The Use of Multilevel Models in Information Evaluation

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<CONTENTS>

A broader perspective on the use of models to evaluate information systems is presented. A multilevel model is used to distinguish the value of information given a formulated problem from the impact of information in the formulation of a problem. At the formulated problem level, statistical decision theory is extended to allow for act dependent states of nature and uncertain outcomes. At the problem formulation level, meta decision theory is introduced as a measure of changes in the decision maker's views-of-the-world. The impact of information at these two levels of the multilevel model are seen to be fundamentally different and cannot be summed as a total effect. A new evaluation technique that includes the larger process of inquiry, as the context of the information system, is called for.

Introduction

The need for information system evaluation is well established in accounting thought.

> Much, if not most, accounting research is aimed at some facet of the general problem of determining what information should be supplied to a particular decision maker in a particular decision context. Broadly viewed, this is a choice (or decision) situation, and the research in question is concerned with ultimately discovering the "optimum" set of information for the particular decision setting. [Feltham and Demski, 1970, p. 623]

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Models for evaluating alternative information systems using statistical decision theory have been developed by Feltham [1972], Demski [1969, 1972], Feltham and Demski [1970], and others [Demski and Feltham, 1972; Marshall, 1972; Mock, 1971; Raiffa and Schlaifer, 1961]. Mock [1971] has criticized that work as focusing on a narrow aspect of the total decision makin process (the choice of actions given a well formulated problem), with a narrow concept of information (the revision of state probability estimates).

This paper concurs in Mock's criticism, and explores the implication of taking an even broader perspective on the information evaluation problem. To do so, an information system is here viewed as an inquiring system. The focus is not on the action choice made by a decision maker with a given level of experience in a well formulated problem situation, but on the larger process of inquiry in which new questions are raised, new problems are formulated and old ones reformulated. It includes the process by which the assumptions and beliefs of the manager, in light of his previous exprience and current evidence, formulate, "the problem" about which he will make a decision.

In taking an inquiring system perspective on the information evaluation problem, we are building on the work of C. West Churchman (1968a, 1968b, 1971). His work emphasizes that information has value, as meaning for a decision maker, to the extent that it helps to complete a partial view-of-the-world already held. "Facts" therefore depend on the implicit assumptions of the decision maker. An information system is a valuable part of the inquiry process to the extent that it is useful in exploring and revising these underlying assumptions. This is especially so in that no one view-of-the-world is capable of presenting a universal and exhaustively true picture. Different views-of-the-world set different boundaries as to what is important to take into account, and what is controllable for the issue at hand. Some views-of-the-world emphasize the role of economic forces, others of human emotions, self perceptions, cultural determinism, or individual initiative.

This paper is in four sections. Section one defines the information system user in an organizational context, and distinguishes his action choice given a formulated problem, from his process of formulating a problem. The role of views-of-the-world in this process is given a concrete example. In section two, statistical decision theory, as currently developed, is discussed as partial method for valuing information given a formulated problem. By partial we mean that only situations that assume act independent states of nature and certain outcomes have been fully explored. An extension of statisitical decision theory to allow for act dependent states and uncertain outcomes in the formulated problem is developed.

Section three presents a multi-level model that relates the inquiry process (fomulating a new problem) to the decision process (solving a formulated problem) developed in section two. The role of information in formulating a problem is seen as a change in the decision maker's view-of-the-world. Section four then introduces meta decision theory as a method for evaluating such changes. There we see that the evaluation of an information system at the problem formulation level is *different in kind, not in degree*, from evaluation at the formulated problem level.[1] The role of information as a change in state probability no longer holds, and we must speak of the "impact" of information as conflict generation or conflict reduction, both of which may have a "value" to the decision maker. At the level of problem formulation, a new evaluation technique is called for.

One suggestion for an expanded evaluation is to shift the attention of information system evaluation away from the information (the product) and toward the system (the process). Thus, we propose the need to identify classes of problems which must be addressed by a decision maker, and inquiry processes that are available to address those problems. The modes of inquiry displayed by alternative information systems (defined to include the user as part of the system) in relation to the types of problems that reqeuire formulation, then becomes the basis for evaluating information systems.

This is a tentative and exploratory study that can, at best, hope to sketch out the domain and difficulties of an expanded approach to information evaluation.

1) Lea [1973] argues that the difference between these two levels can be collapsed by simply extending the specification requirements of the standard decision theory framework. It is shown later that such an extension is similar to the combining of multiple individual specifications, and suffers from the same lack of feasibility.

I. The Information System User in Context

A. The User as An Active Inquirer

We begin by making explicit our assumptions about man as an information system user and the organizational context in which he operates. The model of man as decision maker prevailing in accounting textbooks today is one of homeostatic self-maintenance. The individual is pictured as passively accepting a problem situation. With a given level of knowlege and experience, he seeks to close gaps between the desired and the actual state of affairs. The problems he is presented with are primarily well structured, with known problem formulations, known solution methods, and a recognized "best" solution.

Our analysis begins with the assumption that man is active in defining the problems he will address rather than passive in accepting them. As a problem seeker, the individual is an active sense maker as well as a decision maker. That is, he must build an understanding of his situation, as well as exercise that understanding in an action choice decision. From the viewpoint of an actively inquiring or sense making user, an information system is not only a source of stimuli to which he responds with choices, but is also a medium through which he builds an understanding (a personal comprehension) of the organizational reality which lies beyond his immediate senses.

B. the Context for Inquiry

The informatiom system user is situated in an organizational context, and he must make a coherent sense of both social and technical processes as they relate to multiple facets of the firm's environment.[2] He searches for opportunities or necessities to act, designs potential action alternatives based on his understanding of the "reasons why", and chooses from among the alternatives.[3] The problems he confronts range from well-structured to ill-structured. For the ill-structured problem, a proper formulation is not known, a solution procedure is not known, and a "good" solution can not be defined in advance of its development.

2) Anthony's [1965] description of strategic and managerial planning captures this process.

3) Here we are using Simon's [1977] distinctions between Intelligence (identifying the need to make a decision), Design (developing alternative courses of action) and Choice (selection of an alternative).

The organizational functions an information system user must perform include production (basic task accomplishment); maintenance (mediating task and human needs); boundary spanning (obtaining market, social, financial and governmental support for the firm); adaptive (research, planning and coping with change);and managerial (allocating resources, resolving conflicts, coordinating subsystems, and coordinating environmental input and output).[4] The vast majority of these functions involve situations which are ill-structured rather than well-structured, and result in incompletely specified problems.

