Managerial Information Systems for Planning and Control

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by Zenon S. Zannetos

I wish to thank very much Messrs. Smith and Howard of the Boston Safe Deposit and Trust Company for inviting me to speak before you. I am indeed delighted to be here. Nevertheless, I am mindful that I start from a rather disadvantageous position for two reasons. First of all it may be very difficult for me, even under the most auspicious of circumstances, to keep up with the overall tone of preparedness and quality that has been set by our hosts and the speakers before me, let alone when entering into the picture on a very short notice. But the greatest obstacle that I feel I must overcome, are the expectations that you have built about this particular session. For I know that I am substituting for Dr. Hitch, a recognized authority in the area of management information and control systems. Well, the only thing I can do is to do my best.

The topic of my presentation is Managerial Information Systems for Planning and Control. By this I mean systems whose focus of attention is simply management.

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*Address delivered before the Third International Investment Symposium. This paper draws heavily on the results of the author's research as reported in a working paper entitled, "Toward Intelligent Management Information Systems", Sloan School of Management, M.I.T., 155-65.

Many of the systems currently used are either technique centered or hardware biased. The system designer in most of these cases primarily attempts to employ the tools he has. The needs he satisfies, therefore, are only those suggested by his immediate knowledge, environment, and technical capabilities of his tools. The question "Can management needs be satisfied better?" is rarely asked for it presupposes a knowledge of what information managers need in order to manage better. We have often heard that managers are at the mercy of the accountant and his bookkeepers who thrive on the mysticism of their debits, credits and variances. Recent technological progress is slowly but surely rendering old methods obsolete and in the process freeing management of this bondage, but in its place a new and more formidable one is established. In the future managers will have to contend more and more with the systems-man, his programmers and computers. The sooner managers realize this and take an active interest in the design of the information systems of their organizations, the better off they will be. The stakes now are much greater because of the greater potential for centralization that large computers allow.

The systems with which I will be dealing here derive their characteristics from managerial needs. It is on the basis of these needs that computers justify their existence and not the other way around. The aim is to relieve the manager of a lot of his present repetitive control and decision-making activities, allow him for reasons that I will soon explain, to devote more time to planning, and provide him with information for guiding his actions and determining the efficiency of his planning efforts.

Such systems must be capable of drawing inferences and probabilistic conclusions on the basis of incomplete information, and also generalizing from experience. In short, the managerial information systems of the future must be intelligent.

In order that I carry out the task that I set before me I will divide my presentation into three parts:

In Part I I will provide the motivation for this exercise in future systems design for managerial planning and control, and in the process also establish the general characteristics of the information managers need to carry out these activities.

In Part II I will trace the stages through which an information system must advance before it can be called intelligent, and look for clues and a framework which will help us advance sequentially and design systems possessing more and more of the desirable managerial attributes.

Finally, in Part III I will describe some of my efforts to design intelligent managerial information systems.

Part I: Motivation -- Planning and Information Requirements

If we examine management activities we find that these fall into two general categories:

A. Planning, and

B. Control of plans and operations.

A. Planning

Under planning one can include such activities as:

1. Establishing Overall Organizational Objectives

This activity is concerned with the formalization of the most important value judgments which affect and prejudice organizational plans. It is the birth place of the restrictions which curb freedom of action.

2. Developing the Theoretical (Non-Operational) Plans Which Are Considered Necessary to Carry Out the Overall Objectives

Although a lot of value judgments are made at this stage yet the value-judgment content of managerial plans and decisions is not as great here as at stage 1. And this because the value judgments made at Stage 1 introduce constraints or factual elements (information) for Stage 2, in the same way that the value judgments made at Stages 1 and 2 provide factual elements (information) for every subsequent stage. This process shows that sequentially as we go down the hierarchy of management the freedom to exercise value judgments is curbed by all the fixities and decisions introduced at higher levels. The implications of this realization for the management measurement process are quite significant. For it implies that the information system must provide signals for assessing:

(a) the efficiency of operations, i.e., how well the freedom to exercise value judgments is utilized at the various levels in the organizational hierarchy given the constraints (planning restrictions), and

(b) the efficiency of the planning process, i.e., whether the cause and effect relationships which are assumed in the process of establishing the factual elements, that is to say, the functional relationships inherent in the various transformations of objectives to plans, are efficient.

3. Translating the Theoretical Objectives and Plans to a Whole Chain of Operational Objectives, Subobjectives, Plans and Subplans

It should be obvious at this stage that there is practically an infinite number of ways these translations and transformations can be made. No one, therefore, can be certain that the chosen configuration of plans is the optimum path to the objectives of the organization. Only in a probabilistic sense an à priori evaluation can be made, and this only among the alternatives brought forward by the planning process. For these reasons the information system must be flexible to adapt sequentially, question the plans, and provide signals on the applicability of the assumed functional relationships.

4. Budgeting Plans and Operations

At this point, time relationships are introduced in the planning process. If the information system is to aid managers in their long-run planning activities it must therefore be sensitive to the time profile of plans, operations, resource flows and accomplishments.

5. Assigning Plans to Responsibility Units

By this time, in the process of transformation of objectives, etc., most of the characteristics of the organization structure of the firm have been determined. The technological and technical characteristics of objectives and operations as well as the personal philosophy of top management, on the degree of value judgment allowed their subordinates, have left unmistakably their mark on the organization. The assignment, therefore, of plans to

responsibility units is just the outward manifestation of issues of centralization and decentralization as determined by the process of transformation.[1] That is one of the reasons why the latter is so important for the design of efficient information systems.

