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Communications technology development : A case study in Uruguay

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COMMUNICATIONS TECHNOLOGY DEVELOPMENT: A CASE STUDY IN URUGUAY

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ABSTRACT

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1. HISTORICAL INTRODUCTION

Communication systems have been traditionally sold, designed and sometimes even run by large multinational corporations in developing countries. Uruguay was no exception to this.

The growth of the number of telex users along with a poor service led the Administracion Nacional de Telecomunicaciones (ANTEL) -the State Telecommunications Corporation- to consider the acquisition of a new telex system in 1975.

The design experience described in this article was made possible by an invitation for national tenders issued by ANTEL in 1976 for a small telex exchange. This unusual policy to deliberately exclude large multinational corporations enabled a local design team to bid and be assigned the full design and the production of the prototype. The successful bidders (GMS Limitada, now CONTROLES Limitada and INTERFASE Limitada, both of Montevideo, Uruguay) acted jointly for purposes of this project.

At the same time as the call for national offers was issued, ANTEL started to consider the acquisition of a large exchange by means of an invitation for international offers.

Later developments of the locally designed line of exchanges was successful and became a valid alternative for large, complex systems. This paper refers to the competitive struggle between two possible solutions for a developing country.

This article is divided into three sections. The first is a technical description, the second analyses the costs involved, while the third draws conclusions as to the viability of projects of this type in developing countries. For the sake of clarity, the technical section is self-contained and may be skipped by readers interested only in the conclusions about the project's cost and viability.

The prototype for 128 telex lines entered operation in 1980. A second 128 line unit was installed in 1981. A major redesign introduced various improvements in a new 256 line model. Three such units were put in operation in 1982 totalling 1152 lines. One of these units is the international front processor of the national network. The present situation is that the country does not need to import telex exchanges from multinational corporations.

2. SYSTEM ARCHITECTURE

This section describes some of the technical aspects of the hardware. A more detailed account is given in [1], [3] and [4].

2.1 General design: The general design characteristics were decided in part by ANTEL and partly by the contractors. The aim was that the technical characteristics of the final product should be those of technologically advanced equipment. The main characteristics sought were:

- High reliability with a meantime between faults (m.t.b.f.) of 10 years.

- Full compliance with the Recommendations of the International Telegraph and Telephone Consultative Committee (C.C.I.T.T.) on telex communication.

- Complete flexibility for configuration of lines and trunks, numbering and international traffic policies.

- Billing on paper or magnetic tape.

- Recovery of faulty characters.

- Easy servicing.

- The prototype would have 128 lines, but the design would allow for expansions.

- Options for circular messages, 300 baud communications, magnetic disk units.

The design of a stored program control (spc). telex exchange involves both hardware and software, which must be considered together. We shall, nevertheless, emphasise the architecture of the system.

The choice of 8-bit microcomputers derives from the length of the character codes to be used; the use of 8-bit processors is a cost-effective solution, especially if one considers the possibilities which distributed and multimaster systems offer.

Peripheral processors are needed as interfaces between the line terminators and the switching system itself. All lines are to be switchable at all times, and so the peripheral processor must poll all its external lines. It was decided that a peripheral processor should take care of 16 lines considering the transmission rate and the following tasks to be executed:

(a) Serial-parallel and parallel-serial conversions.

(b) Generation and recognition of all external protocol messages.

(c) Memory self check functions.

(d) Testing of external lines.

(e) Testing of switching system processors.

The peripheral processors are connected to a peripheral bus for fast, modular and parallel communication with the switching system Fig. 1 shows the system architecture omitting t.m.r. for clarity.

2.2 Reliability and redundancy: Redundancy of central processors must be included in the design of the exchanges.

One possible option is to design the system with a pair of central processing units: an active unit and a "standby" or "shadow" unit which takes over when a fault is detected. Incidentally, this is the architecture most commonly implemented by exchange manufacturers.

Another possibility is a duplicated system architecture. A duplicated system must include a self check facility (hardware or software or both). This includes memory recovery and programs that detect all foreseeable errors. For a duplicated 8-bit memory, error recovery requires an additional equal amount of memory. In addition, not all errors can be predicted and no programming techniques can test all results at all times. The reliability of the control module is an additional problem to be solved.

