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DYNAMICS FOR ESTABLISHING THE FLOWS OF INFORMATION NEEDED FOR EFFECTIVE PLANNING, ADMINISTRATION AND CONTROL *

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Dynamics for Establishing the Flows of Information
Needed for Effective Planning, Administration and Control.

ABSTRACT

Many studies have described the life cycle of an existing management information systems and also have prescribed what it should be. Although there are some differences in terminology and in detail, it seems to be broad consensus that one of the first steps is to determine the information requirements of the users and to quantify what benefits can be expected to accrue from filling these needs and also the costs to be incurred. This need, however, for design of a system to determine and evaluate the information requirements of managers has been overshadowed by the technical problems of hardware-software design and optimization. To redress this imbalance the DEFINEPAC system has been designed. This paper reports some early research results of the DEFINEPAC system. The system tested a design for ascertaining and evaluating the information requirements for ill-structured and "wicked" problems of "Management Planning and Control." In the pilot study the system was 17% more effective in ascertaining information requirements than classical method. Moreover, parallel application of the system to several managers having like responsibilities permitted a further 19% improvement.

Dynamics for Establishing the Flows of Information
Needed for Effective Planning, Administration and Control

1. INTRODUCTION

Many studies [4,5,6,10,] have described how the life cycle of a management information system does or should proceed. Although there are slight differences in terminology and in detail there seems to be broad consensus that one of the first steps is to clarify exactly what are the requirements of users and to quantify what benefits can be expected to accrue and costs to be incurred from filling these needs.

A literature search convinced us that the research resources devoted to the various steps of technical systems design and implementation (which follow this initial requirement's analysis), vastly exceed those committed to trying to improve the processed whereby user needs are perceived, specified and evaluated. By the dame token we found that managers tend to complain far more about the ineffectiveness of their MIS support than about its inefficiency. This complaint, moreover, has been fairly well documented [19].

On this basis we launched, in 1972, a concerted research effort to improve the tools available for use in this important but under-researched phase of systems analysis. Four major problem areas were soon found to be of paramount importance:

1. Techniques for documenting requirements in a way which would not preempt critical design choices appropriately part of the implementation process.

2. Techniques for quantifying the benefits which would accrue if suggested system improvements were implemented.

(Such evaluations are essential to the subsequent processes of cost-benefit analysis, project selection and--upon acceptance--project prioritization).

3. Techniques for providing overall structure to the requirements study itself.

4. Techniques for managing the details of analyst-user interviews, to improve communication and thereby raise the probability that all needs would be discovered and accurately described.

The first of these problems (the appropriate problem statement language) has been the subject of intensive research in project ISDOS and elsewhere. These results are well summarized by Teichroew [27].

The second of these problems (practical information evaluation) is the subject of an extensive research effort we are presently conducting. The preliminary highlights from that study are briefly reviewed in section 3 of this paper because they are pre-requisite to an understanding of the research findings we wish to report in section 5.

The third of these problems (the overall structuring of the information requirements analysis) has been under-researched [15,18] and is presently the subject of further research involving the field-testing of a radically improved version of those procedures. But any significant gains in the overall management of projects intended to analyze information requirements must begin with a better understanding of the detailed processes by which individual analysts can go about the task of learning the needs of individual users. Understanding the building-block is pre-requisite to designing the wall.

This, then, is the subject of the research we wish to report here.

In the next section we address and reconcile the fundamental dilemma which has hitherto bedevilled attempts to structure both the total requirements analysis process and its detailed user interview components. In section 3 we delineate the practical approach to quantifying prospective benefits used in our study. In section 4 we describe the pilot study itself. And in section 5 we review its detailed findings. The conclusions which they support may be briefly summarized as follows:

1. It is, indeed, true that simply asking users what they need is an extremely inefficient and ineffective way of discovering their requirements.

2. It is, indeed, possible to adumbrate a model to help give form to the analysis of ill-structured problems _without_ forcing them into a simplistic and pre-conceived mold. Such a model, however, _will_ help trigger the memory and aid users in organizing the specifications of their information requirements.

3. It is, indeed, possible to have users place a value on alternative MIS service levels despite the fuzziness of their problems and the decision procedures they follow.