6. Designing the Information and Control System Which Will Compare the Results from Operations Against the Operating Plans, the Latter Against the Theoretical Plans and Finally Theoretical Plans Against the Overall Objectives

B. Control

In order that the information system perform effective control functions it must:

1. Measure and Determine Deviations From Desirable Performance

This implies that in addition to the rules of measurement we must have the means for generating appropriate signals on the basis of observed differences in performance.

2. Coordinate the Various Activities

The way it is used here, coordination implies reconciliation of interdependencies so that destructive interferences be eliminated and complementarities be accentuated.[2] Note that if we were dealing with

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[1]For an analysis of the factors affecting centralization and decentralization, see: Zenon S. Zannetos, "On the Theory of Divisional Structures: Some Aspects of Centralization and Decentralization of Control and Decision Making", Management Science, Vol. 12, No. 4, December 1965, pp. 49-68.

[2]We say that two activities are complementary if both together generate a value to the organization which is greater than the sum of the values of the individual activities if planned independently of each other.

perfectly competitive markets, coordinative controls would be unnecessary. But under such circumstances economies of specialization, research and development and innovation would also be relatively absent, and the firms would not be earning a profit but something close to a financial rent.

3. Encourage Learning by Making Available Specialized Information

One of the most important purposes of the control process is not to generate signals for reward and punishment but to provide information at the operating level for learning and specialization.

4. Motivate Those Who Determine the Allocation of Resources to Do So Efficiently

Every aspect of the information and control system of an organization as viewed here has motivational purposes. If the recipients of information cannot be influenced through information, it is useless to provide it. There seems to be a lot of confusion approaching schizophrenia on this issue within many organizations.

5. Provide Premises for Remedial Action

The implication here is that the information system must not only provide the signals indicating the existence of problems but also whatever information is necessary for the decisions which should follow.

6. Encourage the Use of Substabilities[3] and Standardization As a Means to Innovation Rather Than as an End in Themselves

Many organizations use their information systems to impose behavioral conformity (human) and are happy if operations are perpetually under control. The systems we will be discussing view these occurrences as opportunities for action rather than inaction.[4]

7. Aid Management in Replanning at Whatever Level in the Hierarchy is Necessary

The above control functions complete the feedback loop and the planning process starts all over again.

C. Computers and Their Impact

Obviously managers need information to carry out their planning and control activities efficiently. The type of information that they have had up to now, mostly came through the regular accounting system of their organizations. Incidentally, accounting is the most comprehensive and integrated information system in operation today, if not the only one. It is very efficient for stewardship purposes but not for internal managerial decisions. It must be supplemented and extensively changed if it is to be

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[3]The term "substability" means a temporary, artificial or assumed stability. Substabilities are very useful for purposes of problem solving in that they order an otherwise chaotic situation and as such are used as stepping stones to higher level solutions.

[4]This topic is treated extensively in: Zenon S. Zannetos and Otto Poensgen, "Innovation, Operational Control and the Management Information System", The Business Quarterly (Canada), Winter Issue, (forthcoming).

used for decision making. Its last major innovation was the introduction of flexible budgets and standard costs but even this aspect as we will shortly point out has not been fully exploited.

During the last twenty years we witnessed considerable progress in the use of operations research techniques, i.e., in the use of mathematical and statistical methods for managerial decision making, and in the behavioral sciences, especially in the area of perception of information and motivation; but above all, the progress has been startling in the area of information theory and computer sciences. We now, for the first time, have the technical capability to do what we should have done a long time ago, to fuse a lot of these areas together, view the firm in terms of interacting subsystems and therefore design information systems that are really managerial.

As our capability develops to exploit the potentials of man-machine interaction systems, pattern recognition, and in general artificial intelligence, managerial planning and control will more and more become a science, utilizing fully the innate capacity of human beings. These systems we feel will serve as an extension to the human brain power, enabling us to do things we have not dreamed before, but for sure these systems will not subjugate us. No doubt managers especially at the middle management levels will be extensively affected. A lot will be rendered obsolete and others will have to go through a painful period of extensive reorientation and change of attitude as "proprietary rights" to internal, sensitive information and loyalty of subordinates begin to collapse.

Up to now we have not made much progress in the area of intelligent computerized information systems for planning and control. Most of the systems in industrial operation today and by this I mean any industry including banking and finance, exploit the speed and consistency of computers for data processing but not much of their potential intelligence. The truth is that most computer installations today are not used efficiently. This is not to deny that most computerized systems are more efficient than the manual systems they displace. The issue is that often the opportunity cost[5] of the computer time utilized by these operations far exceeds the value they generate. Before acquiring new capacity the organization should always analyze to find out if the value of the least valuable operation can justify the cost of the additional capacity. Unfortunately, however, many do not question existing operations to find candidates for elimination but instead rush to increase the capabilities of their installations.

Another characteristic of most existing systems is that they are partial, i.e., they do not cover the entire spectrum of the firm's activities.