A difficulty arises as to how statistical decision theory, which assumes well-structured problems, proves useful in evaluating information systems for inherently ill-structured problems. This difficulty is essentially the difference between an open system versus a closed system perspective. In reconciling classic (closed system) and modern(open system) organization theory, Thompson argues that organizations *are* open systems, but are striving to meet an expectation or norm of closed system rationality. Organizations limit the inputs, outputs and processes they will allow, decouple differentiated components as semi-isolated units, and maintain buffers between units to further reduce their interaction. In effect, they formulate a solvable problem through decomposition. As a result, the total uncertainty of the situation is reduced, and a relatively closed system, amenable to traditional rational organization theory is created.

Similarly, the information system user is an open system facing more potentially relevant variables than he can take into account at one time, and facing cause and effect relations and outside sources of change that lie beyond his limited ability to understand. He strives for rationality, however, and artificially closes his problem space to that which can be adequately dealt with by closed system standards of rationality similar to statistical decision theory.[5]

Below we present a simple example to distinguish the closed system decision process from the open system inquiry process. Assume the decision maker is the general manager of a manufacturing firm. He has two subordinates, each with a unique view-of-the-

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4) This framework is in addition to the resource allocation problem typically employed and is based on Katz and Kahn [1966].

5) Cyert and March's [1963] limited search, localized rationally and sequential attention to goals and March and Simon's [1958] bounded rationality are examples of this process of gaining "closure" by artificially limiting the problem space. Lawler and Rhode [1976] also stress the need to meet an "expectation" of rationality in an organization context.

world, acting as advisors in a cost-volume-profit analysis using a standard costing system.[6] He has asked each advisor to prepare a total cost curve based on historical data, to interpret the current period results in light thereof, and to make suggestions for alternative actions he should take. Each advisor has provided the manager with the basis for one formulated problem.

Specifically, advisor number one (w_1) defines the cost curve (TC) for the factory as linear $(TC|w_1)=160+47Q$, while advisor number two (w_2) defines the cost curve as quadratic, $(TC|w_2)=800+31Q+.1Q^2$. At this point, the reasons why they have proposed such different interpretations are not important. It is sufficient that each, looking at the same situation from his unique view-of-the-world, has come to believe that his cost function is the true representation. For his part, prior to receiving the current report, the manager felt there was a .9 probability that w_1 was correct and a .1 probability that w_2 was correct. We will call this his credence level in the two views-of-the-world. Tables 1 and 2 and Figure 1 summarizes the above assumptions. Note that the cost functions proposed by the two advisors did not conflict with each other with respect to the interpretation of the past data (Figure 2), since the standards based on the two views were quite similar.[7] The report of current period activities, however, raises a problem for the general manager. He may choose one advisor over another, or reject both in favor of some third alternative as he actually formulates his problem.

Table 1: Basic Cost Standards

	Standard Cost	Break-even Quantity	Optimal Quantity	Credence Level
w_1	$160+47Q$	40	Unbounded	.9
w_2	$800+31Q+.1Q^2$	51; 149	$100(\pi=\$200)$	.1

Table 2: Actual vs. Standards

	w_1	Actual	w_2
Sales	\$5,610	\$5,610	\$5,610
Cost	5,330	5,380	5,420
Profit	\$280	\$230	\$190
Cost Variance	50U		40F

6) The problem was adapted from a problem suggested by Professors Green and Dopuch.

7) It is a trivial exercise to generate a set of data such that the residual sum of squares for the two models are identical. Therefore, the two cost functions can be assumed to have been estimated based on the same past data.

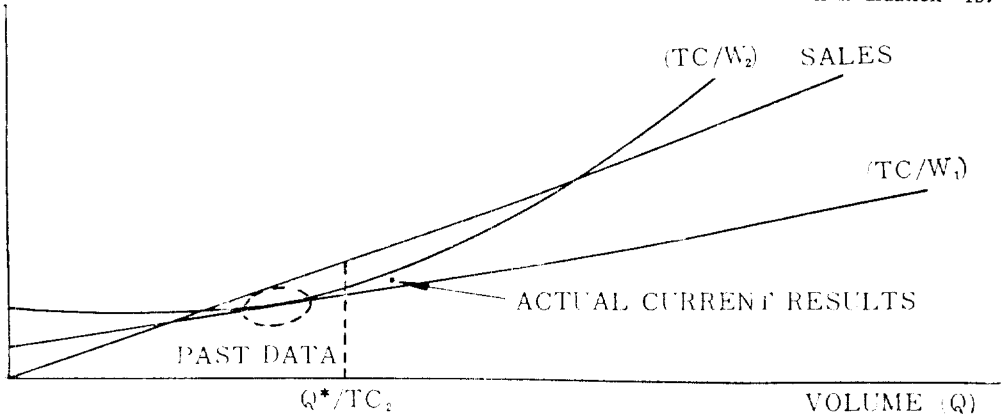

Figure 1. Cost Volume Profit Relationship

Taking the actual performance data as depicted in Figure 1, let us try to infer the "facts" that result from interpreting the actual data with the views-of-the-world presented by the two advisors, separately.

Linear World: w_1	Quadratic World: w_2
(1) The efficiency of the manufacturing department is questionable. An investigate, notinvestigate decision should be made.	(1) The manufacturing department was quite efficient. No need to make an investigate, notinvestigate decision.
(2) The worse than expected profit realized during the period was due to the manufacturing department's inefficiency.	(2) The better than expected profit was due to the manufacturing department's efficiency.
(3) Increased sales and more effective cost control is the means to increase profit in the next period.	(3) Reduced sales, to 100 units, is the means to maximize profit in the next period.
(4) The decision to continue producing this product is dependent upon market demand projections compared to other opportunities.	(4) The decision to continue producing this product is mainly dependent upon the adequacy of the maximum expected profit of $ 200 compared to other opportunities.

Note that the "facts" inferred from the cost accounting report are radically different, depending on which view the general manager adopts. Each set of "facts" constitutes a formulated problem. It is irrelevant which view is the correct one, in fact both of them could be incorrect. We will return for a further interpretation of this example later, but for now the point to be made is this. The evaluation of an information system must not only consider the role of information in revising state probabilities given a formulated problem, but must also consider its role in formulating the problem.

While statistical decision theory as extended in section two provides a means for dealing with either advisor's formulated decision problem, it does not provide the basis for selecting between the two advisors or for inquiring towards a new problem formulation.

Ⅱ. Information at the Formulated Problem Level

Statistical decision theory (SDT) as used in the accounting literature evaluates an information system at the formulated problem level. This section reviews that evaluation process, identifies some technical limitations in the current SDT paradigm, and explores the removal of some of those limitations. In light of the discussion in section one, some conceptual problems in dealing with information value at the problem formulation level are discussed. These conceptual problems are dealt with in section four.

