TOWARDS A BEHAVIORALLY-GROUNDED THEORY OF INFORMATION VALUE

Michael E. Treacy

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(Revised August 1981)

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ABSTRACT

Economic models of information value have had little impact on the theory and practice of MIS. This is due in part to difficulties in operationalizing these models, but more importantly, it is due to problems in the theory that stem from descriptively invalid assumptions. This paper examines those assumptions and reviews five major areas for modification: the decision process, human judgement under uncertainty, the choice of actions, multiple information signal resolution, and multiple decisions over time. Incorporation of valid descriptive assumptions in the economic theory will move the field toward a behaviorally-grounded theory of information value.

INTRODUCTION

The theory of information economics has had little discernible impact on the theory and practice of management information systems design and evaluation, despite large and obvious overlapping interests. The economic theory has provided models of the transmission and communication of information [34][50] and of the value of an information system.[35] It has provided models of the optimal choice from among available information system components [35][40] and of the comparative informativeness of information systems.[7] Yet, none of these models has had much influence on MIS.

Part of the explanation of this unhappy situation is that the theory is difficult to operationalize, because theoretical models of information value require large numbers of input parameters that are sometimes impossible to estimate. Direct applications of the theory by Bedford and Onsi[6], Feltham[18], Mock[41], and others have been awkward and unsatisfactory in their results. This has led some to abandon the unidimensional value model in favor of multiattribute approaches. King and Epstein[30] and Ahituv[1] have each presented operational multiattribute schemes which maintain little of the substance of the economic theory.

The major root of the problem with economic information value theory, though, is not its inoperability, but that it is based upon invalid and unrealistic assumptions about decision making and how managers utilize information. Consider, as an example Blackwell's Theorem[7], probably the best known result of information economics. The theorem directly implies that a more disaggregated information system is always at least as desirable as a less detailed system.[23] Within the confines of severe assumptions, such as unlimited and costless information processing, this result is valid, but in a more typical managerial setting the validity vanishes and the entire point is lost. Thus, the limited impact of information economics on our field stems from problems in the theory, rather than in the practice.

In this paper, we shall expand this thesis and set directions for the development of information value theory that is founded upon valid and realistic assumptions about managerial decision making behavior. We do not seek simply an operational model of information value. Our ultimate objective is to move the economic theory towards what Keen calls "a behaviorally-grounded conception of optimality that meshes the analytic perspective of optimization science with descriptive, pluralistic models of the decision making process."[29, p. 31] We start with a review of developments in the economic theory of information value and a critical examination of underlying assumptions about the decision process and the decision maker. Five major modifications of the economic theory, suggested by descriptive models of managerial behavior found in other fields of study, are discussed in turn. Finally, this entire approach is reviewed in a concluding section that illustrates the utility of a behavioral theory of information value.

ECONOMICS MODELS OF INFORMATION VALUE

Two distinct schools, one in economics and another in statistics, have been concerned with the value of information for more than twenty-five years.[24] Information economics and statistical decision analysis have produced a series of similar models that value information in the context of several restrictive assumptions about the behavior, ability, and knowledge of actors using information.

The models of information value vary along two dimensions: the complexity of the information source and the number of decisions. The information source can be a single signal, a single information system, or multiple information systems and the decisions can be single or multiple. Figure 1 illustrates this diversity and indicates selected references for each type of model.

	SINGLE SIGNAL	SINGLE INFORMATION SOURCE	MULTIPLE INFORMATION SOURCES
SINGLE DECISION	Marschak [33] Raiffa [44] Demski [13]	Raiffa and Schlaifer [45] Marschak [33] Mock [41] Arrow [4]	
MULTIPLE DECISIONS		Schlaifer [48] Feltham [18] Marschak and Miyasawa [36]	Feltham [19] Marschak [34] Marschak [35]

FIGURE 1
Economics Models of Information Value

Each decision is framed as a problem which involves the choice of an action from a predefined set of alternatives. The utility of any action depends on which state of nature occurs and the utility of each action-state pair is known. The set of states is predefined, but the decision maker, who wishes to maximize utility, has only probabilistic knowledge as to which will occur. Information in the form of single or multiple signals from single or multiple information sources is used to refine the probabilistic knowledge through Bayesian revision, which requires that the decision maker have detailed knowledge of the conditional probability of obtaining each different signal given any state of nature. The refined knowledge of states leads to an increase in the expected utility of action. This gain in expected utility is the definition of the value of the information. It is an *ex ante* measure, made before any signals are received, actions are chosen, or states occur. Thus, it deals in expected quantities.