Operational or process control, meaning control of low level manufacturing operations or routine operating tasks manufacturing or clerical, is one of the first areas to be computerized following the

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[5]This term is defined as the expected value from the best alternative use of the scarce resource.

automation of routine accounting functions. And this of course for good reasons. Operating process control is relatively easy as compared to planning process control. But the latter is much more critical for the success of the firm. The few attempts that have been made to simulate planning and operations and develop total systems, gave a tremendous impetus to the state of the art but fell short of solving our problems. And the reason is that these systems are *ad hoc* or special purpose systems with no adaptive capabilities or intelligence with the exception of what is stored through human intervention. Furthermore, these systems do not possess the capability of self-validation nor do they provide for the generation of the data that are necessary for their implementation. No system can succeed in satisfying managerial needs unless it is continuous and builds directly upon an efficient data gathering system. These shortcomings of special purpose systems are indeed critical as anyone who has dealt with these systems can attest.

D. Planning versus Operating Process Control

I have been and will be consistently putting emphasis on the planning (rather than the operating) side of the managerial activities and this may disturb some of my listeners. For after all, are not the operations the flesh and blood of an organization? Doesn't the success or failure of the firm depend on the success and failure of its day to day generation of products and services?

The answer of course is undeniably yes but only in the short run. Planning as we have seen sets the structure within which decisions and operations take place. In this sense it is the skeleton, the foundation on which operations add flesh. And if this skeleton or foundation is weak or absent no amount of plastering or padding can make it take permanently the shape of a beautiful and healthy structure. In its absence, operations will be a bowl of jelly, i.e., amorphous. That is why I will be stressing planning because it sets the structure, establishes factual premises out of value judgments and as such prejudices decisions and operations over the long run. But frankly I believe that we do not have to compromise here or stress the one at the expense of the other. Both planning and operations are inextricably interdependent and in the systems that we are discussing control of operations is a modular part of the planning process. This is one of the things that computers make possible. They allow us to build detailed subsystems which modularly fit into the total system, and most important, enable us to improve on the consistency of parts. In other words they allow us to look at the trees but not forget the forest and vice versa. If we look back at the description of the components of the planning and control process we will readily appreciate how important are these attributes.

Because of their consistency and accuracy, computers also allow us to relegate with confidence to the system all planning which becomes operational and all operations that are amenable to standardization.

Once managers are relieved of routine tasks they can devote more time to plan and learn about new areas of endeavor, only to do the same again as soon as the latter are routinized. This is a never ending process, and so is improvement.

Admittedly it is much easier to design an information system for controlling operations than for controlling the planning process. The reasons for the difficulty in the case of planning are:

1. Absence of structure. We have mentioned that planning sets the structure for operations but presently there exists nothing to set the constraints for planning. Normalization or standardization is not possible as yet and with its absence there can be no problem identification or pattern recognition.

2. Absence of many factual elements. In the case of operations we are dealing with engineering cause and effect relationships on a one to one basis but in the case of planning we are dealing with value premises. But we must stress again that given the factual elements for accomplishing the value premises we have the ingredients of an efficient information system, because it can generate signals on the applicability of the assumed functional relationships and even on the value premises themselves. That is to say the information that is introduced in the process of planning and transformation of plans creates one to one relationships out of situations where normally exist many to many. This is the information that we must introduce into the formal information systems of the organization if we wish to provide managers with signals useful for planning and decision making.

I am sure that as practitioners in this area of general management you more than anyone else appreciate that on an a priori basis there is no way we can determine with certainty whether, given the objectives, the plan that you chose is the best plan or the only plan. Furthermore, once we can agree that there is one-many correspondence between objectives and plans then for sure we must agree that there is one-many correspondence between objectives and operations to implement the plans.

3. Presence of uncontrollable environmental conditions. Environmental conditions play a critical role in both plans and operations. In the case of operations most of these conditions originate within the organization and can therefore be actively controlled in most cases. In contrast, planning has to deal mostly with factors originating outside the organization (exogenous) and therefore uncontrollable. The only thing managers can do in such cases is to predict the consequences of variations in these environmental factors in order to counteract them but for sure not eliminate them.

For the above reasons planning up to now has been done on an ad hoc basis and it is not part of the continuous information system of organizations. Such practices, that is to say planning on an ad hoc basis, obviously are very dangerous. Because:

a) There is nothing to guarantee that planning will be done rationally or consistently;

b) Since extensive time element enters between the adoption of a plan and its implementation, planning is not so repetitive as to:

(i) generate automatic response behavior, or

(ii) allow a planner an opportunity to utilize the knowledge he gained through experience. That is to say, the planner may not be there long enough to meet the same situation twice. So the experience is not exploited. And even if he meets a similar situation and does use the information again, the organization only benefits through his presence. No one else can benefit from his mistakes and accumulated wisdom.

The benefits from learning, therefore, are not accruing to the organization but only to the individual. In other words, the stock of planning knowledge today is not transferable. How then under these conditions do we expect to train planners? Especially if the stock of knowledge is ever increasing? Train through apprenticeship? This is a very serious matter with the present need for managers.

I am sure that you must have heard caricatures of the successful planner similar to this one. He is asked by the aspiring young executive how he plans, and the answer comes back promptly, "through intuition and experience". "But how can I learn from your intuition and experience?" the young man insists. "Rise through the ranks, my boy," the sage old man retorts. This caricature of course does not represent such an exaggeration of what goes on today within organizations. And this does not speak very well for both ourselves as educators of managers or the managers themselves, for it implies that there is not much in terms of fundamental material that can be transmitted formally. Can you imagine what will happen if we were

to depend on apprenticeship to train planners as time goes by and operations become more complex? The apprentices will probably retire before they graduate to the managerial ranks. It is obvious that training future managers is a very critical area for management and that we cannot let it develop haphazardly. We cannot, therefore, depend on apprenticeship nor on the personal information system of each and every planner. We must develop a system which stores the accumulated planning stock of knowledge and makes it available for retrieval and learning.

