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MODELING AND EVALUATION OF ALTERNATIVE INFORMATION SYSTEM STRUCTURESi

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ABSTRACT

A general graphic model for organizational information systems (IS) is proposed. The model includes generalized decision making and data manipulation functions to regulate generalized organizational processes through flows of information. The general IS model serves as a basic pattern to approach the design of any IS. In particular, alternative IS structures or designs can be derived from the model. Structures include not only information that will be computerized but also the prescription of the decision making behavior of the information users. The existence of alternatives leads to a problem of evaluation for which a quantitative modeling approach is proposed.

1. INTRODUCTION

Several approaches to modeling information systems (IS) have been proposed. A few of the most popular are Structured Analysis for the graphic modeling of data flows (Ross 1977; De Marco 1978), Entity Relationship Approach (Chen 1976) and Information Engineering (Martin and Finkelstein 1981) for data modeling, and Structured Design for software modeling (Yourdon and Constantine 1979). None of these methods explicitly considers the users' tasks performed outside the computer as objects of analysis and design in the same way as computer programs and/or data-file structures. The main consequence of this omission is that alternative IS structures associated with alternative methods of performing user's tasks, clearly related to organization structure, are not explicitly brought out as design options.

There are a few exceptions among IS design methods to this lack of formal consideration of IS alternative structures. Most notable among them is BIAIT (Carlson 1979; Kerner 1979), defined by Davis (1982) as a normative approach, which has provided an empirical characterization of IS structure by establishing general patterns of organizational purpose, (people and computer implemented) functions, and data. This method posits that IS structure is dependent on the values of seven variables that can completely characterize an organization.

Our work aims at extending the formal consideration of structure in IS design by explicitly bringing out the problem of alternative structures and their evaluation. We do this by:

a) Developing a general graphic model for organizational information systems which explicitly includes user functions. The model is based on systems theory and general patterns of organizational process regulation derived from empirical observation and experience.

b) Using the general IS model to derive alternative IS structures. Here we extend the concept of IS structure to include not only what will be computerized but also the prescription of the behavior of the users of information by means of policies, rules, procedures and the like. Since there are always alternative behaviors and consequently alternative sets of information to support such behaviors, we are really talking about design. This problem of jointly studying alternative behaviors, sets of information or structures can be related to and supported by organization design theory (Gailbraith 1977; Malone 1987; Melcher 1976). In fact, we will show that these structures correspond to organizational coordination structures as defined by Malone (1987) and others (Simon 1970).

c) Developing a quantitative modeling approach to be able to the evaluate alternatives derived above and to select the best one. Concepts and tools for modeling alternatives are related to Marschack's value of information ideas (Marschack 1954, 1968), modeling of computer processes (Horning and Randell 1973), operations research and management science (OR/MS) modeling, and the software packages available to implement models in practice (Reiman and Waren 1985).

The main thrust of this paper is the integration and operationalization of ideas. Thus many diverse concepts coming from fields such as systems theory, organization theory, information value theory, OR/MS modeling, and modeling packages are combined to work in an operational methodology for the determination and evaluation of alternative structures. The methodology is purposely practical; its development is based on hundreds of real cases from which ideas have been derived and to which the methodology has been successfully applied.

2. AN INFORMATION SYSTEM CONCEPTUAL MODEL

The Organization Information System (IS) conceptual model we propose, which is based on systems regulation theory (Ashby 1970) and has been detailed and justified elsewhere (Barros 1987 b), recognizes the following elements:

a) Organization *resources*, i.e., materials, including products in which they are used, money, capital goods (assets) and human resources. Regulation is then exercised over the flow of these entities determining the system's behavior. We treat regulated entities as the primitives of our organization IS model and assume they are sufficient, in the sense that no other entities are needed to describe what is regulated.

b) *Processes*, which are the operations realized upon resources within the organization in implementing the regulation. Examples of these processes are inspecting, transforming, machining materials; borrowing, investing, applying money; installing, using, disposing capital assets; hiring, training, assigning, firing human resources. Processes can be classified into the generalized types shown at the bottom of Figure 1, where the typical flows of resources that may exist are also displayed. The generalized types and instances are based on the experience derived from hundreds of real cases known to the author.

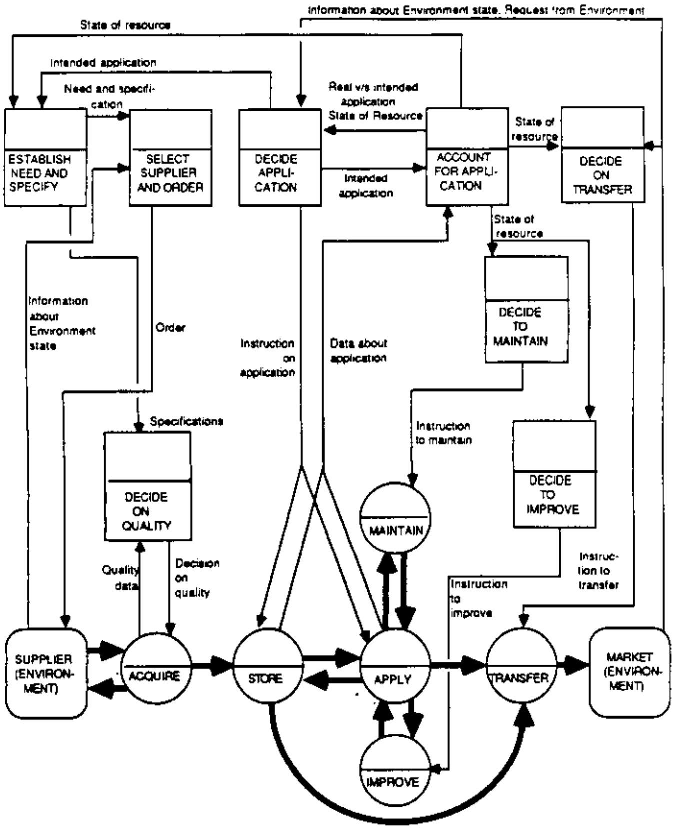

Figure 1. Generalized Process and Functions and Flows of Information

c) Generalized decisions and other types of *functions* necessary to perform regulation in the sense we have defined. Regulation functions are identified by associating, to each generalized process, decision and data manipulation activities that may be necessary for its occurrence. The derived functions are shown in Figure 1, together with their relationships to processes by means of information flows. The flows are given as examples since they are at the heart of the IS alternatives problem.