L.J. Savage, the originator of the fundamental axioms upon which the information economics and decision analysis models are based, wrote that his was, "a highly idealized theory of the behavior of a 'rational' person with respect to decisions."[47, p. 7] Our concern is with the value of information to a typical manager, with all his flaws and imperfections, acting in a more realistic, more complex environment. We are attempting to prescribe the variables that must be considered to produce a valid descriptive model of the value of information to a typical manager. Such a model must be founded upon a valid description of the managerial use of information, rather than upon the sterile, prescriptive assumptions that define 'economic man'.

AREAS OF MODIFICATION

These economics models of information value poorly describe the roles of information in managerial decision making and hence poorly reflect the obtainable value of information in typical managerial settings. The descriptive inadequacies of these models have been organized for discussion into five sections. In each, possible modifications of the models, as suggested by a reading of other related fields of study, are indicated. We conclude with some remarks on the difficulty of implementing such modifications and the efficacy of this approach.

1. The Decision Process

According to economics models, information derives value from its effect on the decision process. This orientation is difficult to fault if decision making is interpreted broadly, for almost all managerial activities which use information can be classified as some phase of the intelligence-design-choice-review decision process.[55, p. 54] Simon writes:

> Decision making comprises four principle phases: finding occasions for making a decision, finding possible courses of action, choosing among courses of action, and evaluating past choices. These four activities . . . . account for most of what executives do.[56, p. 40]

Mintzberg's study of the work of five chief executives reinforces this finding.[38, p. 250] All but time spent in ceremonial activities (12 percent) and in giving information (8 percent) is attributable to one or more phases of decision making.

Witte[66] formally tested for the existence of different phases in the decision process using a sample of 233 decisions to acquire computer equipment. He divided each decision process into ten equal time periods and characterized each activity in each period as information gathering, alternatives development, alternatives evaluation, or choice. The evidence supported the hypothesis that multiple phases exist within the decision process.

The difficulty with the economics models is that they concentrate upon only one phase of decision making, the choice among alternative courses of action. They assume that an occasion for decision making has been found and that all possible courses of action and consequences for every conceivable course of events have been determined. But, by the time these assumptions are satisfied, managers have already used a great deal of information and expended the majority of their effort on the problem.[56, p. 40] As Edwards and Roxburgh[15] have noted, decisions are profoundly affected by information at the intelligence and design phases of the decision making process. Without information to identify problems, structure alternatives, and estimate consequences, no choice is ever made.

Economic models of information value must be expanded to include consideration of these earlier phases, intelligence and design, if they are to accurately reflect the benefits of information. The final phase, review, need not be explicitly modelled since it is usually part of the intelligence phase of other decisions, and could be captured as such in a multiple decision model.

The phase theory of decision making implies not only that decisions are comprised of different activities, but also that these activities follow a set pattern, a progression from initial recognition to implementation of the chosen actions. Witte's evidence does not support the hypothesis that the phases followed a clear progression. Even when each decision was divided into subdecisions, no support for the hypothesis was found.

Mintzberg, Raisinghani, and Theoret[39] also found evidence of cycling through phases during the decision process, in their study of twenty-five strategic decision processes in different organizations. They suggest that cycling is used as a means of comprehending and clarifying complex decision processes and that "the most complex and novel strategic decisions seem to involve the greatest incidence of comprehension cycles".[39, p. 265] Evidence was also found that interrupts, created by internal and external pressures and by the appearance of new options, caused cycling.

The authors build their findings into an elaboration of the simple intelligence-design-choice model and posit that intelligence is comprised of two routines: decision recognition and diagnosis. Diagnosis is an optional routine used to clarify and define the issues. Decision recognition occurs when there are sufficient signals about either a crisis, a problem, or an opportunity. This categorization of problems by stimulus was first suggested by Carter[10] in his study of six strategic decisions within one company. The earlier theory of Cyert and March[12] suggested that decision recognition was always a response to problems rather than to perceived opportunities.