4. In interviewing decision-makers, worthwhile improvements can be gained by interviewing several people about the same topic; though there would be considerable overlap between their suggestions but what one forgets another may well recall and elaborate, and the process can be justified at a certain level of cost.

2. THE FUNDAMENTAL DILEMMA OF INFORMATION REQUIREMENTS STUDIES.

There is a great deal of variety in the ways analysts go about the business (macro and micro) of determining information requirements. Miller [20] makes a fundamental distinction between those who ask their clients (his "research" approach) and those who employ "expertise" and tell them what they need. As we shall see, the matter at issue here on the micro level is essentially the same as that behind the macro level controversy as to whether requirements studies should proceed "top down" or "bottom up" through the organization.

During the first phase of their development, data processing systems were primarily concerned with achieving cost reductions through clerical savings. During this phase the expertise of the methods and procedures analyst was an effective source of requirements specification.

More recently systems improvements have been addressed primarily to the area of operational control--production scheduling, routing problems and other logistic applications such as inventory control. During this phase the requirements specifications have generally originated from the expertise of analysts familiar with the models and decision algorithms of management science.

But today the potential gains from developments of these earlier types are very largely exhausted and now there is a pressing need to supply better information systems support to those more senior levels of management with responsibility for ill-structured problems.*

*Sprague [25], following Gorry and Morton [14], points out that ill-structured problems can also be encountered at fairly low levels of management.

And it is here that we encounter a fundamental dilemma. On the one hand, as Ackoff [1] has pointed out, simply "asking" these managers what they require will not work because the underlying assumption that, unaided, they know their own information needs is demonstrably false (the reservation of Rappoport [22], notwithstanding). But on the other hand there is no ready and obvious way to use "expertise" to specify their needs for them since, by definition, ill-structured problems are amenable neither to modelling nor to algorithmic solution.

A number of attempts have been made to resolve this dilemma but none seems altogether satisfactory. Orden [21] and Chadler and Nador [9] take what is essentially the same approach as the old methods and procedures experts (though in modern guise). They base their process on the analysis of present forms and reports. We have shown elsewhere [16] that effective reporting design must be based on the <u>purpose</u> the reports are to serve rather than the procedures for generating them; we would also stress that reports specification is only a very small sub-set of MIS requirements analysis. Taggart [26] bases his approach upon a textual analysis of job descriptions; but these are notoriously unsatisfactory and, at any rate, give only the sketchiest of clues as to what information is needed to carry out these responsibilities effectively. Burns [8] has used what is essentially a time-diary approach; but this overlooks those problems which are important but infrequent and again describes responsibilities rather than the essential issue, the information needed to cope with them effectively. Blumenthal [6], Zani [28] and

Glans et.al. [13] base their approach upon a "top down" chain of deductive means-end inference from the goals, objectives and major programs of the organization; but this approach is so vague and general that it is tantamount to simply asking executives what they want. On the other hand the operations research approach is to use a decision model preferably mathematical, and then derive information on parameter values. However, this approach is very unsatisfactory for unstructured problems.

By contrast, we assume that effective inquiry requires a structured set of cues to trigger memory and to focus managerial attention. Unstructured inquiry may elicit good suggestions but these will be so far from exhaustive that the resulting MIS will be of marginal value. The dilemma we must resolve, then, is to model the "unmodellable".

Conventionally the quality of a model is judged primarily by some measure of correlation between predicted and actual behavior; and parsimony as a secondary consideration. The normal approach to modelling extremely complex systems is to restrict the variety of performance characteristics which the model seeks to predict whether by excluding "irrelevant" variables from attention or by use of homomorphic aggragations (an extreme case is Keynes' [17] four-variable model of the economy). To apply this philosophy to the study of information requirements for ill-structured problem solving, however, is extremely perilous for there is every likelihood that important variables will not only be overlooked by the model but that the ommission will pass unnoticed because the model--as a self-fulfilling prophecy--has implicitly declared them "irrelevant".

The last thing the requirements analyst can afford is to be parsimonious in his survey of possibly valuable information.