From the introductory material two things are clear: (i) that planning and control of the planning process are very critical managerial functions, and (ii) that if we are to develop information systems for planning we need to:

(a) Incorporate into the information system the environmental conditions which affect the planning variables as well as the functional relationships that tie the two together.

(b) Monitor and search, to sense changes in the assumed functional relations between the environmental conditions and the plans. The differences or deviations picked up by the system will then serve as signals for possible problem identification.

(c) Have a flexible information structure to allow for different aggregations and one-to-one information correspondence between plans and operations.

(d) Develop information systems with prognostic not only diagnostic or post mortem capabilities. It does not help much to know that something went wrong and a lot of resources were wasted. It is better if the information system gives signals that something is going wrong while there is time to curb it, and even better that something will go wrong if certain steps are not taken to prevent it. We need, therefore, information systems that are intelligent, associative and adaptive. Systems which will be adaptable or flexible enough so that we can relegate to them all managerial functions which we can program or can describe in terms of heuristics. And this so that management can free itself to deal with more abstract planning and functional relationships. Note in this conjunction that the system is used continuously as a substability or a stepping stone to higher and higher level problem solving. This is a never ending hierarchical process. Such systems will give us signals ahead of time and so enable us to avoid problems rather than bring them to our attention after the damage has been done.

Let us now turn to the stages through which information systems must advance to acquire intelligence.

II. Steps Toward Intelligence

I hope that the arguments I have just presented do not lead you to the erroneous conclusion that it is a hopeless task to even attempt to provide information systems for managerial planning, and for control of the planning process. That the task is difficult there is no doubt, but hopeless it is not.

In order to design an efficient information system one has to first realize that managerial activities occur within a probabilistic and not a deterministic setting. This obvious sounding observation has been the major stumbling block of many otherwise ambitious and diligent efforts in the past to design information systems which aid managers to plan, decide, and manage better. Once this transition is made, however, and all its implications are realized, half of the battle is won. Because then the characteristics of the environment within which management operates both external as well as internal will of necessity be introduced into the system and thus create flexibility for sequential learning and adaptation through "after-the-event" analysis. This I consider as a great accomplishment if achieved. To the extent that we cannot very well predict the state of all the environmental factors affecting our operations over the time period covered by our plans, *a priori* optimization gives way to sequential analysis, learning, and estimation. That is why I believe that if we succeed in instilling in our information systems flexibility and a healthy questioning attitude then sequentially we will reach better and better solutions and continue improving practically *ad infinitum*. We must not, therefore, wait until we can "optimize" the whole gamut of organizational

activities, whatever that means, before we begin. Let us start from where we are, even if we have to assume a priori that we are doing the best we can, and sequentially exploit the intelligence of our information systems.

Let us now analyze the stages through which an information system must advance to acquire intelligence and ponder over the implications of this maturing process for managerial information systems. In order that an information system become eventually intelligent, it must gradually acquire the capability for:[6]

1. Storage of Raw Data: At this stage the system has cells for storage and a method of storage of data. As long as there are empty cells data are recorded haphazardly. To be useful, the method of storage must somehow provide for rejection of information if no empty storage cells exist so as to avoid cluttering.

2. Classification of Data into Homogeneous Entities: In order to be helpful, an information system must not only be able to store data but comprehend some type of rules for classification of the data into meaningful entities. This is an elementary self-organization capability. Without it learning cannot start. Somehow the system must begin to classify the data on the basis of their common characteristics. It must, therefore, be also capable of active perception not only passive absorption.

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[6] See Zenon S. Zannetos, "Toward Intelligent Management Information Systems", SSM, MIT Working Paper #115-65. These steps are in many respects similar to the steps toward artificial intelligence discussed by Marvin Minsky in Computers and Thought, Edward A. Feigenbaum and Julian Feldman (Eds.), McGraw-Hill Book Company, New York, 1963, pp. 406-450.

3. <u>Extracting Differences</u>: One of the requirements of any information system which is used for control purposes, is its ability to generate signals on the basis of deviations. It does this through a matching process. These differences that are generated by the matching process often indicate the existence of potential problems. The next step therefore after an ability to classify is the ability to perceive quantitative (not qualitative as yet) differences in classifications that are otherwise qualitatively identical.

4. <u>Storage of Cues for Automatic Response at the Operating Level</u>: The next step in terms of increasing sophistication is for the information system to react on the basis of the comparisons it performs and take elementary remedial action. The types of reaction, however, and the relationships between signals and responses are determined exogenously (outside the system) and stored in the system for fast response. One such example of elementary remedial action on the basis of perceived differences is performed by our thermostats. Once a difference between the preset and the environmental temperature is observed, on the basis of stored cues into the system, a mechanism is triggered to turn on the furnace. The system as yet, however, is not intelligent enough to reason out or understand what are the principles which govern the matching process or the cause and effect relationships. There is a simple one-to-one correspondence between a signal and the reaction.