We introduced triple modular redundancy (t.m.r.) in the design of our exchanges. The reason was not to boost the reliability figure (in fact it is lower than in a duplicated system because more components are active) but to detect and recover all possible faults. This can be done by careful choice of the majority voters in the system. We insist that all possible errors are recovered with t.m.r. and a voting scheme.

The operation of the exchange is based on the massive interchange of information between the central and peripheral processors. This information includes all traffic data, communication protocols and billing details. We choose, therefore, the peripheral processors as majority voters of the central processors. In this way all the results of processing and transmission are tested for majority and even transient errors can be detected and recorded.

The choice of the peripheral processors as majority voters has another important consequence. In t.m.r. the weak point is usually the reliability of the voters, but in our exchanges, there are from eight to 32 voters for every group of three redundant processors. Moreover, a central processor is not reset by a single accusation from a voter but needs a high error count from various voters. The voting system would fail only if in 24 hours all 16 peripheral processors fail, and in this case there would be only one reset of a working processor with no consequences for the operation. On the other hand peripheral processors can be re-initialised by their central processor on the basis of a much lower error count. This difference in hierarchy between processors gives a great logical stability to the system.

The exchange never stops, and tolerates every combination of faults except two simultaneous identical ones occurring in two central procesors, because in this way a false majority is generated. This situation has a very low probability of occurrence.

We have shown that a system that includes adaptive majority voting redundancy techniques can guarantee a continuous operation over a very long time. T.m.r. also has a great advantage in routine maintenance. A report of all discrepancies is given daily as well as on request by the console: this allows the operator to observe and study the bahaviour of hardware in normal operation. One of the redundant processors can be turned off and changed with no system downtime. This follows the present trends in maintenance-effective policies.

The adoption of t.m.r. for the central procesors has three consequences in the architecture of the system:

(a) There must be fast inter-processor links for recovery after reset of a faulty unit.

(b) The peripheral bus is also triplicated to allow the peripheral processors to act as majority voters.

(c) The modularity of the architecture has to permit the operation of the system after faulty units are excluded or absent. Such a system is known as a "gracefully degrading system".

The design of small exchanges (up to 64 lines) does not include t.m.r. of processors since a calculated m.t.b.f. of over eight years and human fault detection are considered adequate for a small p.a.b.x.

2.3 Software overview: The design of s.p.c telex exchanges in a Multimaster and Redundant Processor environment includes a heavy share of software design. A detailed description of the real time executive implemented is given elsewhere [4]. It is of interest to highlight the main peculiarities of the software designed for this project.

In designing message electronic exchanges the time requirements are very demanding. In such applications the general purpose real time executives are useless because overhead times are not specified. This is felt particularly when synchronization of redundant processors is needed and when time critical communication between processors are designed. If a real time executive is to take care of these functions, it must include primitives with known overhead times. Time slices as short as 100 microseconds are implemented in the illustrated exchange.

The concepts of semaphore and mailbox, usually implemented for inter-task transfers, need to be further defined to encompass communications between masters belonging to the same bus and between masters in infrequent but dense interaction (like redundant or front-end processors).

The real time executive offers primitives to create, receive and modify semaphores in a multimaster environment. These flexible semaphores should therefore range from a mere software flag to a bit on an interrupt line.

Similarly, mailboxes should be managed by real time executives so as to interchange data not only between tasks, but also between distinct processors. In the illustrated example transfer rates of 30 Kbytes per second between processors are found.

3. ECONOMIC ANALYSIS

The most interesting results of the present experience deal with the possibility of duplicating such projects in developing countries. The results of the economic analysis are totally unexpected if one believes the widely held view that large corporations produce the more efficient sophisticated equipment.

All figures shown here correspond to cost and not to selling prices. A mention of them is made as a basis for the following discussion on the viability of similar projects in developing countries.

The present analysis will divide costs in the main historic phases of the project. The first phase corresponds approximately to 1977-1980 and the second phase to 1981-1982. The first phase includes all preliminary studies, the design of a 128 line prototype, its production and start up as well as the production of a second 128 line exchange. This phase was described in an invited paper in the International Telecommunication Union Journal [2]. The second phase is a redesign and production of four 256 line exchanges with major improvements but maintaining the same architecture and compatible components.

