traffic demand, network optimization, and cost allocation between final and intermediary services. LRIC model is generally accepted as best practice. This approach is most efficient in calculating interconnection costs based on current technology rather than exiting book assets. It usually leads to lower interconnections rates and stimulates competition but provides lower revenues to incumbent operator.

In this paper we demonstrate the results of use of software tool based on adaptable interconnection model. We choose hypothetical network example on local national level and calculate LRIC including common costs, LRIC excluding common costs and common costs. In practice, this cost modeling enables regulators and operators to improve their knowledge on the industry cost structure, and its efficiency frontier.

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