A. Review and Extension of the SDT Model

A general model of a formulated action-choice (AC) problem (within the SDT framework) can be stated as:

$$[A,\ S,\ \Phi,\ U,\ Z|\Omega]$$

where

- $A=\{a\}$ is the set of acts available to the decision maker (DM)
- $S=\{s\}$ is the set of payoff relevant states of nature
- $\Phi=\{\phi\}$ is the set of probability functions
- $Z=\{z\}$ is the set of outcomes, normally defined by the act-state pair $\rho(a_i, s_j)=z_{ij}$
- U is the value system on Z
- Ω is the DM's view of the world based on which the components of the AC problem are specified. [8]

The AC problem is to select an act, $a_i \in A$, such that the DM's expected utility is maximized. [9] In symbols, select the optimal act, a^*, such that

8) Demski [1972] and Feltham and Demski [1970] labeled the set Ω the "level of experience."

9) An expected utility maximizing DM who spends resources to obtain information is assumed in this paper. Other criteria, such as min-max and max-min, can be analyzed within the above structure by supressing certain components.

$$EU(a^*) \geq EU(a_i) \text{ for all } a_i \in A \quad (1)$$

where

$$EU(a_i) = \sum_{s} U(z_{ij})\phi(s_j | a_i)$$ [10]

The value of an information system under a SDT framework is defined as the increase in the DM's expected utility due to his ability to take different acts based on the signals generated by the information system.

Let $a_l^* = a^* | y_l, \eta$ such that

$$EU(a_l^*) = EU(a^* | y_l, \eta) = \underset{a \in A}{\text{Max}} \sum_{s} U(z_{ij})\phi(s_j | a_i, y_l, \eta) \quad (2)$$

where y_l is the signal received from the information system η.

Then, the expected utility of the DM if he chooses to use the information system η is:

$$EU(a^* | \eta) = \sum_{y} EU(a_l^*)\phi(y_l | \eta) = \sum_{y} [\underset{a \in A}{\text{Max}} \sum_{s} U(z_{ij})\phi(s_j | a_i, y_l, \eta)]\phi(y_l | \eta) \quad (3)$$

and the expected value of the information system η is:

$$V(\eta) = EU(a^* | \eta) - EU(a^*) \quad (4)$$ [11]

Then the information systems choice problem is to select the system η^* such that:

$$V(\eta^*) \geq V(\eta_k) \text{ for all } \eta \in H \quad (5)$$

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10) Although the standard SDT framework assumes act-dependent states of nature [Savage, 1954; Raiffa and Schlaifer, 1961], our formulation allows for act-dependent states of nature since some writers in accounting [Feltham, 1972; Feltham and Demski, 1970] have ***partially*** dealt with act-dependent states.

11) Another useful concept of the value of information is called the conditional value of information [Raiffa and Schlaifer, 1961, §4.5.1] and is defined as

$$V'(\eta) = EU(a^* | \eta) - EU'(a_k) \quad (4)'$$

$$EU'(a_k) = \sum_{y} [\sum_{s} U(Z_{kj})\phi(s_j / a_k, y_l, \eta)]\phi(y_l / \eta)$$

where a_k is the optimal act based on the AC problem specification *before* the employment of the information system η:

$$EU(a_k) = \underset{a \in A}{\text{Max}} \sum_{s} U(z_{ij})\phi(s_j / a_i) \text{ for all } a \in A.$$

The major difference between (4) and (4)' is that equation (4) compares the ex-ante, ex-post (before the decision, after the information) measure against the ex-ante, ex-ante measures, while equation (4)' compares the ex-ante, ex-post measure to the ex-ante, ex-post measure. Ex-ante (before the information) values of EU(a^*) and EU'(a_k) are equal. While the expected values of the equations are the same, the formulation (4)' insures the value of "surprise" information to be non-negative. However, since we cannot assess the value of V'(η) before the adoption of a given information system, equation (4) will be used for information systems choice decisions.

where H represents the set of all available competing information systems. If an information system can predict the occurrence of the payoff relevant states with certainty, we call the information system "perfect". The vaue of a perfect information system (η_p) can be calculated as:

$$V(\eta_p)=\sum_{y}(z_*)\phi(y_l|\eta_p)-EU(\eta^*) \quad (6)$$

where z_* is the outcome of the act state pair (a_l^*, s_l),

and s_l is the state predicted by the signal y_l.[12]

The $V(\eta_p)$ is the maximum value of any information system for the formulated AC problem. The measure can also be interpreted as the (opportunity) *cost of uncertainty* in the formated problem. That is, the decision maker "lost the opportunity" to enjoy the utility of optimal acts due to uncertainty of the states of nature.

We can now relax an assumption stated in the standard SDT formulation: certain outcome prediction. Up to this point, we have assumed a homomorphic mapping of the act-state pair into the outcome space (*i. e.*, $\rho(a_i, s_j)=z_{ij}$). In an actual decision situation, this assumption is not likely to hold true (e. g., profit for a given amount of sales). Thus, we let the (a_i, s_j) pair map into the outcome space Z with corresponding probabilities for the elements of Z: $\rho(a_i, s_j)\rightarrow Z\sim\phi(z_k/a_i, s_j)$.

Then the expected utility measures need to be adjusted as given below:

$$EU(a_i)=\sum_{s}[\sum_{z}U(z_k)\phi(z_k|a_i, s_j)]\phi(s_j/a_i)$$

$$EU(a^*)=\underset{a\in A}{Max}\sum_{s}[\sum_{z}U(z_k)\phi(z_k|a_i, s_j)]\phi(s_j|a_i)$$

$$EU(a_l^*)=EU(a^*|y_l, \eta)$$

$$=\underset{a\in A}{Max}\sum_{s}[\sum_{z}U(z_k)\phi(z_k|a_i, s_j, y_l, \eta)]\phi(s_j|a_i, y_l, \eta)$$

$$EU(a^*|\eta)=\sum_{y}EU(a_l^*)\phi(y_l|\eta)$$

$$=\sum_{y}\{\underset{a\in A}{Max}\sum_{s}[\sum_{z}U(z_k)\phi(z_k/a_i, s_j, \eta_l, \eta]\phi(s_j|a_i, y_l, \eta)\}\phi(y_l|\eta)$$

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12) Under an act dependent state occurrence framework, as presented in this paper, the state predicted by a signal may not be unique. That is, it is possible to have

$\phi(s_i|a_i, y_l, \eta_p)=1$ and

$\phi(s_j/a_j, y_l, \eta_p)=1$, yet

$s_i\neq s_j$.