An example of the processes, functions and flows for a simplified real situation is shown in Figure 2.

It is clear from the above model that information manipulation (processing) and flows are basically a means to:

a) Collect information, determine and inform state of processes to regulation functions.

b) Convey orders and instructions about regulation operations or actions to be carried upon processes.

c) Communicate regulation functions to each other.

d) Calculate, project, evaluate, analyze, etc., consequences of planned actions within certain regulation functions, particularly "Decide Application" and "Establish Need and Specify"; e.g., establish material requirements based on a production plan in the example in Figure 2.

e) Collect information about environment state and, within certain functions, forecast future state.

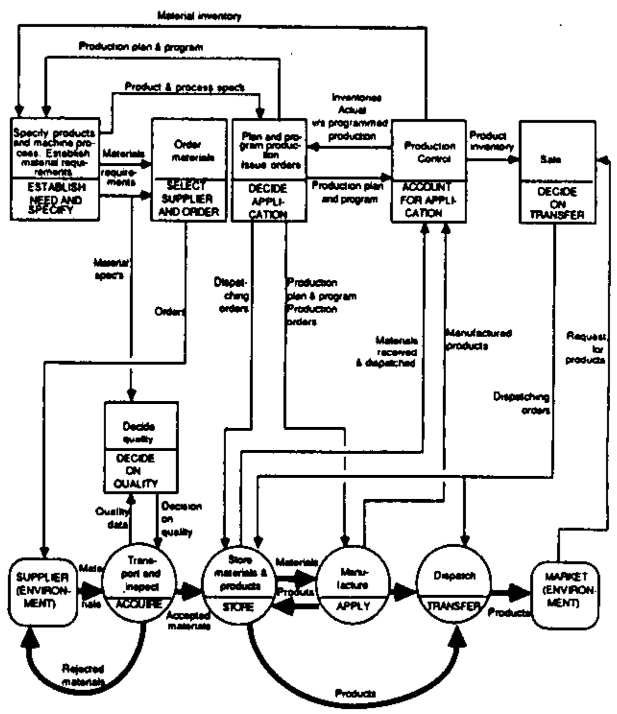

Figure 2. An Example of Materials and Production Management (Simplified)

Hence, information processing and flows hold together regulation functions and processes and communicate them to the environment. Thus information, decision and actions (results) over processes cannot be separated and must constitute a unique system. We consider this the information system of the organization.

This approach is related to organizational coordination structures defined by Malone (1987) as patterns of decision-making and communication among a set of actors (our processes and functions) that perform tasks in order to achieve goals. Thus, information systems in our definition are also coordination structures, with the only constraint that information be formalized and designed to accomplish a certain purpose.

3. ALTERNATIVE STRUCTURES IN INFORMATION SYSTEMS

In this section, we show how the generalized IS model naturally leads to the definition of alternative structures for IS.

It is obvious that alternative methods of implementing the decision functions defined in the general IS model will create the need for different sets of information processing and flows. Each function alternative, together with its corresponding requirements of information processing and flows, defines an alternative structure for an IS in a given situation.

Organization design theory is applicable in generating these alternative IS structures.

In approaching the design of a particular IS, we start with a current situation. The generalized model tells us what processes and regulation functions may exist in such a situation. By matching current activities within the scope of the situation with generalized processes and functions, it is very easy to generate a model for the current situation.

In order to exemplify the concepts above we show, the current situation model for a problem in cash flow management (Figure 3). This example has been deliberately kept simple to facilitate understanding; it covers a part of only one resource regulation problem. There are no limitations in the model we discussed in Section 2 to fully cover one resource regulation and even the regulation of several resources interacting in a complex way. The example emphasizes resource requisition, but there is no inherent limitation to expand the problem to consider resource utilization and services or goods production.

The current situation is characterized by a very simple decision function rule and limited information requirements. Thus, a loan requisition is decided on the basis of getting negative bank account balances to zero, and a short term investment is decided by allocating positive bank account balances.

Given a model for the current situation, we can generate alternative structures by discovering regulation functions or relationships absent or imperfectly implemented with respect to the generalized IS model.