Economize he must, however, if his study is to be kept within manageable bounds. The approach we take, therefore, is to minimize the effort devoted to specifying the relationships between variables. Normally a model requires closed-form functional specification of all relationships. Economists, using the "comparative statics" approach, have been successful in reducing this requirement--without total loss of utility--to mere specification of the signs of all partial derivatives. We propose that for information requirements analysis it is possible and desirable to go yet one step further: all that is needed is an incidence matrix indicating which input variables are (somehow) relevant to decisions about output variables.

Following this philosophy, we have derived the model illustrated in fig. 1 as a general but unrestrictive framework for our interview protocol. Given a knowledge of the activities and resources for which a manager is responsible, we follow the philosophy of Forrester's Industrial (or Systems) Dynamics [12] in asserting that decisions should be made about each of the flows indicated in fig. 1 and only about these. We use this simple framework for assuring that the analyst, when interviewing each MIS user, has an exhaustive agenda of all required decisions in need of informational support. However, the costs and benefits of exhaustive agenda should not be lost sight of. The analyst then works with the manager to model his system in the greatest complexity possible in terms of situational and internal variables considered as candidates for inclusion.

But he works in the greatest simplicity possible in terms of the specification of their precise interrelationships.

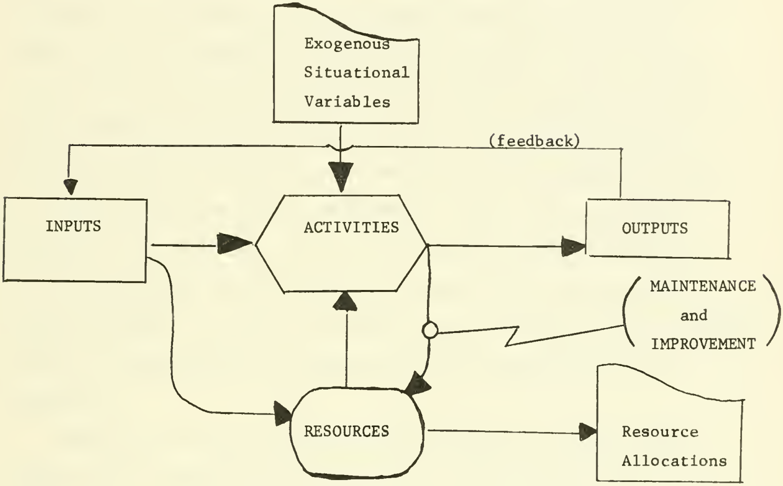

Fig. 1 Framework for decision modelling

A pilot study test of this approach is discussed in section 4 and 5. But before reviewing these we must first digress briefly to consider the measurement of information value since this is central to the interpretation of our results.

3. A PRACTICAL APPROACH TO INFORMATION EVALUATION

Such properties as timeliness, relevance and accuracy help to make information more valuable, and direct mapping from measures of these properties to an indicator of dollar value is possible. There seems, in fact, to be fairly general consensus that information having above properties obtains its value from the improvements in decision making which it causes and that its value is to be measured by the incremental profits (or other indicators of goal accomplishment) caused by these improved decisions. In estimating the value of proposed new types of information the approach generally taken (see, for instance, [11]) is some variant of Bayesian analysis. In order to estimate the data required for this approach a number of authors (see, for instance, [7]) have proposed the use of simulation.

Despite its obvious intellectual appeal we have found this approach pragmatically infeasible for three reasons. First, as Ackoff [2], Simon [23] and Anthony [3] have pointed out: information is not merely used for decision-making, it is also used for such diverse but important activities as training and motivating subordinates, problem-finding and strategic policy-setting; and there is no <u>direct</u> linkage between messages and performance in any of these cases since the relationship proceeds via complex chains of intermediaries and takes the form of a distributed lag function. Second, many of the more important uses of managerial information are related to ill-structured problems which are not well enough

understood for Bayesian modelling and simulation. Where simulations are forced on such situations they distort and simplify reality to the point where their results are invalid for information requirements specification. Third, in managerial information systems of realistic complexity the same information is typically used by several managers and is, moreover, used by each for several different purposes. And to confound matters still more, each element of basic data will typically give rise to several elements of disparate information as a result of different types of processing. Coping with this complexity requires a far more elaborate form of classificatory model than has heretofore been proposed.