In this case the act state pair that determines the outcome z^* is the pair(a_l^*, s_l) such that

$$\underset{(a, s)\varepsilon(A, S)}{Max} U(z_{ij})\phi(s_j/a_i, y_l, \eta_p).$$

$$V(\eta)=EU(a^*|\eta)-EU(a^*) \quad (7)$$

Equation (7) is more comprehensive than the standard SDT formulation since it incorporates uncertain outcomes as well as act dependent states of nature. Consequently, the problem specification requirements are more extensive. The additional specification requirements include the prior probabilities and the rules to revise them after the receipt of information. Under the standard form the necessary probability distributions are: $\phi(s_i), \phi(y_l|\eta)$ and $\phi(y_l|s_i, \eta)$ and all the necessary probability revisions are performed according to Bayes' rule.[13]

B. Additional Technical Requirements

Under the expanded formulation given above, the specification requirements are far more extensive and the probability revision rules are more complex. Specifically,

(1) The state probability function needs to be specified for each act. In fact, the marginal probability of the states of nature is meaningless under this formulation, since one and only one act is to be selected. Thus we need to specify $\phi(s/a)$ for each $a \in A$.

(2) The uncertain outcome assumption requires the DM to specify the probability measures $\phi(z|a, s)$ for each (a, s) pair in A, S.

(3) The interpretation of the term $\phi(y/\eta)$, can be quite complex. If the information system were to report the observations of past events, the condition probability could be stated as:

$$\phi(y/\eta)=\sum_{\bar{s}}\phi(y/\bar{s}, \eta)\phi(\bar{s})$$

where the $\bar{s}$ is the set of past states.

Note, however, the $\phi(\bar{s})$ is conditional on the past act selected $\bar{a}$. Therefore the entire expression $\phi(y/\eta)$ is conditional upon $\bar{a}$.[14]

If the informatioin system were to report the values of an experiment yet to be performed, then selection of the act (or acts) to be used in the experiment, a_e, becomes

13) See Feltham and Demski [1970, p. 625] for a more expanded illustration.

14) Feltham and Demski [1970] treated the probability measures $\phi(\bar{s})$ to be independent of the past acts. It is difficult to rationalize the act independence assumption for past events when the model calls for act dependence for future events $\phi(s/a)$.

another choice problem and the $\phi(y|\eta)$ is again conditional upon the act selected. The impact of this dependence on the act selected ($\bar{a}$ or a_e) upon the probability revision process is discussed next.

(4) The conditional probability $\phi(s|a, y, \eta)$ needs to be elaborated upon. Let us consider the role of information in revising the act dependent state probabilities. The prior state probability $\phi(s|a)$ reflects two major components: (a) the perceived action effectiveness in inducing the state [Mock, 1971], and (b) the general likelihood of the state occurrence. The DM may find a signal to be informative with regard to the action effectiveness and/or the general likelihood of the state occurrence. Therefore, the revision process of the state probabilities must be able to reflect the potential impacts of information on both components.[15]

Now let us consider the calculation process of $\phi(s|a, y, \eta)$. Without loss of generality, let us assume the information system reports on the past state occurrence $(\bar{s}, \bar{a})$ as described in (3) above. The probability revision can be calculated as follows.

$$\phi(s|a, y, \eta) = \sum_{\bar{s}} \phi(s|\bar{s}, \bar{a}, a)\phi(\bar{s}|y, \eta)$$

$$= \sum_{\bar{s}} \phi[(s|a)|(\bar{s}, \bar{a})] \frac{\phi(y|\bar{s}, \bar{a}, \eta)\phi(\bar{s}|\bar{a})}{\sum_{\bar{s}} \phi(\eta|\bar{s}, \bar{a}, \eta)\phi(\bar{s}|\bar{a})} \qquad (8)$$

where $\bar{s}$ is the past state observed by the information system η and $\bar{a}$ is the act taken in the last period.

The second component $\phi(\bar{s}|y, \eta)$ refers to the accuracy of the observation system η while the first component $\phi[(s|a)|(\bar{s}, \bar{a})]$ refers to the informational impact of the past act taken, $\bar{a}$, and the state resulted, $\bar{s}$, upon the evaluation of the future state probabilities. Schoner [1973] has suggested a means to calculate the revised probabiliy $\phi[(s|a)|(\bar{s}, \bar{a})]$. One crucial requirement is that the DM specify the probabilities of one state (s_j) obtaining under one act, (a_i), conditional upon the knowledge of states (s_j or s_l) obtaining under one or more other acts, (a_k), $\phi[(s_j|a_i)|(s_l, a_k)]$, which he calls *cross-prior probabilities*.

15) Feltham and Demski's formulation [1970, p. 625] did not address the action-effectiveness component, and Mock [1971] labeled it the "Action Effectiveness Value of Information," but did not incorporate it into the decision model.

(5) The uncertain outcome formulation requires prior probabilities on $\phi(z|a, s)$ for the Cartesian product $A \times S$. The impact of information is reflected in the revised probabilities $\phi[(z|a, s)|y, \eta]$.[16] The revision process is quite similar to the state probability revision discussed above, except that the information system observes the outcome $(\bar{z}|\bar{s}, \bar{a})$ along with the $(\bar{s}|\bar{a})$. The information signal then could be thought of as the pair $[\eta(\bar{z}|\bar{s}, \bar{a}), \eta(\bar{s}|\bar{a})]$.

C, Some Reflections

Two points emerge from the above discussion: an expanded view of information system evaluation, and some technical limitations of SDT as a model for evaluating information systems.

(1) Under the expanded formulation incorporating uncertain outcomes and act dependent states of nature, the potential value of information is divided into three components: (a) the outcome mapping of the act state pairs, (b) the action effectiveness evaluation, and (c) the general likelihood of the state occurrence. These components were suggested earlier by Mock [1971], and are formalized in this paper.

(2) To make this model operational, procedures for revising the probabilities, $\phi[(s|a)|y, \eta]$ and $\phi[(z|a, s)|y, \eta]$ are necessary. Unfortunately, standard Bayes' rule does not provide the means for these revisions. In fact, only the act independent and certain outcome cases can be handled by Bayes' Theorem and consequently only the state likelihood component of information can be evaluated under the standard SDT. This problem is a technical one (vs. conceptual) since its solution, once developed, can fit into the basic framework of SDT.

Once the DM specifies all the components listed above, he has a formulated problem. If, however, we admit a question as to what criteria to use in making those judgments, we have a meta decision theory problem. This problem is at the world view level, and is a conceptual rather than a technical problem. It is conceptual in that it lies beyond the standard SDT framework. Information analysis at the formulated problem level, as

16) Mock [1971] called the increase in the expected utility due to the revised outcome probabilities, the "Model Value of Information," but he did not incorporate it into the decision model.

developed above, took place within a given world view (Ω_0). Since SDT assumed agreement on the assumptions behind the formulated problem, we cannot use it to question those assumptions.[17] Type I and Type II errors can be discussed at the formulated problem level only because agreement on the world view is assumed. To question the world view we need to introduce the possibility of a Type III error: having formulated the wrong problem.[18] In order to address this question and the role of information in its resolution, we must appeal to a theory that lies beyond SDT—a meta theory for SDT that evaluates information at the world view level.