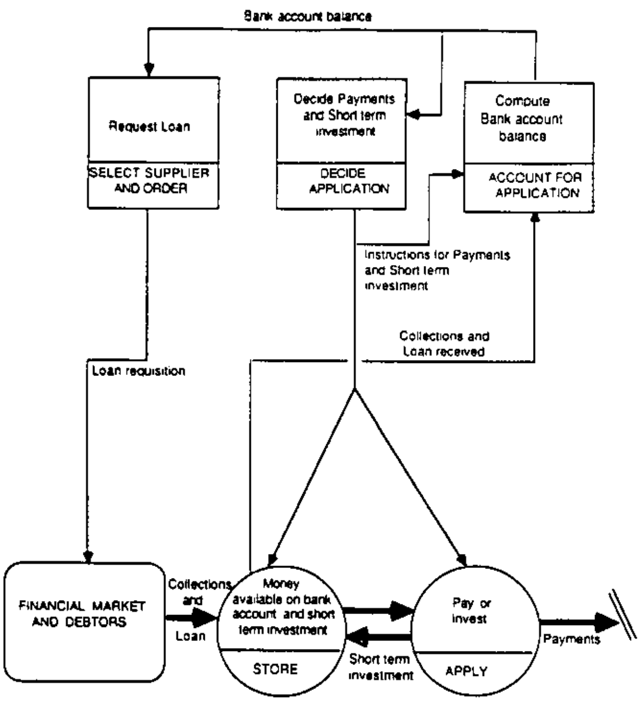

Figure 3. Current Situation Model for Cash Flow Management Problem

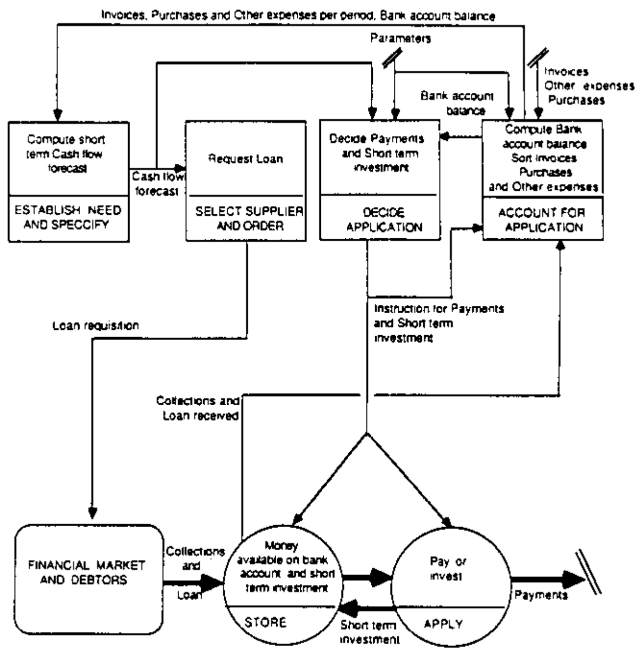

Figure 4. Model for Alternative in the Cash Flow Management Problem

In the cash management problem we observe that the only basis for loan and short term investment decisions is the current bank account balance. The general IS model indicates that the ordering (Select Supplier and Order) of a resource (loan) may be based on its projected need (Establish Need and Specify). This suggests defining an alternative, shown in Figure 4, where the currently absent function "compute short term cash flow forecast" (Establish Need and Specify) is created to support the loan and investment decisions. In turn, this implies expanding the "Account for Application" function to provide the necessary information to be able to forecast cash flow.

Searching for alternative structures can be guided by Organization design theory (Gailbraith 1977). As detailed elsewhere (Barros 1984, 1987a), different implementations of functions and relationships with corresponding sets of information requirements produce different degrees of coordination and organizational structures. These in turn will imply different consequences in terms of results achieved (measured as the quality of regulation in our terminology). However, coordination can be approached with two types of mechanisms. On the one hand, we can reduce interaction, hence the need for coordination and flows of information, among units by using slack resources (e.g., buffer inventories and backlogs) and unit self containment. On the other hand, we can increase the capacity to coordinate by providing more information and coordinating agents, such as assistants, staff and lateral roles, e.g., liaisons (Gailbraith 1977).

As is usual in IS, in the example we have presented the alternative goes in the direction of increasing the capacity to coordinate and reducing the use of slack resources. Thus, the explicit forecasting of cash flow allows for better planning and negotiation of the loans required (better coordination between needs and requisition). This in turn affects the slack resource interest payments (income) since better loan (investment) conditions can be obtained if negotiated in advance.

Of course, the coordination arguments for the alternative we are giving a posteriori can be used a priori in their generation.[2] In addition, it is obvious that the identification of slack resources affected by the alternatives is a key factor in the evaluation we will attempt in the next section.

Alternative IS structures are also related to the ideas of coordination structures as defined by Malone (1987). Although Malone refers the macro structure of an organization, he makes specific micro-level assumptions about how decisions are handled and the amount of information (messages) required. Different sets of assumptions lead to different generalized "pure" structure types: product hierarchy, decentralized market, functional hierarchy and centralized market. It is evident that these types can be considered general patterns of coordination that can be used for an organization as a whole, and that each type will generate different IS designs.

Malone (1987) analyses different types of structures in terms of production, coordination and vulnerability costs. Rough quantitative approximations to these costs allow evaluation of the desirability of each structure for a given situation. Hence, Malone's ideas appear to be a good way to screen possible general macro structures for the Organization Information System. The generalized IS model and the evaluation procedure we will develop in Section 4 will allow detailing of the alternative IS structures and select the most cost effective one.

4. QUANTITATIVE MODELING AND EVALUATION OF IS

4.1 Basis of modeling

Modeling the IS essentially means modeling the processes. There are several ways in which we can model a process: using Petri Nets (Peterson 1977) or Finite State Machines (Minsky 1967). We have chosen the following approach due to the fact that it can be supported by easily available software packages, as we will show later, and that it can be related to most of the modeling work that has been done in OR/MS.

A process is characterized at a given point in time by *state variables*. A given *state* is defined by a specific assignment of values to the state variables.[3]

Changes of or transitions between states are specified through an *action function* which, for a given initial state, establishes an immediate succeeding state for a process. By repetitive application of the action function, we can generate a simulated behavior, or a sequence of states, starting from a given initial state.

This basic model obviously relates to the graphic regulation model of Section 2. Thus, certain regulation functions, such as "Account for Application," exist for computing state of processes; others, such as "Decide Application," are for actually generating action functions, i.e., taking action based on current state to carry a process to a certain new state.

We specify an action function by defining:

Y_t: state of a process at time t (given values of a vector of state variables or variable set at time t).