5. Storage of Cause and Effect Relationships for Operations: At this stage the system has the prerequisites for exercising elementary intelligence. It can associate the signals it generates through comparisons with functional relationships of general applicability. Notice here that the correspondence between the data and the functional forms is "many-one" that is to say the association occurs on the basis of the semantic content of variables and forms and not on the basis of their numerical levels alone.

To clarify some of the points that we raised let us use a very simple example. Let us assume that we want to use a control system to check on our ability to multiply. The general functional relationship here is:

$$Y = CX$$

where Y is the answer, C is the scalar of multiplication and X is the multiplicand (independent variable). If we cannot store in our system cause and effect relationships then we must store all the possible answers for all possible scalars and multiplicands. That is how, incidentally, we used to be taught multiplication, by memorizing the multiplication tables. Alternatively we can store the semantic content of the equation and forego storing every possible structural relationship we might need. In the first case es soon as we specify C and X the system through matching will readily retrieve the corresponding answer if stored, or else get confused. In the second case, it will associate the operation to be performed with the appropriate

functional relationship, introduce the specified scalar and variable into the equation, in a way that preserves its meaning, and carry out the multiplication before reporting the answer.

The example that we used here points out another characteristic of intelligence. Given limited storage capacity we will always be faced with a choice between (a) storing a lot of raw and semi-processed data, such as we are now doing in accounting records, or else (b) store "indecomposable" (in their rawest form) data and general purpose functional relationships. In the first case we obtain fast retrieval of only the things that we stored and in the form we stored them, while in the second we have a slower system but with manipulative capability to relate data to cause and effect relationships. So always there will be "trade-offs". For control of operations at the low levels fast retrieval is important, but for planning, especially at high levels in the organization, manipulative capability is much more important because the time sensitivity of decisions in general is smaller the higher up we go.

6. Inferring Probabilistically and Challenging the Current Models: We have already mentioned that flexibility and questioning attitude are necessary to lead us sequentially to better and better systems. Stage 5 above led us to what I like to call a "functional" accounting system. The latter is operating on

assumed functional relationships whose validity up to now the system has no intelligence to question. So the next step is to introduce into our managerial information system the capability to:

(a) Assess the probabilistic significance of the results from operations and so separate those observations which probabilistically are the result of purely stochastic (chance) elements from those which indicate probable existence of problems. This, as you can appreciate, will allow real management by exception on the assumption that the functional relationships are correct.

(b) Question the functional relationships themselves on the basis of the results from operations, and re-evaluate the faith management placed in the various alternative models.

7. <u>Deriving General Purpose Cause and Effect Relationships From Experience:</u>

With stage 6 above the information system acquired some deductive reasoning capacities. Now we wish to introduce into it inductive reasoning. This can be accomplished if the system acquires associative powers so that it can search, recognize patterns, propose alternative hypotheses, design and analyze experiments to test the alternatives, learn from experience and derive more general purpose (abstract) functional relationships to report to

management. Environmental, behavioral, as well as technical considerations enter into these patterns which in turn condition managerial expectations and influence their plans and actions. All this of course must be done on the basis of incomplete information because of the very probabilistic nature of the various cause and effect configurations. Stage 7 opens the way to associative information systems.

The above arguments seem to imply that in order to reach this stage of intelligence we need to store into the system two types of data. (two data bases):

a) Indecomposable observations

b) Functional relationships associated in terms of conditional patterns.

It is obvious, of course, that the observations serve as inputs to the patterns, which change on the basis of what the observations probabilistically dictate.

8. Deriving Functional Relationships to Test the Applicability of Functional Relationships:

This last step is the epitome of intelligence. It refers to meta-systems and will be necessary for any system which automatically provides managerial planning process control, and helps management to plan better. Although the description of this stage sounds very formidable, actually the difficulty lies not in Stage 8 but in the transition from Stage 6 to Stage 7. Once the latter is reached,

then Stage 8 will automatically follow, since it utilizes the same logical operations used at Stage 7 but at a more abstract level.

I already made the statement that usefulness aside, accounting is the only continuous, integrated, and most comprehensive managerial information system that we have today. It may be interesting, therefore, to rank it in terms of intelligence. I am sure that no one will be surprised if I classify it as being at Stage 3, that is to say, at the pre-intelligence level. Intelligence starts at an advanced Stage 4, so there is plenty of challenge ahead of us.

III. Efforts Toward Implementation

The question now facing us is: How can we start developing a managerial information system with the characteristics alluded to in the previous section?

I would like to report briefly on two general approaches that I tried. My report on one of these two attempts will be very short because its results can be summarized in the word "failure". The two approaches are:

A. Total Approach Starting From Scratch. That is to say, ignoring the existing system, and planning and designing a managerial information system based on theory, with no constraints whatsoever except those imposed by theory and technology. This method creates an infinite number of instabilities for the system theoretician, chaos,

disorganization and at least in my case, failure. I presume that this will also be the fate of the organization which completely scraps its existing total information system and attempts to install a new one in its place.

If a lot of limiting assumptions are made and a lot of variables are fixed, or if a part of the total system is redesigned, then some progress can be recorded. As you can appreciate, however, the results in this case will be of limited value.

B. Start with the Existing System and Improve Continuously at the Margin. This approach, unlike the previous one, accepts things as they are and applies theory and optimization techniques at the local level. In order that it succeed, it must first of all provide for procedures by means of which the area encompassed by the analysis becomes everexpanding. In this way the chances for incompatibilities between the various subsystems are extensively reduced.