The costs will be divided into three groups:

(a) design costs

(b) production costs

(c) overhead costs

3.1 Design costs: Table I shows the design efforts involved in both phases of this project.

TABLE I: Design Effort

	MAN-MONTHS OF DESIGN (Engineering)
PHASE 1 (Prototype and second unit)	
Preliminary project	4
Design	13
Auxiliary design	8
Start-up	4
TOTAL PHASE 1	29
PHASE 2 (Redesign and four units)	
Redesign	13
Auxiliary design	4
Start-up	2
TOTAL PHASE 2	19
TOTAL	49

At a cost of 30.000 US Dollars per year, the engineering costs come to about 75.000 US Dollars for the first design and 48.000 US Dollars for the redesign phase. We must allow 50% extra for administration and use of equipment. This yields 120.000 US Dollars and 75.000 US Dollars in round figures respectively.

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As expected these design costs are quite independent of the number of exchanges, while the production costs are definetly not, as we shall see now.

3.2 Production costs: The production cost breaks down into three components: labour, materials and depreciation of equipment. The total labour cost includes all domestic social security contributions. The materials, whether domestic or foreign, are valued at domestic prices and their cost thus includes all domestic import taxes.

Table II gives the cost of production in round figures. An additional column shows the proportion of each item which is of domestic origin.

TABLE II: Production costs

	US DOLLARS	DOMESTIC PERCENTAGE	US DOLLARS/LINE
PAHSE 1 (prototype and second unit)			
Labour	16.000	100%	
Materials	60.000	30%	
Depreciation	8.000	30%	
TOTAL PHASE 1	84.000	43%	330
PHASE 2 (redesign and 896 lines)			
Labour	80.000	100%	
Materials	135.000	32%	
Depreciation	15.000	30%	
TOTAL PHASE 2	230.000	58%	256
TOTAL (1152 lines)	314.000	52%	270

The domestic share of materials and depreciation consists of the actual proportion of value added in the country as well as the indirect proportion of domestic taxes, which represent an interna. redistribution.

The domestic share of the cost of materials is quite constant whereas the cost of labour is higher in the second phase, since four larger exchanges are manufactured instead of only two.

3.3 Overhead costs: Given the above cost breakdown, the overheads consist of the financial costs, income taxes, staff training costs, documentation costs, firms operating costs, etc.

By their nature they represent a domestic redistribution and are of little importance for the following analysis. For purposes of comparison, we estimate 3000 US Dollars per exchange

3.4 Total costs of exchanges: The cost of telex exchanges is obtained by adding all costs involved in the design and production of the exchanges. Table III shows rounded figures.

TABLE III: Cost of telex exchanges

	US DOLLARS	%	US DOLLARS/LINE
PHASE 1			
Design	120.000	57	
Production	84.000	40	
Overheads	6.000	3	
TOTAL PHASE 1	210.000	100	820
PAHSE 2			
Design	75.000	23	
Production	230.000	71	
Overheads	20.000	6	
TOTAL PHASE 2	325.000	100	360
TOTAL	535.000		510

The cost per line is a good overall index for exchanges. The production of the prototype and a second unit led to a cost of 820 US Dollars per line. The cost dropped to 360 US Dollars per line for the second group of four exchanges produced. This figure is nevertheless distorted by the fact that the initial design was heavily used for the redesign of the exchanges. The correct figure is obtained as in the last line of Table III where the cost of all 1152 lines is shown. A cost of 510 US Dollars per line can lead to highly competitive prices on an international basis.

3.5 Projection of costs: It is interesting to examine a cost projection for a redesign and production of 4096 lines as eight 512 line exchanges. These figures are shown in Table IV.

TABLE IV: Cost projection for 4096 lines

	US DOLLARS	%	US DOLLARS/LINE
Design	60.000	7	
Production	800.000	89	
Overheads	40.000	4	
Total	900.000	100	220

Table IV shows a dramatic reduction in the cost per line of the exchanges. This follows the trend of increasing the production volume. With the figures of Table IV the national participation to the cost is reduced to about 40%. If production increases still further, then one could consider producing more parts locally.

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4. MULTINATIONAL DOMINATION VS. LOCAL DEVELOPMENT

It is often argued that developing countries are not capable of developing communications technology. The reasons put forth include lack of capital and lack of know-how. Both are widely available in developed countries, where large corporations share the world market.