X_t: values of the vector of action or decision variables that affect the state of a process (decision variables are the ones that can be set freely by regulation functions).

Then

$$Y_{t+1} = F(Y_t, X_t) \qquad 4\text{-}1$$

where F is a vector function that assigns a successor state to an initial state for given values of the decision variables.

The determination of Xt can be done in many ways depending on the characteristics of the problem and degree of realism we wish to include in the model. For example:

a) Deterministic Error Correction.

$$X_t = G(Y_t, Y_{t-1}, Y_{t-2},...,Y_0) \qquad 4\text{-}2$$

I.e., values of decision variables only depend on current or past state, which corresponds to the usual feedback control or regulation by error scheme. This is the Systems Dynamics approach proposed by Forrester (1970). In Systems Dynamics terminology, 4-1 is the Level equation and 4-2 is the Rate equation.

b) Deterministic Anticipation-Simple.

$$X_t = G(Y_t, Y_{t-1}, Y_{t-2},...,Y_0; \bar{Y}_{t-1},...,\bar{Y}_T \qquad 4\text{-}3$$

where $\bar{Y}_t$ means projected future state, T is the horizon and G is a vector of close-expression mathematical functions.

c) Deterministic Anticipation-Algorithmic.

Here G is not a vector of close-expression mathematical functions, but the result of an algorithm. This will be the case when functions in G form a system of simultaneous equations for the determination of Xt or when Xt is the solution of a mathematical programming optimization problem. In these cases one finds that in projecting a future state one must also establish future decisions. Hence, current decision is based on projected future decisions. This is the case, for example, in production smoothing where, under seasonal demand, today's production must consider future production and its relationship to future peak demand.

d) Stochastic.

Obviously, expressions 4-1 and 4-2 have parameters whose values must be forecasted when simulating behavior. Since forecasting is subject to error, one can have a better representation of reality by representing future values of parameters as stochastic instead of deterministic variables. In this case, decision variables must be determined under uncertainty based on the probability of occurrence of states and system's behavior also established in a probabilistic way.

Up to now we have implicitly assumed time as discrete. If we wanted no loss of state information, the time increment should be variable and determined by the time interval between events that change process state. However, we will choose to consider time increments as fixed, but as small as necessary to avoid loss of state information. The reason for this is that the available software that we will use for implementing IS models can only accept discrete time increments.

4.2 Tools for Modeling

The purpose in modeling an IS is to be able to accurately represent a given alternative, as discussed in Section 3, and to calculate its organizational effectiveness by simulating its behavior. This is geared to make a cost-effectiveness analysis of the alternative to determine if it is preferable to the current situation or to other possible available alternatives.

Hence, we need tools for implementing models of the type discussed in Section 4.1 that allow as quick and effortless an evaluation as possible. Fortunately, these tools already exist, although they were developed for other purposes. They are the modeling software packages available for building DSS (Reiman and Waren 1985). These packages use as a calculation paradigm a matrix where columns usually represent time (in discrete increments) and rows or lines are items, such as states, decision variables or parameters, to be projected in time. They contain powerful expressions and modules that allow specifying how an item is to vary in time and also to "solve" the specifications.

Hence, these packages make it possible to build a model and simulate an alternative under consideration in very little time and to estimate the results it would produce if applied in practice, thus evaluating its effectiveness.

We have extensively tested this scheme with alternatives for a variety of IS using IFPS (Execucom Systems Corp. 1987). In all instances, the approach has worked quite well in making the quantitative evaluation of alternatives possible. In the next section, examples of the application of the approach are given.

4.3 Modeling Examples

The model of the cash flow management problem presented in Section 3 and shown in Figures 3 and 4 is developed below.

In the current situation for the cash management problem given in Figure 3, a loan is requested to satisfy the last period deficit and a short term investment is made to use the last period surplus. Both loans and investments are due in the next period. A model that simulates this current situation for a given series of collections and payments, together with the results for 12 periods, is given in Figure 5.

The alternative for the cash flow management problem, given in Figure 4, attempts to forecast cash flow based on Invoices, Purchases and Other Expenses information. The forecast, which is assumed to be known for the current period, is then used to anticipate the need for a loan and negotiate it in advance, hopefully with a smaller borrowing rate than in the current situation. For the sake of simplicity, we assume that short term investment is made just to allocate the current period surplus with maturity in the next period. Thus, we ignore the obvious possibility of making short term investment for more than one period, with possibly better rates, on the knowledge of a cash flow forecast. A model that simulates this alternative together with the results for 12 periods in given is Figure 6. The slack resource affected in this case is clearly Cumulative Net Interest Income (Expense). Notice that this is greatly improved with respect to the current situation.

