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.

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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-

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.

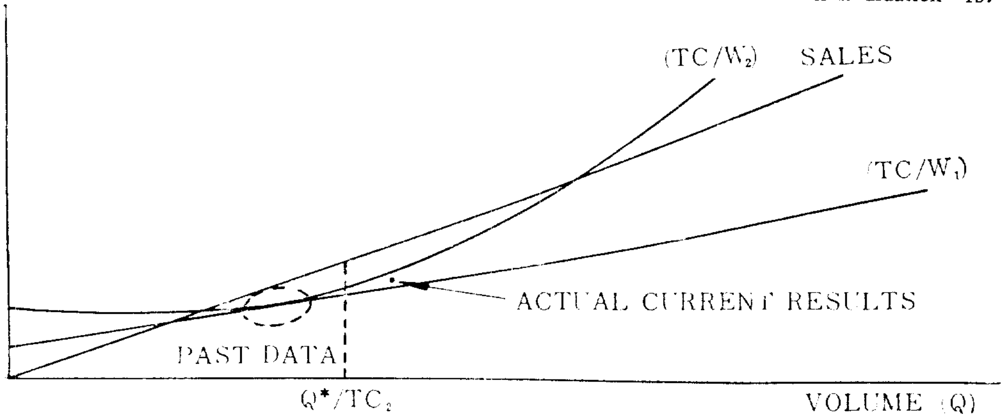

Figure 1. Cost Volume Profit Relationship

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:

$$EU(a^* | \eta) = \sum_y EU(a_l^*)\phi(y_l | \eta) \quad (3)$$

$$= \sum_y [\underset{a \in A}{\text{Max}} \sum_s U(z_{ij})\phi(s_j | a_i, y_l, \eta)]\phi(y_l | \eta)$$

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-independent 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:

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

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:

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

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

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

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

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

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

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:

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

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 $\phi(s/a)$.