Then we must also somehow make certain, that the boundaries or lines of demarkation between subunits and subsystems are drawn correctly. That is to say, we must provide for measurements of the efficiency of organization structures.

I have been quite encouraged in my efforts to design intelligent information systems using an approach as described under B above. So let me now give you a step by step superficial sketch of the whole system as far as I succeeded in pursuing it.

1. Choose the Highest Level in the Organization Where the Dominant Operations Are Amenable to Characterization. This level will be the starting point of the whole analysis. Some type of standardization of the operations at this level must be possible otherwise there will be no way one can analyze the results from operations and determine their significance. I must stress that complete standardization is not necessary, only some temporary characterization. If an operation can be brought under existing budgetary planning and control schemes then it does most probably have the desirable attributes. Furthermore, the techniques that I will describe are applicable not only in manufacturing operations, but anywhere tentative cause and effect relationships can be established.

2. Analyze the Results from Operations. We mentioned previously that information systems are generating signals on the basis of observed differences. That is to say, differences between the tentative planned levels, and the assumed cause and effect (functional) relationships underlying these plans. So we must have a system for measurement and the present accounting system can suffice for data gathering purposes. We must only make sure that it collects the data that are necessary for checking if: (a) the operations are efficient and (b) the cause and effect relationships are correct.

Once we observe the differences then the system asks: Are the deviations (accounting variances) statistically significant given that our characterization of the process is correct? This is the first step toward a probabilistic control system and it can be applied today.[7] It operates on sampled information and saves the organization a lot in terms of data gathering, storing, processing, reporting and reviewing superfluous and often meaningless information. The sample size of data to be analyzed, the degree of aggregation and the duration of the reporting cycle are among the items determined by the system itself. By storing into the system the method used by managers to determine the significance of the observed deviations, and also storing the decision rules that they apply on the basis of their findings, the system can carry out these functions automatically and report to managers only what is relevant. This is a real management by exception.

In order to give you an appreciation of the potential savings in terms of time, energy and resources involved in a change from the present deterministic systems to a probabilistic system, let me say that in one case where this approach was

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[7] The theory underlying this system and its operational implications are described in: Zenon S. Zannetos, "Standard Costs as a First Step to Probabilistic Control: A Theoretical Justification, an Extension and Implications", <u>Accounting Review</u>, Vol. XXXIX, No. 2, April 1964, pp. 296-304.

tried it reduced the entries in the weekly report of the Vice President for Distribution of one large firm from over 2000 multi-column entries to 22. Furthermore, this approach provides management with better information because it also reports the probability that the observed deviations are caused by chance versus by a system which is out of control.

If persistent, variances close to zero and around invariable averages are, according to this system, a sign of stagnation and sickness rather than excellence. For it implies that the advantages of learning and proceduralization are not used toward further improvements but only for relaxation and easy life. Exceptionally favorable variances are as much the focus of attention of a probabilistic system as the exceptionally unfavorable, because these may be the result of successful experimentation which should be spread within the organization.

3. Check on the Budgets and Standards. In order to check on the probabilistic significance of the results from operations we have to assume that the functional relationships behind the budgets and standards are correct. Next we turn around and accept the results in order to question the budgets and standards. This type of analysis, known as Bayesian, marries managerial intuition to objective analysis and in this sense subjects managerial judgments to statistical validation sequentially. So back and forth we apply Steps 2 and 3 and get better and better feel of the situation.

I must also add that this system has memory. It does not close out the variances to the Income Statement or anywhere else and forget them. On the contrary, the cumulative memory of the information system is brought to bear on each and every observation, and the system sequentially converges on the most probable levels of performance.

4. Analyze the Causes of Variations in Performance. The next step is to subject the "accounting variances" to statistical analysis of variance. Notice that so far we have been dealing with individual observations, budgets and standards, although all these may have been aggregated. While it is true that we have provided in the system for sequential tests, the latter were not applied to groups of observations or to the components of the aggregates, to determine if there are any differences among them and establish patterns of performance. To elaborate a little further, suppose that for a given department we observed a variation from expected performance $\dot{v}$, the system as described up to Step 3 will then determine how probable it is that v was caused by chance alone. It will also check on the alternative standards to reassess their applicability in the light of the new information provided by operations. There is nothing to guarantee, however, that within the department there are no significant differences in the performance of groups which in the aggregate are

canceled out. This is very relevant information for managers. It is also important to observe how the performance of the subunits within groups changes over time (accounting period by accounting period). So we apply statistical analysis of variance to the output of the accounting process.[8]

In addition to a comparison of the performance (a) among various subunits within a group or department for an accounting period (week, month, etc.) and (b) of the various subunits over several accounting periods, the statistical analysis of variance provides us with tools to establish elementary cause and effect relationships. And this because part of this analysis is the explanation of the components of the total statistical variance, that is to say, an explanation of how much of the variability can be explained by the various causal factors.