The next section presents a model for distinguishing between the formulated problem level and the world view or problem formulation level of information evaluation. It identifies types of information and types of learning processes that must be taken into account in the two levels of information evaluation.

III. A Multilevel Model for Information Evaluation

In order to explore an inquiring systems perspective for evaluating information systems, we propose a multi-level, hierarchical model. It is a four-level representation of the individual information system user that extends from interaction in an organizational context (the lowest level) to the meaning of that interaction for the decision maker (the highest level). He is implementing decisions in an organizational context (level one), through a framwork of attention or a problem formulation (level two) which is developed from the perspective of a world view or his underlying assumptions and beliefs(level

17) To do so we would commit an error of logical types. We would be trying to reconcile two statements—one (s) a statement of a formulated problem, the other (s)' a statement about that statement. To discuss the language of (s) a meta language is necessary. We realize this is a problem without bounds—"There is no ultimate meta language which can comment on the system of relationships, because the mean of analysis—meta language—like the observer, is also part of the system being analyzed." [Wilden, 1972, p. 94] Our purpose is not to resolve the problem of meta languages, but to discuss its implications for evaluating information systems, as the relationship of the world view level to the formulated problem level.

18) We are aware that this terminology is awkward. To be clear about the different "logical types" involved, we should refer to the risk of having formulated the wrong problem as a Type I error at a different (higher) level of generality. We will use the Type III terminology, however, as it has already been introduced into the decision theory literature by Mitroff [1971].

three) in order to gain meaning from, and give meaning to, his experience (level four). The basic model is depicted in Figure 2.[19]

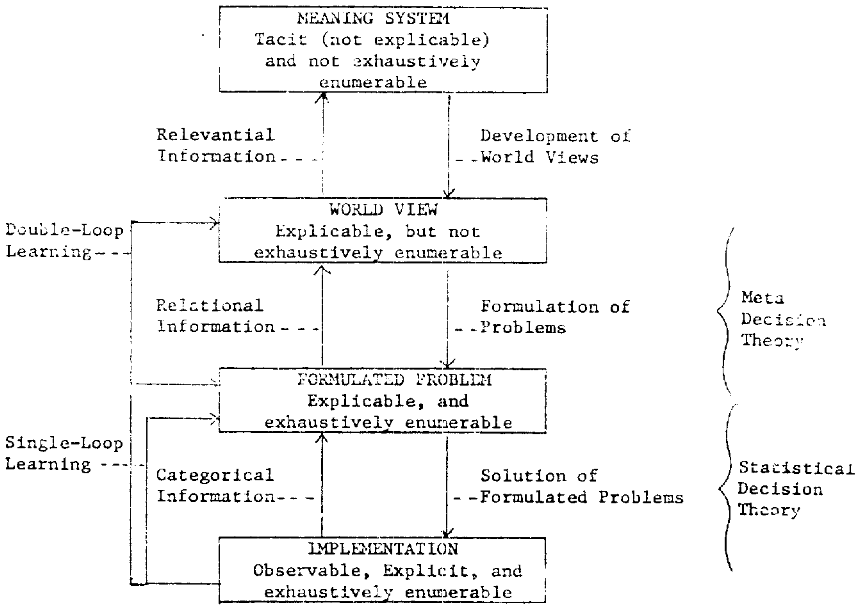

Figure 2. A Multi-level Hierarchical Model of the Information System User From an Inquiring Systems Perspective

The information system user is in the process of interacting with his environment. He is attending to a limited number of elements and relationships in his environment, and interprets the signals he receives through a world view. He makes sense of his situation by identifying the elements and relations to be taken into account (formulating his problem) and taking action in light of what he attends to (solving his problem).

Each higher level of the model becomes successively less available for formalized analysis. First, on the dimension of observability, implementation actions of the information system user are observable, but his problem formulation, world view and personal meaning, are not. Next, while we could argue the ability to exhaustively

19) There are a number of analogous multi-level models to represent the process of active sense making. For instance, Watzlawick, Beavin and Jackson [1969] use a metacommunicative framework, Osgood [1968] uses an encoding-decoding framework, Mead [1934] uses a symbolic interaction framework, Torbert [1972] uses a level of consciousness framework and Messarovic [1970] uses a cybernetic control framework.

enumerate his implementation behavior, or his currently formulated problem, we could not claim to exhaustively enumerate his world view or his personal meaning—at the very least because of their symbolic nature.[20] Finally, while we could argue that implementation, problem formulation, and world views could be stated explicitly, the basis of personal meaning remains tacit.[21]

The model is hierarchical to emphasize the following relations between levels:

1) each higher level serves as a basis for selectively retaining or eliminating data at the next lower level,
2) higher levels are revised in light of feedback from lower levels,
3) lower levels experience change and revision at a faster frequency than higher levels, and
4) as a result, higher levels serve as a source of stability, integrity, or rationality for lower levels.[22]

The model is used as a basis for defining the types of information and learning processes that must be taken into account in evaluating an information system. Our evaluation procedures will only be applied to the two middle levels of the model, the formulated problem and the world view levels. The implementation of action choices and the meaning to the individual information system user will not be evaluated, but are introduced to give boundaries to our discussion.[23]

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20) While there is no general agreement on this point, Sperber [1975] argues that symbolism is a cognitive "…mechanism that alongside the perceptual and conceptual mechanisms, participates in the construction of knowledge and in the functioning of memory" [p. xii] He contrasts symbolic knowledge with semantic knowledge in that the later is of categories and classifications while the former is about the world itself. While it is possible to have an exhaustive, "encyclopedic", knowledge of the meaning of a word, it is not possible to have an exhaustive knowledge of that which the word represents.

21) Polanyi argues that "all thought contains components of which we are subsidiarily aware in the focal content of our thinking…in an act of tacit knowing we *attend from* something for attending to something else; namely from the first term to the second term of the tacit relation." [1967, p. x] The subsidiary awareness from which we attend to focal awareness remains tacit, personal, and beyond explicit analysis, yet is the basis for knowing our focal awareness to be true. Thus, "One can know more than one can tell." [p. 7]

22) Space limits the discussion of the full implications of a hierarchical theory. Interested readers are directed to Pattee [1973] or Messarovic [1970].

23) The larger process of inquiry has also been explored by Johnson [1970] in his paper on events theory, but in a nested rather than multi-level hierarchical model. We feel our model is in a similar spirit, but an adequate mapping between the two approaches is beyond the scope of this paper.