Our approach is less intellectually appealing and is clearly in need of empirical testing (to which we are presently submitting it). But it is, at least, pragmatically implementable. Basically, its motivation is as follows. We assume that managing and decision-making are, on the whole, more important and demanding than data preparation. Therefore wherever it is appropriate to entrust decision responsibility for ill-structured problems to the intuitive skill of managers, we believe it is *a fortiori* appropriate to trust the judgement of these same individuals in evaluating their actual and potential supplies of information. To do so, however, it is necessary to remove bias and to reduce all such appraisals to a common scale of measurement. And it is necessary to gather these appraisals in a sufficiently complex web to be able to evaluate the separable parts of a proposed system as well as its totality.

In reviewing the use to which these appraisals are put, however, we conclude that relative rankings--rather than absolute measures of dollar value--will generally suffice. This is so because most organizations are constrained by shortages of skilled systems people and implement only a fraction of the feasible and cost-effective systems proposed to them. A knowledge of absolute value is needed to determine the optimal cut-off point in an unconstrained situation; but relative rankings suffice under a situation analagous to capital rationing.

Consider, first, the problem of evaluating the information supplied to a single manager. In appraising his information needs we begin with a list of the decisions for which he is responsible. To evaluate the relative importance of the information elements which serve him we simply ask the manager to rate each of his decision-types (on any arbitrary scale; say 1-9) in terms of its importance to the overall success of his job tenure and contribution to his organization. We check to ensure that these ratings take due cognizance of the varying frequencies of occurrence of the different types of decision (scaling the initial ratings by relative frequency if this factor has not been properly considered). Then we normalize these ratings such that the normalized factors (across all frequency-adjusted decision types) sum to unity. Next, we systematically review each decision type and list all information elements which would contribute to its effectivenesss. In order to evaluate information, at this juncture we simply ask the manager to rate the importance of the contribution of each information element to the decision under review (again on any arbitrary scale). Once again we normalize so that the

rankings of all information elements for any given decision sum to unity. We are now in a position to evaluate the contribution of each element to each decision as the product of the normalized weight of the decision and the normalized weight of that information element respectively. And in cases where the same information is used in more than one decision we simply determine its overall utility by summing the values of its several contributions as thus determined. From the above, of course, it will be apparent that the total value of all information elements used by this manager is neccessarily unity. In this sense, we have avoided bias and have introduced consistency.

For purposes of the present study it is not necessary to consider a technique for comparing information value across users. Suffice it to say, then, that we have devised a recursive procedure whereby the superior of the base decision-maker rates each of the subordinates and personal decisions for which he has authority. After normalization we can then determine a weighting factor to scale down the information value of any given subordinate. Worked recursively up the organization to the chief executive the end result of this process is a system such that the sum of the values of all information elements is unity and that the distribution of this value can be identified: by decision-maker, by decision type or by information element or sub-element.

Since we were dealing with single decision-makers in our pilot study, only the first part of this procedure (excluding the recursive scaling) was used.

Mathematically, the process can be described in the following way:

Suppose there are "m" number of factors (or pieces of information or data) that are affecting all the decisions of the organization; $f_1, \ldots, f_m$.

Suppose there are "n" number of decisions made in each department or organizational sub-unit; $D_1, \ldots, D_n$.

Suppose there are "r" number of organizational sub-units or departments in the system; $d_1, \ldots, d_r$.

Then in general f_{ijk} denotes, information element 'i' affects (or is needed for) decision "j" in department 'k' where

$i = 1, \ldots, m$

$j = 1, \ldots, n$

$k = 1, \ldots, r$

Let 'σ_{jk}' represent the frequency of decision "j" in department "k".

Let 'α_{ijk}' be the importance (rank) of factor 'i' in decision "j" in department "k".

Let "β_{jk}" be the importance (rank) of decision "j" in department "k".

Let "γ_k" be the importance (rank) of department "k" in the system.