Pounds[43] has presented a theoretical structure for analysing problem identification, one type of decision recognition, as a process of comparing information about actual conditions against the predictions of a chosen 'model' of how things ought to be. The models managers use are implicit or explicit derivations from historical and planning data or models imposed by others or derived from outside the organization.

The design phase of decision making is not well understood. Cyert and March[12] posit that design is largely a matter of problem-directed search for acceptable alternative actions. How this search is accomplished, though, is somewhat less than clear.

Mintzberg, Raisinghani, and Theoret[39] suggest that design activity is very different depending upon whether the decision maker sought a ready-made or a custom-made solution. They note that search is appropriate for ready-made solutions, but that more elaborate models are necessary for the description of the design of custom-made solutions. Reitman[46] and Alexander[2] have further detail on the various forms of design activity.

In summary, there is general agreement in the literature that intelligence and design activities exist as important phases of the decision process. The addition of some consideration of the intelligence and design processes to the model should provide a more accurate evaluation of the managerial uses of information. The exact nature of each phase and their order from decision recognition to decision implementation appears to vary among classes of decisions. Therefore it may be necessary to build specialized information value models, using the general information economics approach, for different types of decisions or different roles of management. For example, using Pounds[43] model of the process of problem finding as a description of how managers utilize information for problem finding, one could build a model of the value of information for monitoring. The general approach to this model would be the same as in information economics, but the underlying assumptions about managerial behavior would be more accurate and would result in more valid, more useful, and more usable theory.

2. Human Judgement Under Uncertainty

There are two competing paradigms of how information is utilized in judgement and choice, the Bayesian and the regression schools of thought. The essential difference between the two is in the manner of assessment of the relationship between information and the states about which one is drawing inference. The Bayesians propose the use of conditional probabilities and Bayes' theorem to assess the impact of information upon prior judgements of the states' probability of obtaining. The regression school, formalized in the lens model proposed by Brunswik [8][9], uses correlations of states with information signals to weight the importance of each information signal in the final judgement. After several hundred psychology studies of human judgement, the rivalry between the two schools remains intense.

Despite obvious conceptual overlap, attempts at unifying the two views have met with limited success.[57]

Mock and Vasarhelyi[42] have attempted to synthesize the lens model of human information processing with the economic model of information value. Their conceptual schema suggests that this may be accomplished simply by substituting the lens model for the Bayesian model of signal utilization. Hilton[22] has taken a different approach towards integrating the two views in an information value model. He has absorbed some of the features of human information processing into a Bayesian view by extending the dimensionality of the utility function to cover each feature. Of course, a utility function with enough dimensions can be made to fit any situation. Thus, the complex resultant formulation is of dubious value.

Economics has adhered to the Bayesian view of information utilization ever since Savage[47] first joined the concepts of utility and subjective probability into a formal, axiomatic theory of decision making. This is why the economics information value models require that the decision maker have knowledge of the prior probabilities of states occuring, $p(s)$, and of the conditional probabilities of each signal, $p(y|s)$, for the derivation of $p(s|y)$, the probabilities of each state occuring revised upon receipt of signal y. It is a curious formulation of the decision maker's problem, for it is a simpler matter to produce directly subjective estimates of $p(s|y)$ in the presence of y, than to estimate both $p(s)$ and $p(y|s)$ and apply the Bayesian revision formula.

Consider, for a moment, weather forecasts and tomorrow's weather conditions. The forecast is information; it corresponds to y. Tomorrow's weather condition (rain or sun) is the uncertain state. Now think of your favorite weather forecaster and estimate the probability that he will forecast rain given that it will be sunny tomorrow, $p(y|s)$. An important difficulty immediately arises. The problem is backwards to the normal fashion of thinking about information and states. The probability of sun tomorrow, given a forecast of rain, $p(s|y)$, is a more natural assessment, because it is chronologically ordered (first an information signal, then an inference about the state) and it measures the natural notion of reliability of information. This example illustrates the inadequacy of Bayesian revision as a descriptive theory.