In our model, data is transmitted up, and actions are transmitted down. Actions are here taken to mean the mental activities of developing world views, formulating problems, and calculating solutions (or action choices) as depicted in Figure 2. To characterize the types of information which link the four levels of the model we draw on Maruyama [1966]. He identifies three levels of information that organize the universe in our thought processes—the classificational level of information, the relational level of information, and the relevantial level of information.[24]

The classificational level of information consists of substances that persist in time and obey the laws of identity and mutual exclusiveness. It is a categorical classification of items as "something". It is noun oriented, discrete and objectively determinable. The categories in the classification scheme are mutually exclusive though hierarchically formulated as subdivisions in a multi-criteria classification scheme. For our model, information which flows from implementation to the formulated problem is classificational information. It is the information the decision maker attends to.

The relational level of information is event oriented rather than thing oriented. Definition is given by interactions and interrelations as "how does it relate to other things". At this level of information, mutuality of causations and interactions are possible, and subjectivity is as important as objectivity in seeking "truth". This level consists of the potential relationships that may be taken into account by an individual. For our model, information linking the formulated problem level and the world view level is relational information. It is the individual's understanding of how things are and how things work.

At the relevantial level of information, definition rests with the unique concerns of the individual, and varies between individuals. The concern is with existential meaning and the information may be used for self-centered, other-centered or dominant-submissive reasons. The relevantial level of information is situational and used in immediate action. At this level, using Vickers' terminology [1970], the individual merges value judgments and reality judgments as action judgments in an "appreciation." Information which links the world view level to the meaning level is relevantial information. It is the basis for the individual's assertion of self through action in a specific situation.

24) Again, a similar but not identical set of distinctions has been made by Johnson [1976] between facts, interpretation and evaluations.

If the objective is to evaluate an information system as it relates to the implementation of action choices, then all three levels of information must be evaluated. As we saw in the last section, however, information evaluation in accounting literature has dealt primarily with the classificational level of information in isolation from the other levels.

We can also use the model as a basis for discriminating at least two types of learning. Here, we willl draw on the distinction Argyris [1976] makes between single loop and double loop learning. By single loop learning he refers to learning that goes on within a given problem framework. Goals, objectives, values and underlying assumptions of the current problem formulation are not questioned, and learning is in the form of increased efficiency and effectiveness in processes for solving the formulated problem. Double loop learning, by contrast, refers to a questioning and revision of goals, values and implicit assumptions which underlie the problem as it is currently formulated. Double loop learning, in turn, leads to a fundamental rather than cosmetic reformulation of the problem.

For our model, single loop learning takes place at the level of the formulated problem, while double loop learning effects both the world view and the problem formulation. As before information evaluation in accounting literature has dealt with only one type of learning—single loop learning, but both types must be evaluated in judging the impact of an information system.

For the problem solving process, we have accepted that man's limited cognitive ability necessitates the framing of problems by eliminating all the elements and relations involved in the situation which are not seen as essential. The formulated problem can then always be criticized as incomplete, as indeed it always must be. But it is because the formulated problem is simplified and incomplete that calculation of a solution is possible. This type of incompleteness of the fomulated problem is not at issue in this paper. What is at issue is the lack of attention given to the role of information in reformulating problems over time, through double loop learning and the relational level of information. The next section describes a meta decision theory framework for doing so.

IV. Information at the World View Level

The meta theory decision problem is "to discover a procedure for formulating one's decision theory problem [Mitroff and Betz, 1970, p. 14]." At the formulated problem level of our decision model, the DM's view-of-the-world, Ω_0 was assumed as given. The object of inquiry in this section is the implication of the conditioning elements Ω on the formulated problem, and the impact of information on the DM's view-of-the-world. Up to this point, the analysis assumed that the receipt of infomation did not cause the DM to question the validity of the formulated AC problem. We now expand the concept of learning to a higher-order of problem formulation (double loop learning), and evaluate relational level information.

The analysis reported here is at best preliminary and mainly consists of assertions and hypotheses, which we hope can serve as a basis for further research. We believe, however, that the impact of learning on a DM's view-of-the-world and the role of information in the learning process is quite impotant in evaluating potential information systems, and warrants substantive research.

One type of meta theoretic approach to the application of SDT at the formulated problem level is an inquiry systems framework first developed by C. W. Churchman [1971] and further elaborated by Mitroff and Betz [1972], Mitroff and Pondy [1974], and Mitroff, Betz and Mason [1970]. It is a meta theory in the sense that it does not address the solution to a formulated problem, but the process by which implementation, formulated problems, world views and meaning systems interact as an inquiring system. Types of inquiring systems differ as to their use of sense data, consistent theory, multiple theories, and implementation as a basis for establishing "truth". Very briefly, Lockean inquiry systems (IS) rely on consensus of empirical data in the absence of theory, Liebnizian IS rely on formal theory in the absence of data, Kantian IS rely on multiple theories (as world views) interpreting common data, and Hegelian IS rely on conflicting "deadly enemy" theories debating thesis and antithesis using common data. Churchman-Singerian IS employ all modes plus implementation. Mitroff and pondy [1974] give a good overview of each.

Hegelian or dialectical IS have been used by some authors to explore change in the

DM's world views [Mason, 1969; Mitroff, 1970, 1971, 1972]. For an Hegelian dialectical inquirer, disagreement, not agreement, is the method of conducting inquiry. Thus, learning takes place through debates between strongly conflicting views on an issue. A dialectical inquiring system has two expert debaters with opposing views debating for the benefit of the decision maker. The DM then forms his own view by adopting or transforming the views expressed by the experts and incorporating them into his previous view. We wish to evaluate the information system based on its ability to take on the role of debaters, or alternatively, its ability to induce the DM to consider other views. We start the analysis with a discussion of the role and structure of a world view.

A. Ω: View-of-the-world

The view-of-the-world (or world view) is the DM's understanding of the logical relationship among variables. That is, as the DM receives a datum y_i, describing a past, present, or future event, he decodes the symbol y_i into an information bit through his world view. Specifically,[25] let Y be a set of "data" initially possessed by the DM, $Y=\{y_1, y_2, \cdots, y_K\}$, let Ω be a set of models (world views) $\Omega=\{w_1, w_2, \cdots, w_l\}$, and let x be operator conjoining an element of the set Y with an elements of the set Ω, such that forevery $y_i \in Y$ and every $w_j \in \Omega$, there exists one and only one element of a set F: $y_i x w_j \rightarrow f_{ij}$. The operator x is called the interpretative operator and the set F, which we call the information set of a given Ω, contains the "facts" as the DM understand the y_i within the context of a given decision problem. Thus, a "fact" cannot be separated from the DM's current view-of-the-world. Then, the AC problem specification is based on the facts in $Y_0 \times \Omega_0 \rightarrow F_0$, where the subscript 0 indicates the present. That is, all the components of the AC problem are specified based on the facts as they are known to the DM at the time of problem formulation. We wish to evaluate the potential impact of new data $y_j \in Y_0$ upon the world view Ω_0, and thus on the "facts" F_0.