Then the importance (rank) of factor "f_{ijk}" for decision "j" in department "k"

$$= \tilde{\alpha}_{ijk} \, (\tilde{\beta\sigma})_{jk} \, \gamma_k = \Omega_{ijk} \qquad \text{where } \tilde{\alpha}_{ijk} = \alpha_{ijk} / \sum_i \alpha_{ijk}$$

$$\text{and } (\tilde{\beta\sigma})_{jk} = \beta_{jk} \sigma_{jk} / \sum_j \beta_{jk} \sigma_{jk}$$

Therefore, the importance (rank) of the information element "f_i" in the total system

$$= \sum_{k=1}^{r} \sum_{j=1}^{n} \left(\tilde{\alpha}_{ijk} \cdot (\tilde{\beta\sigma})_{jk} \cdot \gamma_k \right)$$

$$= \sum_{k=1}^{r} \sum_{j=1}^{n} \Omega_{ijk}$$

$$= \nu_i \text{ (say)} \qquad i = 1, \ldots, m$$

From the preceding equations, it is apparent that $\Sigma\mu_i$--the total importance of all information elements summed--must equal unity times the number of departments. From this it follows that each $_i$ is a measure of relative importance. Also the sum of the values of those information elements now provided can easily be interpreted in terms of efficiency in meeting total (ideal) information needs.

Thus, the process allows us to arrive at the importance index (μ_i) of all factors (information) we need to keep in the MIS. Depending on the budgetary constraints and the computed ranks of all the information elements, the inclusion or exclusion from the data base of MIS may be determined.

4. Pilot Study

The School of Management of Case Western Reserve University was the organization selected for our pilot study. Partly, of course, this was for the sake of ease and economy. But the main reasons were: first, that the problems of department chairmen are quintessentially ill-structured in nature, second, that there are five such chairmen each with essentially similar responsibilities (thereby permitting some very modest statistical testing) and, third, that these chairmen are an abnormally sophisticated group of managers who would be unusually skilled in articulating their information needs and therefore more likely to confirm the null hypothesis that our protocol is no more effective than a conventional interview.

Our test consisted of three parts. First we identified the present flows of information (initially by reference to the administration of the school, subsequently by follow-up with the chairmen themselves) and we asked each chairman for criticisms and suggestions in the conventional manner. Next we ascertained the activities and resources for which these chairmen are responsible (initially by reference to department members, subsequently by follow-up with the chairmen themselves) and we used these decisions as a basis for obtaining further suggestions from the chairmen of their information requirements. Finally, we collated our results, reviewed them with each chairman and had him evaluate not only his own suggestions but also any information requirements suggested by any of his colleagues but initially overlooked by him.

These steps, when told simply, sound like a rather negligible piece of work. In practice we found it quite difficult and time-consuming even to discover what reports were presently available. The analyses of activities and resources were even more onerous. Many hours spent with each chairman in discussing the decisions for which he was responsible; and still more hours in exploring what information would be helpful in each of these cases. Ultimately some eighty-eight items of information of one type and another were found to be of value.

5. PILOT STUDY RESULTS

The findings of this study are summarized in table 1 (which has data for only four of the five chairmen since one, being away on sabbatical, proved unavailable for participation).

To help the reader grasp the significance of this table we will explain how it was prepared.

At the final round of interviews each chairman subjectively assessed the importance and frequency of each type of decision made by him. Then, for each decision, he subjectively evaluated the contribution to its effectiveness that would be made by any of the information elements proposed from any source as being useful in that context. To prepare the table we first normalized these ratings assuming independence so that all information use-values by information element and summed so that we knew the total value across all its various uses of each of the eighty-eight information elements which had been cited. Then, for each chairman, we sorted the information elements into categories indicating when and how their usefulness had first been recognized by him. These values are entered in table 1; certain averages and percentages have also been added to clarify our conclusions.

In column 1 are listed the totals of the subjective values of all those items which are covered by the present reporting systems. On average the subjective value of these, it will be seen, amounted to only 64.3% of the values of all information ultimately discovered.

In column 3 are listed the subjective values placed on those items not now reported but suggested by the chairmen when they were asked to criticize present systems--in the manner of the classical interview technique ("what extra information would you like?"). These unguided suggestions were the source of a 12.6% improvement.

In column 5 are listed all <u>further</u> suggestions which resulted from the interviews we conducted on the basis of the protocol developed in section 2 following the framework ther depicted as fig. 1. In these

Table 1.