As a further example of modeling, we consider an extension of the cash flow management problem shown in Figure 4, leading to a second, more refined alternative. This assumes that the cash flow forecast is known for the whole horizon and that investment and borrowing decisions will be made on such a forecast. Also, investments and loans can be taken optionally for maturity in one, two or three periods in the future. Due to the large number of variables that these assumptions generate, the only way to make decisions in this case in to use an LP-based algorithm. In Figure 7, we show an LP-based model for the problem just described using the format of OPTIMUM, the IFPS optimizer package (Execucom Systems Corporation 1983; Roy, Lasdon and Lordeman 1986), and the results for the same 12 period data used in the alternative in Figure 6. Notice that optimized decisions lead to a better Cumulative Net Interest Income.

```
COLUMNS 1..12
\
\     PROCESS STATE DETERMINATION BASED ON PREVIOUS ACTION
\
COLLECTIONS=1200, PREVIOUS * 1.05
PAYMENTS=1000,1500,1500,1300,1000,1000,1500.2000,2000,1500,1700,1800
BANK ACCOUNT BALANCE=INITIAL BAB - PAYMENTS - SHORT TERM INVESTMENT+'
              COLLECTIONS + LOAN, PREVIOUS - PAYMENTS - SHORT TERM INVESTMENT
              + PREVIOUS SHORT TERM INVESTMENT * (1+IR:) + COLLECTIONS + LOAN'
              - PREVIOUS LOAN * (1+BR:)
\
\     DECISION BY DETERMINISTIC ERROR CORRECTION.
\
LOAN = MAXIMUM (- PREVIOUS BANK ACCOUNT BALANCE, 0)
SHORT TERM INVESTMENT= MAXIMUM (PREVIOUS BANK ACCOUNT BALANCE, 0)
\
\     SUMMARY OF EFFECTIVENESS
\
INTEREST INCOME = 0, PREVIOUS SHORT TERM INVESTMENT * INVESTMENT RATE
INTEREST EXPENSE = 0, PREVIOUS LOAN * BORROWING RATE
NET INTEREST INCOME = INTEREST INCOME - INTEREST EXPENSE
CUMULATIVE NET INTEREST INCOME = NET INTEREST INCOME, PREVIOUS + NET INTEREST INCOME
\
\     PARAMETERS
\
IR:INVESTMENT RATE = 1.3%
INITIAL BAB =90
BR: BORROWING RATE = 2.4%
```

	1	2	3	4	5	6
COLLECTIONS	1200.0	1260.0	1323.0	1389.2	1458.6	1531.5
PAYMENTS	1000.0	1500.0	1500.0	1300.0	1000.0	1000.0
BANK ACCOUNT BALANCE	290.0	-240.0	116.8	-156.6	576.9	371.2
LOAN	0.0	0.0	240.0	0.0	156.6	0.0
SHORT TERM INVESTMENT	0.0	290.0	0.0	116.8	0.0	576.9
INTEREST INCOME	0.0	0.0	3.8	0.0	1.5	0.0
INTEREST EXPENSE	0.0	0.0	0.0	5.8	0.0	3.8
NET INTEREST INCOME	0.0	0.0	3.8	-5.8	1.5	-3.8
CUMULATIVE NET INTEREST	0.0	0.0	3.8	-2.0	-0.5	-4.2

	7	8	9	10	11	12
COLLECTIONS	1608.1	1688.5	1772.9	1861.6	1954.7	2052.4
PAYMENTS	1500.0	2000.0	2000.0	1500.0	1700.0	1800.0
BANK ACCOUNT BALANCE	692.5	64.5	474.5	426.9	735.3	684.9
LOAN	0.0	0.0	0.0	0.0	0.0	0.0
SHORT TERM INVESTMENT	371.2	692.5	64.5	474.5	426.9	735.3
INTEREST INCOME	7.5	4.8	9.0	0.8	6.2	5.6
INTEREST EXPENSE	0.0	0.0	0.0	0.0	0.0	0.0
NET INTEREST INCOME	7.5	4.8	9.0	0.8	6.2	5.6
CUMULATIVE NET INTEREST	3.3	8.1	17.1	17.9	24.1	29.7

Figure 5. Model for Current Situation: Cash Flow Management Problem

```
\ COLUMNS 1..12
\      PROCESS STATE DETERMINATION BASED ON PREVIOUS ACTION.
\
COLLECTIONS=1200,PREVIOUS * 1.05
PAYMENTS=1000,1500,1500,1300,1000,1000,1500,2000,2000,1500,1700,1800
BANK ACCOUNT BALANCE=INITIAL BAB - PAYMENTS - SHORT TERM INVESTMENT '
            + COLLECTIONS + LOAN, PREVIOUS - PAYMENTS - SHORT TERM INVESTMENT'
            - PREVIOUS LOAN * (1+BR:) + PREVIOUS SHORT TERM INVESTMENT * (1+IR:)'
            + COLLECTIONS + LOAN
\
\      PROJECT FUTURE STATE.
\
INVOICES = 1260,PREVIOUS * 1.05
PURCHASES = 1300,1300,1100,800,800,1300,1800,1800,1300,1500,1600
OTHER EXPENSES=200
COLLECTION FORECAST = INITIAL COLLECTION, PREVIOUS INVOICES
PAYMENTS FORECAST = INITIAL PAYMENTS, PREVIOUS PURCHASES + OTHER EXPENSES
CASH FLOW FORECAST= COLLECTION FORECAST - PAYMENTS FORECAST
\
\      DECISION BY DETERMINISTIC ANTICIPATION-SIMPLE.
\
LOAN REQUISITION = LOAN
LOAN = MAXIMUM( 0 , - INITIAL BAB - CASH FLOW FORECAST ) , '
       MAXIMUM( 0 , PREVIOUS LOAN * (1+BR:) - PREVIOUS BANK ACCOUNT BALANCE - '
                PREVIOUS SHORT TERM INVESTMENT * (1+IR:) - CASH FLOW FORECAST )
SHORT TERM INVESTMENT = MAXIMUM( 0, INITIAL BAB + CASH FLOW FORECAST ),'
       MAXIMUM( 0 , PREVIOUS BANK ACCOUNT BALANCE + CASH FLOW FORECAST '
                + PREVIOUS SHORT TERM INVESTMENT * (1+IR:) - PREVIOUS LOAN * (1+BR:) )
\
\      SUMMARY OF EFFECTIVENESS.
\
INTEREST INCOME = 0, PREVIOUS SHORT TERM INVESTMENT * INVESTMENT RATE
INTEREST EXPENSE= 0, PREVIOUS LOAN * BORROWING RATE
NET INTEREST INCOME= INTEREST INCOME - INTEREST EXPENSE
CUMULATIVE NET INTEREST INCOME = NET INTEREST INCOME,
                                  PREVIOUS + NET INTEREST INCOME
\
\      PARAMETERS.
\
INITIAL BAB=90
IR:INVESTMENT RATE=1.3%
BR:BORROWING RATE=2.0%
INITIAL COLLECTION=1200
INITIAL PAYMENTS=1000
```