Let us modify the structure of the world view somewhat and introduce uncertainty as to the validity of some competing views. The DM does not possess one world view, but a

25) The notations are adapted from Churchman [1971]. We bring some structure into the discussion of the world view (subsection A) and the value of information in meta decision theory (subsection B) in order to emphasize the pertinent issues. We do *not* intend to argue that the structure given here is *the* true structure, or even a typical one.

set of views with credence attached to each view in the set.[26)]

Let $\Omega_0 = \{c_1 w_1, c_2 w_2, \cdots c_l w_l\} = c' w$

where w_i is a unique view in the set

c_i is the credence attached to w_i

$c_i \geq 0$, and $\Sigma c_i = 1$

In addition to the impact of information reflected in the AC problem formulation, the receipt of a datum may change the DM's world view and/or change the "fact" known to the DM before the receipt of the datum. That is, a datum may impact both the categorical and the relational levels of information for the DM. Consider $y_i \in Y$, $\Omega_0 \times y_i \rightarrow f$, facts based on Ω_0. The fact f is actually a set of facts with credence attached to each of them: $\Omega_0 \times y_i = \{c_1 w_1, c_2 w_2, \cdots, c_l w_l\} x y_i \rightarrow \{c_1 f_1, c_2 f_2, \cdots, c_l f_l\}$.

Of course, it is possible for all the facts $(f_1, f_2, \cdots, f_l)$ to be the same, in which case the DM has no uncertainty with respect to the meaning of the datum y_i. Upon receipt of a datum $y_j \in Y$, the DM decodes the symbol into information $\Omega_0 \times y_j \rightarrow \hat{f}$, then checks the triple $(y_i, \Omega_0, \hat{f})$ for reasonableness with repect to his personal meaning system. This filtering process may indicate the credence vector needs to be revised in order to accommodate the new datum and the interpretation of it. Recall that the world view sets the criteria for a formulated problem specification.

The change in the world view, Ω_0 to Ω_1, is equivalent to the change in one or more criteria for a formulated problem. The change could have the effect of reducing uncertainty as to the proper view (conflict reduction) or it could actually *increase* uncertainty (conflict generation) and induce the DM to seek additional information in order to reduce his internal conflict. The effect of changes at the world view level can result in different specifications of the act space and the utility assessment, as well as the components that were subject to uncertainty at the formulated problem level. One should note that the change in world view dictates a fundamental change in the formulated problem, and the comparison of utility measures under two different world views is invalid, analogous to the inter-personal utility comparison. The impact of information for world view level changes cannot be evaluated based on the utility measures of the given formulated problem. Therefore, we are suggesting the magnitude of the changes(conflict

26) A special case of this formulation is the certainty case (i. e., $c_j = 1$ and $c_i = 0$ for $i \neq j$).

reduction or generation) as a measure of the impact of information in the meta-decision theory framework. In the next subsection, we speculate as to the plausible formalization of the above discussion.

B. Value of Information in Meta Theory

Consider a DM with initial world views and past Data Y.

$$\Omega_0 = \{c_1 w_1, c_2 w_2, \cdots, c_l w_l\}$$

Then the AC problem specification is based on the Ω_0:

$$\Omega_0 \times Y \rightarrow \{A_0, S_0, Z_0, U_0, \phi_0\} = \delta_0$$

The formulated problem δ_0 may be consistent with all the views in $\Omega_0; w_i \times Y \rightarrow \delta_0$ for all views $w_i \in \Omega_0$. More likely, some views are consistent with δ_0 while others are not. Then the δ_0 can be stated as the AC problem with the greatest credence attached to it:

$$C_{\delta *} = \underset{\delta \in \Delta}{\text{Max}}\ C\delta_j = \underset{\delta \in \Delta}{\text{Max}} \sum_{w} c_i g(w_i, \delta_j) \qquad (9)$$

where $g(w_i, \delta_j) = 1$, if $w_i \times Y \rightarrow \delta_j$

0 , otherwise.

The credence attached to the formulated problem δ^* is $C_{\delta *}$ and the measure $(1-C_{\delta *})$ represents the magnitude of a DM's internal conflict as to the correct specification of the formulated problem. Mitroff [1971] refers to the measure of conflict $\gamma = (1-C_{\delta *})$ as the probability of an error of the third kind: the error of formulating the wrong problem. The conflict reducing role of information is to increase the credence attached to the formulated problem. Thus, the maximum amount of conflict reduction that can be expected given the current state of the DM's world-view is $(1-C_{\delta *})$. If a given information system can reveal the "true environment" for the formulated problem, the DM can adjust the credence vectors such that all the component specifications are consistent with each of the remaining views.[27] Thus, the conflict reducing value of information system η is:

$$I(\eta) = E[C_{\delta 1}{}^*] - C_{\delta 0}{}^*$$
$$= E[\underset{\delta \in \Delta}{\text{Max}}(C_{\delta j} | \eta)] - \underset{\delta \in \Delta}{\text{Max}} C_{\delta 1}$$

27) Complete faith one view, $c_i = 1$, is sufficient but not necessary to achieve the state of $C_{\delta *} = 1$.

$$=E[\underset{\delta\in\Delta}{\text{Max}}\sum_{w}(C_i|\eta)g(w_i,\ \delta_j|\eta)]-\underset{\delta\in\Delta}{\text{Max}}\sum_{w}C_i g(w_i\delta_j) \quad (10)$$

where δ_{j*} is the formulated problem at time period i.

One should note that the value of information in (10) above does not possess the same properties of the value of information at the formulated problem level as defined in equation (7). The conflict reducing value (10) applies to the task of formulating the correct problem while the traditional value (7) applies to the task of choosing an optimal act given a formulated problem. Therefore, the two value measures cannot be summed together to yield the total value of information.

Now, let us consider the conflict generating role of information. Hegel argues that synthesis (the meaning system level) does not exist without prior conflict—ideas are generated out of opposition [Churchman, 1971, pp. 170~179]. Therefore, the generation and/or recognition of conflict is a necessary condition for a person to learn. Earlier we assumed a datum could increase the credence (and decrease the conflict) attached to a formulated problem. But a new datum can decrease the credence (and increase the conflict) as well. That is, $C_{w1}^* < C_{w0}^*$, which implies that the DM is less convinced that the formulated problem is correct than he was before the receipt of the daum, thus increasing the subjective probability of the error of the third kind by $C_{w0}^* - C_{w1}^*$. Consequently, the amount of conflict reduction that can be received has increased to $(1-C_{w1}^*)$. Note than the state of the DM's world views which maximizes the conflict is where every formulated problem is equally credible:

$C_{\delta i}=C_{\delta i}$ for every $\delta\in\Delta$.