4.1 Exclusion of local development: Local development of communication equipment is often not even considered as an alternative to the acquisition of universally known brands. There are two factors that account for this:

(a) The attitude of administrators.

(b) The actions of multinational corporations.

It is much "safer" for an administrator to specify or support a deal with an internationally known company than to have a domestic counterpart. The administrator feels more comfortable with the prestige of the large selling company. This attitude is sometimes due to a lack of technical expertise and economic common sense. Such attitudes arise when short term solutions to long term problems are sought. In developing countries with free enterprise, unplanned economies, the administrators also feel that domestic high technology is not to be considered. The present international division of activities is meticulously respected: high technology for developed countries, intermediate and primitive technology for developing countries.

Multinational corporations are active in the field of sales promotion using a large network of subsidiaries, local branches, personal contacts with administrators and the like. Sales promotion includes creating the need, offers of government to government deals, "gifts" of samples etc.

An additional pressure on local administrations is present in the case of small countries where the size of the multinational corporation is several times the size of, say, the State Communication Corporation.

It is clear that all the efforts of the multinational corporations tend towards the exclusion of local alternatives for communication technology.

4.2 Advantages of local developments: The comparison of local development of technology with the installation of "turnkey" systems is possible thanks to the present eight years experience. No comments will be made over specific circumstances for obvious reasons, but the type of problems will be made clear.

Probably the only advantage a State Communication Administration has when buying technology from a large multinational corporation is that the equipment is installed sooner. This advantage vanishes if extensive planning is made, especially for large systems like telex, telephone or data networks.

The main advantage of domestic development of communication technology over "turnkey" acquisition is that the overall economy of the developing country benefits. We refer to the internal recirculation of wealth as opposed to payments abroad. In some cases, as in the present experience, the overall cost can be lower for equipment of equivalent operating characteristics.

We also find political and social disadvantages for the developing country in case of a "turnkey" purchase abroad. Forming design teams with technologically advanced objectives is a clear deterrent for the "brain drain". There is a close affinity of long term objectives between the local designer and the State Communication Corporation. There are no common objectives with a multinational corporation. This refers to the maintenance, updating and evolution of the system that can be simply discontinued by a multinational corporation for "commercial reasons".

Table V shows in a condensed form a comparison of characteristics of local development of communication technology with import of turnkey systems.

TABLE V: Comparison of domestic development vs. purchase from multinational corporations

DOMESTIC DEVELOPMENT	MULTINATIONAL CORPORATION AS PURVEYOR
Needs planning	Immediate purchase
Stops "brain drain"	Favours "brain drain"
Product adapted to needs	Needs must be adapted to available product
Designers "at hand" for maintenance and evolution of system	Difficulties for updating of systems when not in multinational corporation's plans
State administration of communications in a position to deal on equal grounds with purveyor	State administration of communications subject to willingness of a much larger corporation
Can be cheaper	More expensive
Internal recirculation of money	Payments abroad
Needs an initial capital investment	No initial investment
A step towards technological independence	Adheres to present international division of labour

4.3 Viability of local developments: Technology is practical know-how based on experience. The only way for a developing country to acquire technology is to do things. The experience must be guided by a clear understanding of priorities in the process of development of technology.

We have found that there are three requisites for local development of communication technology:

(a) General formal training and information updates.

(b) An initial capital investment.

(c) Political determination to support the development.

Engineering schools are usually adequate for the general technical training which allows technicians to be informed of the latests components and parts available on the world market.

The initial capital investment is relatively modest for the development of equipment based on microcomputers, like the one described here. This is due to the presence of design and programming and to the craftman-like nature of these activities [2]. In general terms, a non negligeable share of the capital investment has already been made by the country running higher education institutions. The remaining investment for equipment, components and salaries to be used during the design is small considering the results obtained.

The political support is necessary to support the effort, to resist and exclude the commercial aggression of multinational corporations and possibly to generate the capital investment needed.

5. A NOTE IN CONCLUSION

This paper describes an eight year experience of original design and production of telex exchanges in a developing country. The success of the enterprise is examined on the basis of the technical characteristics of the products, an economic analysis and a mention of the actions taken by multinational corporation of communication equipment.

It is concluded that when political determination combines with an initial capital investment and a technical design team, developing countries can promote their own communication technology.

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