	1	2	3	4	5	6
COLLECTIONS	1200.0	1260.0	1323.0	1389.2	1458.6	1531.5
PAYMENTS	1000.0	1500.0	1500.0	1300.0	1000.0	1000.0
BANK ACCOUNT BALANCE	0.0	0.0	0.0	-0.0	0.0	-0.0
INVOICES	1260.0	1323.0	1389.2	1458.6	1531.5	1608.1
PURCHASES	1300.0	1300.0	1100.0	800.0	800.0	1300.0
OTHER EXPENSES	200.0	200.0	200.0	200.0	200.0	200.0
COLLECTION FORECAST	1200.0	1260.0	1323.0	1389.0	1458.6	1531.5
PAYMENT FORECAST	1000.0	1500.0	1500.0	1300.0	1000.0	1000.0
CASH FLOW FORECAST	200.0	-240.0	-177.0	89.2	458.6	531.5
LOAN REQUISITION	0.0	0.0	122.5	35.8	0.0	0.0
LOAN	0.0	0.0	122.5	35.8	0.0	0.0
SHORT TERM INVESTMENT	290.0	53.8	0.0	0.0	422.1	959.1
INTEREST INCOME	0.0	3.8	0.7	0.0	0.0	5.5
INTEREST EXPENSE	0.0	0.0	0.0	2.5	0.7	0.0
NET INTEREST INCOME	0.0	3.8	0.7	-2.5	-0.7	5.5
CUMULATIVE NET INTEREST	0.0	3.8	4.5	2.0	1.3	6.8

	7	8	9	10	11	12
COLLECTION	1608.1	1688.5	1772.9	1861.6	1954.7	2052.4
PAYMENTS	1500.0	2000.0	2000.0	1500.0	1700.0	1800.0
BANK ACCOUNT BALANCE	0.0	0.0	0.0	0.0	0.0	0.0
INVOICES	1688.5	1772.9	1861.6	1954.7	2052.4	2155.0
PURCHASES	1800.0	1800.0	1300.0	1500.0	1600.0	1600.0
OTHER EXPENSES	200.0	200.0	200.0	200.0	200.0	200.0
COLLECTION FORECAST	1608.1	1688.5	1772.9	1861.6	1954.7	2052.4
PAYMENTS FORECAST	1500.0	2000.0	2000.0	1500.0	1700.0	1800.0
CASH FLOW FORECAST	108.1	-311.5	- 227.1	361.6	254.7	252.4
LOAN REQUISITION	0.0	0.0	0.0	0.0	0.0	0.0
LOAN	0.0	0.0	0.0	0.0	0.0	0.0
SHORT TERM INVESTMENT	1079.7	782.2	565.3	934.3	1201.1	1469.1
INTEREST INCOME	12.5	14.0	10.2	7.3	12.1	15.6
INTEREST EXPENSE	0.0	0.0	0.0	0.0	0.0	0.0
NET INTEREST INCOME	12.5	14.0	10.2	7.3	12.1	15.6
CUMULATIVE NET INTEREST	19.3	33.3	43.5	50.8	63.0	78.6

Figure 6: Model of Alternative: Cash Flow Management Problem

```
COLUMNS INITIAL, 1..12
\ PROCESS STATE DETERMINATION BASED ON PREVIOUS ACTION
COLLECTIONS= 0,1200,PREVIOUS * 1.05
PAYMENTS=0,1000,1500,1500,1300,1000,1000,1500,2000,2000,1500,1700,1800
\ PROJECT FUTURE STATE
INVOICES = 0,1260,PREVIOUS * 1.05
PURCHASES  =  0,1300,1300,1100,800,800,1300,1800,1800,1300,1500,1600
OTHER EXPENSES = 0,200
COLLECTION FORECAST = 0,INITIAL COLLECTION, PREVIOUS INVOICES
PAYMENTS FORECAST= 0, INITIAL COLLECTION, PREVOIUS PURCHASES + OTHER EXPENSES
CASH FLOW FORECAST = 0,COLLECTION FORECAST - PAYMENTS FORECAST
\ BANK ACCOUNT BALANCE = BAB
PROJECTED BAB = BAB,PREVIOUS + CASH FLOW FORECAST + LOAN1 + LOAN2 + LOAN3 - PREVIOUS LOAN*(1+BRI:)'
                      - PREVIOUS 2 LOAN2* (1 + BR2:)- PREVIOUS 3 LOAN3 * (1 + IR3:) - STI1 - STI2 - STI3'
                      + PREVIOUS STI1 * (1 + IR1:) + PREVIOUS 2 STI2 * (1 + IR2:)+ PREVIOUS 3 STI3 * (1 + IR3:)
\ DECISION BY DETERMINISTIC ANTICIPATION - ALGORITHMIC (LINEAR PROGRAMMING).
\LOAN DECISION FOR PAYMENT ONE,TWO,THREE PRERIODS IN THE FUTURE
LOAN1= 0
LOAN2=0
LOAN3=0
\SHORT TERM INVESTMENT (STI) DECISION-MATURITY AT ONE,TWO,THREE PERIODS.
STI1=0
STI2=0
STI3=0
\ SUMMARY OF EFFECTIVENESS.
INTEREST INCOME=0,0,PREVIOUS STI1 * IR1: + PREVIOUS 2 STI2 * IR2: + PREVIOUS 3 STI3 * IR3:
INTEREST EXPENSE=0,0,PREVIOUS LOAN1 * BR1: + PREVIOUS 2 LOAN2 * BR2:+ PREVIOUS 3 LOAN3 * BR3:
NET INTEREST INCOME=INTEREST INCOME - INTEREST EXPENSE
CUMULATIVE NET INTEREST INCOME = NET INTEREST INCOME, PREVIOUS + NET INTEREST INCOME
\ PARAMETERS.
IR1: INVESTMENT RATE ONE PERIOD     = 1.3%
IR2: INVESTMENT RATE TWO PERIOD     = 2.7%
IR3: INVESTMENT RATE THREE PERIOD   = 4.2%
BR1: BORROWING RATE ONE PERIOD      = 2%
BR2: BORROWING RATE TWO PERIOD      = 3.9%
BR3: BORROWING RATE THREE PERIOD    = 5.8%
INITIAL COLLECTION                  =  1200
INITIAL PAYMENTS                    =  1000
BAB                                 = 90
OBJECTIVE
        MAXIMIZE CUMULATIVE NET INTEREST INCOME (12)
DECISIONS
        LOAN1(1)
        LOAN2(2)
          :
        LOAN1(12)
        LOAN2(1)
        LOAN2(2)
          :
        LOAN2(12)
        LOAN3(1)
        LOAN3(2)
          :
        LOAN3(12)
        STI1(1)
        STI1(2)
          :
        STI2(1)
        STI2(2)
          :
        STI2(12)
        STI3(1)
        STI3(2)
          :
        STI3(12)
CONSTRAINTS
        PROJECTED BAB(1) .GE. 0
        PROJECTED BAB(2) .GE. 0
          :
        PROJECTED BAB(12) .GE. 0
```