Then the maximum expected conflict increasing value of information can be stated as: $C_{w0}^* - \frac{1}{k^0}$ where k_0 is the number of $\delta\in\Delta$ at time 0.

The role of conflict increasing information is such that the DM would be motivated to generate new ideas at the meaning system level while trying to resolve the conflict.[23)]

28) Mock [1971] has recognized this role of information and has suggested the following hypothesis:

Anti-Learning Information System-Designs: Information systems should be designed such that "learned" views-of-the-world and their underlying assumptions are continuously challenged.

It is interesting to note that Mock, using an uncertainty reduction framework for the value of information, and attending to the formulated problem level, refers to this essential aspect of the inquiring process as *anti*-learning.

While the mechanics of generating the measures of conflict reducing and conflict increasing impacts of information are the same, and the two measures only differ in sign, they are fundamentally different. While the first reduces internal conflicts for alternatives already held by the DM, the second provides the opportunity for new alternatives and additional conflict reduction in the future.

While we were able to identify the measures and some properties of information in meta-theory, we were not able to define the means to systematically revise the credence measures based on information received. Note that the formulated problem is conditional upon the DM's world-views being constant, and capable of being explicitly stated. Likewise, the explicit specification of world view changes requires that our meaning system be static, at least during the analysis, and be susceptible to explicit specification, which we are not able to do under our current state of knowledge. Thus, the means to include the conflict increasing and decreasing role of information in an information system are mainly conjectural and speculative (see Mitroff and Betz [1972] and Mason [1969] for examples.)

In short, within the framework of SDT, the role of information is defined as uncertainty reduction. In the framework of meta theory, the role of information is in reducing as well as increasing conflict. However, the explicit treatment of the world view revision, and thus the impact of information has not been included in this paper.

C. The Example Revisited

We now return to our example from section I. Recall that the general manager was presented with two radically different interrpretations of the meaning of the actual current period performance measures, based on the two different world views of his advisors. The diverse conclusions may prompt the manager to reassess his credence levels in the validity of the two world views. This could lead to an increased internal conflict in the general manager's mind. While we cannot determine exactly how the credence levels would be revised after the receipt of the accounting report, it is likely that the credibilities attached to the views would change, C_i vs. $(C_i|y,\eta)$.

Recall that the manager's probability of an error of the third kind (γ) was zero in the past, since both views-of-the-world yielded the same standard cost criteria. The expected measure of γ for future periods was .1, since the linear world view (w_1) had a credence of .9 under Ω_0. The ex-post measure of γ, $(\gamma|y, \eta, \Omega_0)$ is $1-\underset{w}{\mathrm{Max}}\ P(w_i|y, \eta)$, which may be different from .1: $E(\gamma|\Omega_0) \gtreqless (\gamma|y, \eta, \Omega_0) = (\gamma|\Omega_1)$. If the ex-post measure $(\gamma|\Omega_1)$ were smaller than the ex-ante measure $(\gamma|\Omega_0)$, the accounting report had a conflict reducing effect, and if the ex-post measure were larger than the ex-ante measure, the information had a conflict increasing effect. Should the conflict increase, the general manager is likely to seek additional information to reduce the conflict. It is argued that the accounting system designer should explicitly consider the impact of information at the world view level in addition to the value of information at the formulated problem level in evaluating an information system.

It is interesting to note that our "adversary system" of trial court procedure is a form of dialectical inquiring system. The adjudication process is to inquire into the "true" nature of the dispute and the determination of the appropriate questions of law and the relevant facts. This is the problem formulation process we have been discussing. In an adversary system, the opposing sides stage a series of debates for the benefit of the judge and the judge and jury—with the judge acting as a relatively passive umpire. The advantages of the system are said to be (1) a fuller presentation of relevant facts and arguments on both sides of a point, and (2) the adjudication itself will be more objective since the adjudicator himself does not directly manage the trial process [Mermin. 1973, p. 193].

The American Bar Association Joint Conference on Professional Responsibility identified the role of bias in too quickly assuming what the "problem" really is, to be of major concern:

> What generally occurs in practice is that at some early point a familiar pattern will seem to emerge from the evidence: an accustomed label is waiting for the case and, without awaiting further proofs, this label is promptly assigned to it. It is a mistake to suppose that this premature cataloguing must necessarily result from impatience, prejudice or mental sloth. Often it proceeds from a very understandable desire to bring the hearing into some order and coherence, for without some tentative theory of the case there is no stanard of relevance by which testimony may be measured. But what starts as a preliminary diagnosis designed to direct inquiry tends quickly and imperceptibly to become a fixed conclusion, as all that confirms the diagnosis makes a strong imprint on the mind, while all that runs counter to it is received with diverted attention. [Fuller and Randall 1958, p. 1160]

In the example presented above, the prior credence levels would constitute the initial cataloguing that brings order and coherence to the current month's report. In this sense, the initial credence levels constitute a bias in the larger inquiry into the 'true' nature of the problem. Overcoming this bias, the Joint Committee concludes, is the critical justification for an adversary role in the judicial process.

> An adversary presentation seems the only effective means for combating this natural human tendency to judge too swiftly in terms of the familiar that which is not yet fully known [p. 1160]. [29]

We see, then, that from an inquiry systems perspective, what was originally presented as a problem for our general manager (two advisors with conflicting views-of-the-world) is really a part of the solution. It is at this point that the general manager should activate an Hegelian inquiry system and let his conflicting advisors debate their two positions.

Summary

We have introduced a multilevel model for the evaluation of information systems, and focused our discussion on the value of information at two of those levels—the formulated problem level and the world view level. The analysis has pointed out that the impact of information at each level is fundamentally different.

At the formulated problem level, information has value to the extent that it changes state probabilities under a standard SDT framework. While our analysis has attempted to point out some technical problems in the probability revision process for act dependent and uncertain outcome formulations, the state probability revision value of information remains valid.

At the world view level, however, the impact of information may be conflict increasing or conflict decreasing for the individual. While the same datum may have both information impacts, the state uncertainty and internal conflict changes are not additive,

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29) These assertions have subsequently been given empirical support in a laboratory experiment. Inquisitorial data presentation techniques (a decision maker reviewing and interpreting the facts himself) were compared with adversary presentation techniques (a decision maker views two adversaries each present their conflicting intepretation of the facts before making his own judgment). The adversary technique did reduce decision makers bias. [Thibaut, et al., 1972]

and there is no continuity of uncertainty between two formulated problems for the same individual. Each formulated problem results from the perplexity or conflict of a different set of world views.

The various possible modes of inquiry and mixes of conflict generation or conflict reduction over time is largely unexplored, and the research questions are difficult and subtle. However, an adequate evaluation of the impact of any given information systems requires attention to these broader questions.

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