5. Introduce the Cause-Effect Relationships Into the Information System. Once we derive elementary cause and effect relationships which are statistically significant, then naturally the next step is to introduce them into the continuous information system of the firm. This is a significant development and the birth of

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[8]The proof that this can be done, with an illustration, can be found in: Zenon S. Zannetos, "Toward a Functional Accounting System: Accounting Variances and Statistical Variance Analysis", Industrial Management Review, Volume 7, Number 2, Spring 1966, pp. 71-83.

what I elsewhere chose to call a "functional accounting system".[9] By means of this system we can: (a) learn about the consequences of alternative plans, decisions, and actions, once we establish their impact on the various independent variables that enter into our functional relationships; (b) carry out the implications of observed variations in the causal variables; and (c) generate better data for evaluation of the performance of those in charge of operations. In other words, through these capabilities of the information system, the managers will not only be relieved of reviewing a lot of unnecessary information, but will also get plenty of help from the information system in establishing the meaning of what has been singled out for their attention. They will be given an explanation of what caused what part of the variability, and a projection of its consequences. In fact, especially if the relationships occur with time lags, the system can revise the operating plans and budgets of subsequent operations if necessary.

Such an analysis as described above, will aid managers in evaluating the performance of their suboperations because it will separate the part of variation in performance that is

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[9] I chose this term because of the functional relationships that are stored in the accounting system. In reality it is a functional and probabilistic system.

caused by: (i) pure chance, (ii) factors controllable by those in charge of the operations, and (iii) factors which originate outside and therefore are not directly controllable by the unit whose performance is studied.

6. Measure the Interrelationships Between Units. The statistical analysis of variance generates some information which will be wasted if it is applied solely at the unit level. We notice that among other things it could tell us what percentage of the variation in the performance of a unit is caused by forces that are beyond its control. Some of these forces originate within the company but in other subentities than the one whose performance we are analyzing. If we could somehow measure and analyze the forces which cause interdependencies in the performance of units, we would then be able to coordinate the activities of these units for greater total efficiency. So the question is: How are the various units interrelated? That is to say, how and why do they affect each other?

One measure of such interrelationships is given by the statistical covariance. As the name implies, this measure gives us information on how things vary together. The necessary inputs for this analysis are the same raw data we used for the other analyses.[10] So this is, in effect, another step toward

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[10] The statistical variances are components of the covariance.

intelligent use of the information, and a very significant one, because now we can derive cause and effect relationships among units.

The information generated at this step can be used to facilitate (a) planning, (b) evaluation of performance, and (c) redesign of the organization structure of the firm. Why this information facilitates planning and evaluation of operations should be obvious from our previous discussion. Not so obvious, perhaps, is the third claim, that the system provides information for restructuring the organization, so let us deal with this aspect briefly.[11]

First of all, we know that all the operations within the firm are interdependent, otherwise they should not be under the same roof. We also know that the organization structure with its particularities of relative centralization and decentralization creates an artificial partitioning of the total firm, or a mock independence for the various subunits to help them plan and operate in the short run. This configuration is just a means to an end, and should not be permanent. The above analysis,

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[11] Those interested in pursuing this topic in more detail may wish to read: Zenon S. Zannetos, "On the Theory of Divisional Structures: Some Aspects of Centralization and Decentralization of Control and Decision Making", Management Science, Vol. 12, No. 4, December 1965, pp. 49-69; and Measuring the Efficiency of Organization Structures: Some Implications for the Control System of the Firm, M.I.T. Sloan School of Management Working Paper, No. 117-65.

accepting these premises, asks: On the basis of present cause and effect relationships, are the existing buffers between subunits as well as the number of subentities necessary, or did they become ends in themselves?

The analysis of covariations gives us indications as to how the subunits are interrelated in terms of the dimensions we choose to measure. Are they, for example, reinforcing (positive covariation) or offsetting (negative covariation) each other? Are these relationships symmetrical or are there asymmetries for variations above versus below expected levels of performance? How do variations at the subunit level affect the total organization?

A study of the covariances can give us a lot of help in understanding these forces and how they relate to the total within the firm. Negative covariances normally indicate the need for centralization. The cause of negative covariation in these cases is the use of a common resource which is dominant and critical for the operations of the units that are related in this fashion. If, therefore, these units are allowed to plan on a relatively decentralized basis then of necessity they will create a lot of unnecessary excess capacity and slack in the system to buffer their operations. The remedy here is joint planning and relative recentralization to eliminate the slack. Mere increase in the flow of information between the units will not be sufficient in this case, because what is necessary is

flexibility for fast deployment of the critical resources. If, however, we obtain negative covariations with one variable lagged, then information transmission may be sufficient depending on whether the lead time provided by the faster transmission of information is sufficient to allow the second unit to replan and shift the necessary resources.

Positive covariances (both units moving in the same direction up and down) normally indicate a need for neutralization by separating or buffering the related units. The organizational changes that take place in such cases lead toward relative decentralization. The assumption, of course, here is that whether the movements are up or down they are harmful to the total operations when units are coupled together. If asymmetries exist in the consequences of variations, that is to say, if a variation above the planned level for unit A forces a similar variation for unit B and no harm and wasting of resources occur, but a variation below for A causes the same for B and a lot of harm ensues, then appropriate information filters and capacity or time buffers can be introduced to utilize the beneficial influence but eliminate the destructive.

Once we analyze the covariances and their components (variances and correlation coefficients) we will obtain clues (a) on the type of functional relationships among units that need to be stored in the system, and (b) whether time lags are necessary. These characteristics will further improve the planning capabilities of our information systems and for the

first time we will be able to obtain as part of the routine flow of information with the firm, signals for assessing the efficiency of organization structures. What is more, with the introduction of time lags, our information systems more and more become prognostic in nature.