Figure 7: Model of Alternative 2: Cash Flow Management Problem

	1	2	3	4	5	6
PROCESS STATE DETERMINATION BASED ON PREVIOUS ACTION.						
COLLETIONS	1200.0	1260.0	1323.0	1389.2	1458.6	1531.5
PAYMENTS	1000.0	1500.0	1500.0	1300.0	1000.0	1000.0
PROJECT FUTURE STATE.						
INVOICES	1260.0	1323.0	1389.2	1458.6	1531.5	1608.1
PURCHASES	1300.0	1300.0	1100.0	800.0	800.0	1300.0
OTHER EXPENSES	200.0	200.0	200.0	200.0	200.0	200.0
COLLECTION FORECAST	1200.0	1260.0	1323.0	1389.2	1458.6	1531.5
PAYMENTS FORECAST	1000.0	1500.0	1500.0	1300.0	1000.0	1000.0
CASH FLOW FORECAST	200.0	-240.0	-177.0	89.2	458.6	531.5
PROJECTED BAB	.0	.0	.0	.0	.0	.0
DECISION BY DETERMINISTIC ANTICIPATION-ALGORITHMIC (LINEAR PROGRAMMING).						
LOAN DECISION FOR PAYMENT ONE,TWO,THREE PERIODS IN THE FUTURE.						
LOAN1	.0	.0	87.4	.0	.0	.0
LOAN2	.0	.0	.0	.0	.0	.0
LOAN3	.0	34.6	.0	.0	.0	.0
SHORT TERM INVESTMEN (STI) DECISIONS-MATURITY AT ONE,TWO,THREE PERIODS.						
STI1	202.8	.0	.0	.0	123.1	.0
STI2	87.2	.0	.0	.0	.0	.0
STI3	.0	.0	.0	.0	298.8	656.2
SUMMARY OF EFFECTIVENESS.						
INTEREST INCOME	.0	2.6	2.4	.0	.0	1.6
INTEREST EXPENSE	.0	.0	.0	1.7	2.0	.0
NET INTEREST INCOME	.0	2.6	2.4	-1.7	-2.0	1.6
CUMULATIVE NET INTEREST I	.0	2.6	5.0	3.2	1.2	2.8

	7	8	9	10	11	12
PROCESS STATE DETERMINATION BASED ON PREVIOUS ACTION.						
COLLECTIONS	1608.1	1688.5	1772.9	1861.6	1954.7	2052.4
PAYMENTS	1500.0	2000.0	2000.0	1500.0	1700.0	1800.0
PROJECT FUTURE STATE.						
INVOICES	1688.5	1772.9	1861.6	1954.7	2052.4	2155.0
PURCHASES	1800.0	1800.0	1300.0	1500.0	1600.0	1600.0
OTHER EXPENSES	200.0	200.0	200.0	200.0	200.0	200.0
COLLECTION FORECAST	1608.1	1688.5	1772.9	1861.6	1954.7	2052.4
PAYMENTS FORECAST	1500.0	2000.0	2000.0	1500.0	1700.0	1800.0
CASH FLOW FORECAST	108.1	-311.5	-227.1	361.6	254.7	252.4
PROJECTED BAB	.0	.0	.0	.0	.0	1473.3
DECISION BY DETERMINISTIC ANTICIPATION-ALGORITHMIC (LINEAR PROGRAMMING).						
LOAN DECISION PAYMENT ONE, TWO, THREE PERIODS IN THE FUTURE.						
LOAN1	.0	.0	.0	.0	.0	.0
LOAN2	.0	.0	.0	.0	.0	.0
LOAN3	.0	.0	.0	.0	.0	.0
SHORT TERM INVESTMEN (STI) DECISIONS - MATURITY AT ONE, TWO, THREE PERIODS.						
STI1	.0	.0	.0	.0	254.7	.0
STI2	.0	.0	.0	474.2	.0	.0
STI3	108.1	.0	456.7	.0	.0	.0
SUMMARY OF EFFECTIVENESS.						
INTEREST INCOME	.0	12.6	27.6	4.5	.0	35.3
INTEREST EXPENSE	.0	.0	.0	.0	.0	.0
NET INTEREST INCOME	.0	12.6	27.6	4.5	.0	35.3
CUMULATIVE NET INTEREST I	2.8	15.4	43.0	47.5	47.5	82.8

Figure 7: Model of Alternative 2: Cash Flow Management Problem (Continued)

There are many other ways in which the models can be extended; for example, considering some variables as stochastic, such as lead time and consumption in the material management system, and collections and purchases in the cash flow management problem. Also, rigorous statistical procedures, e.g., replication, can be used to obtain valid estimates of effectiveness improvements over the life time of the system.