SUMMARY OF THE PILOT STUDY RESULTS

(assumes linearity and unity of scale)

Dept.	Rank-Sum of Currently Available Information	Rank-Sum of Inf. due to classical interview method	Improvement due to interview method over inf. inventory method	Rank-Sum of required inf. due to solo DEFINEPAC	Improvement due to solo DEFINEPAC over inf. inventory method	Improvement due to solo DEFINEPAC over classical interview method	Improve- due to pooled DEFINEPAC over inf. inventory method	Improvement due to pooled DEFINEPAC over classical interview method	Improvement due to pooled DEFINEPAC over solo DEFINEPAC
	1	2	$3 = \frac{2 - 1}{1}$	4	$5 = \frac{4 - 1}{1}$	$6 = \frac{4 - 2}{2}$	7	8	9
1	0.64	0.64	0%	0.7613	0.19=19%	0.19=19%	0.563=56.3%	0.563=56.3%	0.341=31.4%
2	0.613	0.712	0.162=16.2%	0.868	0.42=42%	0.22=22%	0.631=63.1%	0.41=41%	0.152=15.2%
3	0.72	0.832	0.16=16%	0.933	0.30=30%	0.121=12.1%	0.39=39%	0.2=20%	0.072=7.2%
4	0.6	0.71	0.183=18.3%	0.814	0.36=36%	0.15=15%	0.67=67%	0.41=41%	0.23=23%
Average	0.643	0.7235	12.626%	0.844	31.75%	17.03%	56.35%	39.58%	19.2%

interviews, that is to say, we first identified needed decisions from an analysis of resources and activities and then we enquired as to the information needed to support each of these decisions. By now, of course, it was becoming much more difficult to discern unfilled needs since the existing reports and the unguided suggestions should, presumably, have unearthed all the more obvious requirements. Despite this heightening difficulty, however, it is interesting to observe that our protocol not only produced new insights but that these actually had a greater incremental value than those disclosed by the unguided interview--17.0% verses 12.6%; this difference, moreover, proved statistically significant at the .01 level on the basis of a paired test the details of which can be found in [18].

From column 4 of the table it will be noted, however, that even after this last interview, the average of the aggregate information value of the requirements discovered from all three sources (the existing reports plus the classical unstructured interview plus the interview shaped by our DEFINEPAC protocol) ammounted to only 0.844. The remaining information elements (with an aggregate use value of 0.156) owed their discovery to the pooling of ideas across the four chairmen. From column 4 it will be observed that some of our subjects were more productive than others: chairman 3, for instance, came up with 93.3% of his requirements from his own interviews alone, whereas chairman 1, came up with only 76.1% of his needs and picked up the remaining 23.9% from his colleagues.

Ignoring these interpersonal differences we have developed a naive sequential-sampling type model* of this discovery process which fits the data of this pilot study tolerably well, as reported in [18]. This model suggests that wherever a group of managers have similar and interdependent responsibilities it will be worthwhile to interview several; but diminshing returns set in fairly rapidly and it will not usually be worth interviewing all of them. In our pilot study, for instance, if the fifth chairman had become available we should have expected him to contribute rather less than a 1% gain to the overall discovery of information requirements.

Two further conclusions, though somewhat subjective in nature, deserve reporting. First, when we were assembling samples of the present reporting system we found that chairmen could not, in fact, name all their present information supplies. Given the volume and heterogeneity of these reports this is scarcely surprising. But it does highlight the need for a structured framework in any interviewing process. That the framework we employed was, indeed, highly productive is clearly indicated by our results; but there still remains the possibility that our "modelling of the unmodellable" failed in its attempt to avoid construction. Did our interviews force a well-structured mold on what are really ill-structured problems? In

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* We are in the process of refining this model to allow for interpersonal differences in serendipitous ability. After testing we hope to be able to report its application to committee problem-solving as well as to information requirements analysis.

denying this charge we must resort to a second--highly subjective--conclusion. On examining the list of information requirements finally discovered we were very struck by the wide variety of their coverage (they included data about such obvious topics as student enrollments, school budgets, faculty publication lists; but they also called for demographic data about alumni, personal data about trustees and a variety of other useful but surprising topics). We have been unable to quantify this impression but are convinced by its qualitative and subjective "feel" that our protocol did <u>not</u> act as a straightjacket.

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