7. Expand the Analysis of Covariances. By encompassing larger and larger units in our analysis, we can expand our investigation to the total organization. We can, therefore, introduce into the managerial information system functional relations of greater and greater applicability. We can also expand this analysis over a greater and greater span of time if it is necessary to obtain prognostic indicators. Once obtained, of course, all these relationships are made part of the information system of the firm.

It must be mentioned in conjunction with variance and covariance analysis, that we are not dealing with deterministic cause and effect relationships. We are not completely sure whether what we have is fundamental and not accidental. This much must be realized and conceded. However, if the system allows flexibility and checks sequentially to find better and better solutions, we need not worry excessively about these shortcomings.

The advantages on the other hand of the system that I sketched here are many.

(i) It is inexpensive. It mostly operates on sampled data. In many respects this system is less expensive than the current accounting systems for low level operations.

(ii) It is probabilistic and naturally provides more meaningful information for managerial decisions. It sifts through the generated data and singles out only what is important to merit executive attention. The decision rules applied by the system can be those used by the executive. Therefore, it provides a real management by exception.

(iii) It stores cause and effect relationships, uses them for evaluation, planning and operating decisions, and adjusts them step by step as new information is introduced. In this sense it provides a lot of the necessary information the executives need before they take efficient remedial action.

(iv) It can be applied at any level and expanded. It takes things as these are, and sequentially asks: Can we do better? It is not an attempt toward an overall analytical optimum which I am convinced we cannot achieve. It uses optimization techniques for subparts as needed and also simulation, but it is neither.

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(v) The analysis of covariances points out the most sensitive spots in the organization. This information is not only important for problem identification purposes, but also for seeding innovation. Innovative capabilities are very scarce. Instead of encouraging innovation at all levels within the organization, it is not unreasonable to choose a few units to concentrate our efforts and let the information system through the cause and effect relationships spread (force) innovation all through the firm. What I am suggesting in effect is to exploit the "gravitational forces" within the firm to accomplish our goals with the minimum of effort.

(vi) It uses organization structures as a variable or as an input to the system to be manipulated as conditions dictate. This is a very powerful attribute since information systems and organization structures are two sides of the same coin. If one fails the other will too, for there can be no effective motivation under these circumstances. Also, since there is a need for flexibility, so that the information system becomes more intelligent through

experience, the organization structures must be equally flexible.[12] The tools provided here can help us obtain information for possible reorganizations on a routine basis.

(vii) It questions the established organizational buffers and re-examines their value versus the cost of keeping them.

(viii) It incorporates in it behavioral aspects as well as capabilities for design and analysis of experiments.

(ix) It is prognostic.

As I hope you will agree this system goes a long way to aid management in its planning and control activities of both operations and organization structures. It can check on the efficiency of the chosen plans but it cannot generate by itself alternatives and suggest them to management for action on the basis of changes in the planning variables that the information system sensed. For the latter we need advanced associative faculties and capabilities for recognizing patterns about which we do not as yet know very much.

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[12]From a theoretical point of view it appears that organization structures may have to alternate between relative centralization and decentralization. And this because for specialization and innovation we need relative decentralization, but for dissemination and proceduralization of the acquired knowledge we need relative centralization.

Once we succeed in storing into our continuous information system pattern recognition capabilities then we can develop the structure within which plans are made, and from then on be able to control the planning process as contrasted to the control of chosen plans. One way of starting this part of the information system is to store the patterns of environmental conditions and availability of operating capacities which dictate certain plans, as well as the assumed functional relationships which relate them. I am sure you will appreciate that this is not an easy task because of the enormous number of dimensions of these patterns. But if we overcome these difficulties then the indecomposable data of information systems for planning process control will be patterns of relationships and the system can go through the steps we described in Part III to increase its sophistication.

IV Conclusion

I hope that I succeeded in conveying to you the significance of the characteristics of the information systems for the management process. I tried to present to you the many facets of an integrated system which occupies quite a bit of my research efforts. Some of the ideas I presented in my talk I explored rather fully in the past, but many others only superficially as yet. Hopefully some of you and your organizations will in the future devote more of your research efforts in the area of effective managerial information systems for planning and control.

The focus of my attention was mostly on the planning effort of managers because it sets the structure within which decisions and operations take place. That is why I want the information systems to be

intelligent enough to relieve managers of many of their present tasks, as soon as the latter can be routinized or characterized, so that they can devote more of their efforts to higher level and long-range planning. But one may ask: If the system is to relieve managers of the planning tasks they succeed in routinizing, why should they continue doing it? Who wants to deal with the unknown all the time? Planning is not easy!

I am sure you know the answer to the above questions. It is the fate of managers to deal with unstructured situations. Most certainly it is easier to fight fires, count how many you put out and get an immediate sense of accomplishment, than to assess your planning efforts to prevent them. There is no way one can get an immediate indication of accomplishment in the area of long-range planning and this disturbs many people to the point that they favor routine tasks. Managers who complain that routine trouble shooting does not leave them with any time for planning become nervous wrecks as soon as they are given the long sought time and freedom to plan. The turmoil, soul searching, and reorientation is very painful, but the other alternative is abdication. The new managerial information and control systems are with us and we cannot ignore them. The sooner we as managers learn to live with them and exploit their potentialities, the better off we will be in every respect. But there is no sense denying it, it is rough to be a manager. Thank you.

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