4.4 Alternative Evaluation

It is clear that, by modeling a given alternative structure according to the ideas in Sections 4.1 through 4.3, we can measure the organization effectiveness, e.g., slack reduction, the alternative will induce in practice under given conditions. This will allow the comparison of the effectiveness of this alternative with respect to the current situation or to other alternatives. Difference of effectiveness of an alternative with respect to a given base situation represents the marginal value the alternative has with respect to that situation. This is what Marschack (1968) calls information value.

Information value, or the value associated to a given alternative, should then be compared with the cost of going from the base situation to the alternative. Cost determination includes the specification of the regulation and information processing functions that will be computerized and the estimation of development cost by a suitable methodology such as Function Points (Albrecht and Gaffney 1983). If cost is less than the discounted value generated over the life time of the system, then the alternative is cost-effective and is worth implementing. Otherwise it should be discarded.

As an example of an alternative evaluation, we consider the cash flow management case modeled is Section 4.3. We take as the base case the current situation presented in Figure 5 and, as alternatives 1 and 2, situations that are respectively modeled in Figures 6 and 7. In order to simplify the analysis, we assume that Cumulative Net Interest Income figures for period 12 in the base case and alternatives are representative of what will occur in any given year over the life time of the system. Then we can easily calculate each alternative marginal value with respect to current situation, which is shown in Figure 8. In the same figure, we also show the equivalent marginal annual costs over the life time of the system for each alternative with respect to the current situation[4] and net marginal value (marginal value less marginal cost). It is clear that the values in Figure 8, based on the specific data presented, lead to a recommendation of alternative 1 over alternative 2.

5. CONCLUSIONS

We have tried to show that information systems exist in organizations to regulate their processes. This point of view has allowed us to define what an IS should be in terms of general validity to accomplish such regulation. Thus, we have developed a model that includes generalized functions to regulate generalized processes through flows of information, which can serve as a basic pattern to approach the design of any IS.

From the generalized IS model, we conclude that the design problem in IS consists of searching for alternative structures, including policies and rules for decision functions and associated information processing and flows; i.e., the design of the organizational components within the scope of the IS or the *External Design*.

Linking the problem of alternative structures to the ideas of organization theory has also provided us with criteria to generate alternatives that would most likely increase organizational effectiveness. This raises the problem of evaluating such alternatives. The modeling approach explained in Sections 4.1 through 4.4 provides a practical way to quantitatively perform this evaluation and to assure that the external design we arrive at is cost effective. This type of evaluation also changes the focus for IS justification in practice, from efficiency improvements (usually coming from personnel reductions) to effectiveness improvements. The later comes from better process regulation which is, according to our approach, the real purpose of an information system.

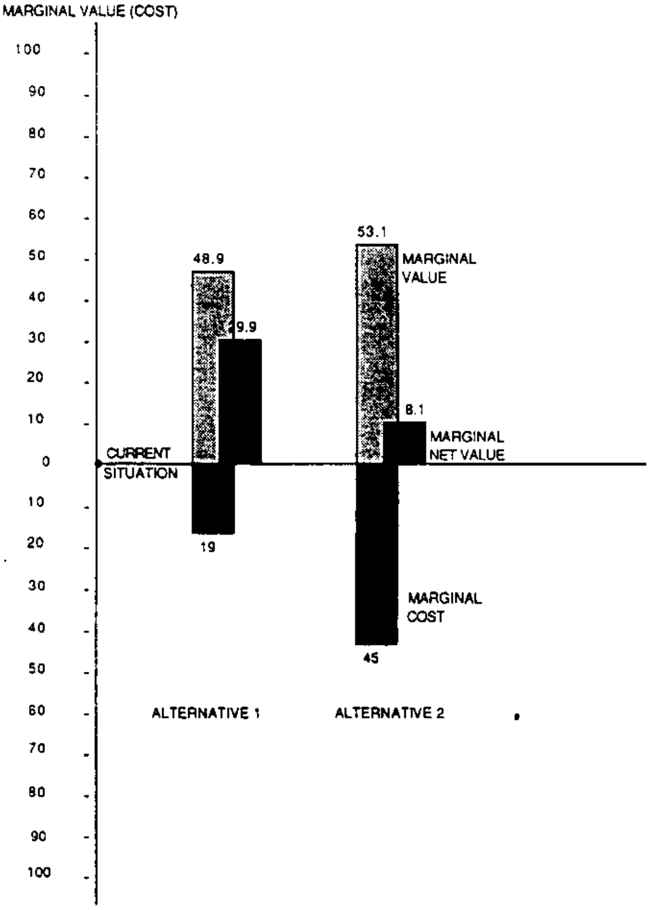

Figure 8: Marginal Value and Cost for Alternatives

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7. ENDNOTES

1. This research work has been supported by FONDECYT.

2. For further examples of uses of coordination ideas in generating alternatives, see Barros (1984, 1987a).

3. This characterization is similar to one that has been used for computer processing (Horning and Randell 1973).

4. We do not give the technical details of these estimations, but they are based on the Function Points Methodology (Albrecht and Gaffney 1983).