Reformulation of the model to indicate direct estimation of $p(s|y)$ by the decision maker simplifies the model formulation, but further complications must be considered. There is a large and growing body of psychology literature that documents and theorizes on evidence of systematic bias in the estimation of probabilities. Tversky and Kahneman have identified three important heuristics by which people estimate probabilities and have demonstrated how these lead to systematic biasing of estimates.[27][62][63] The 'prospect theory' they have developed sheds considerable light on how outcomes are framed as gains and losses in evaluating utilities and on the transient nature of these values.[28][64] A model of information value needs to include consideration of these systematic biases, for they induce a systematic subutilization of information, and decrease the obtainable value of information.

3. The Choice of Actions

Economics information value models require that the decision maker explore the consequences of every action, from their potential action set, in every state of nature. He chooses the action which maximizes the expected value of outcomes. There is considerable evidence that actions are chosen on a much simpler basis.

Simon was one of the first to question the maximum expected value model of choice. He developed the well known idea of satisficing, and submitted it as a better description of individual behavior and as a normative model of rational behavior under conditions of costly information gathering and processing.[51][52][53][54] He suggested that an action choice rule more descriptive of human behavior would be to determine a minimum aspiration level, L, for a decision outcome and sequentially search and test potential actions until an action a' is found such that:

$$\min_{s} u(s,a') > L$$

In this formulation, u(s,a') need not be accurately determined; one only needs to know whether u(s,a') is greater than L, the level of aspiration. L and u(s,a') could be multidimensional. Then, the action choice rule need not be modified, but the chosen action a' must satisfy the rule along every dimension. This obviates the need for a tradeoff among dimensions of the objective.

Cyert and March[12] extended this idea to the theory of the firm and considerable work has continued in this area of bounded rational theory.[31] Stigler[60] has explored the economics of the search activity. Many of these ideas could simplify a model of information value and serve as a better description of decision making behavior.

Soelberg[58][59] studied the behavior of fifty-two graduate students making job decisions. He found evidence that individuals had more than one acceptable choice alternative before ending their search, in contradiction to strict satisficing behavior. Soelberg developed a theory of decision making that combines the notions of maximizing along the most important one or two dimensions of outcome and satisficing along all others, to explain his findings.

The conflict between Simon's and Soelberg's theories of choice behavior can be resolved using Mintzberg, Raisinghani, and Theoret's differentiation between ready-made and custom-made solutions. They write, "The hypothesis with the strongest support in our study is that the organization designs only one fully-developed custom-made solution. . . In contrast, organizations that chose ready-made solutions typically selected them from among a number of alternatives".[39, p. 256] Soelberg's sample was of decision makers seeking and choosing from among ready-made solutions (job offers), whereas many of Simon's conclusions appear to have germinated from his observations of problems involving custom-made solutions, such as the widely referenced description of a computer aquisition decision made in the early 1950's.[11]

Different simplified choice rules could also be modelled. For example, one could model the practice of developing plans based upon assumptions about most likely future scenarios. This is equivalent to identifying the most likely state of nature and choosing an action to maximize the value of the outcome if that state obtains. The decision rule would be, choose a', such that:

$$u(s',a') = \max_{a} u(s',a)$$

$$\text{where } p(s'|y') = \max_{s} p(s|y')$$

Clearly, the appropriate model of action choice varies among classes of decisions. Research has provided some understanding of when and where different choice strategies are used, but not enough to be able to construct one integrated model of action choice. Therefore, models of information value should be specialized to particular classes of decisions or types of managerial roles, so that the appropriate action choice model may be incorporated.

4. Multiple Signal Resolution

There is little evidence that individuals resolve multiple and possibly conflicting signals through a complex Bayesian revision process. Even Bayesian psychologists have developed theories about individuals' misaggregation of multiple signals to explain the apparent conservative revision of prior probability estimates.[5][16][20][22][63][65]

The regression paradigm offers only a slightly better description of multiple signal resolution. Summers[61] and Dudycha and Naylor[14], studied the utilization of orthoganol information signals and concluded that the lens model provided an accurate description of how individuals utilize uncorrelated information signals in forming judgements. Brunswik[9] suggested that intercorrelations among information signals are the rule rather than the exception. His lens model has been used to evaluate how well individuals are able to make adjustments for intercorrelations, by comparing an individual's weighting of signals with regression weights. The evidence indicates that these adjustments generally are not made very well.[3][17][21][25][49]

As with modelling the design phase of the decision process, the direction to take in modelling multiple signal resolution is not clear. Nevertheless, it should be possible to improve upon the descriptive validity of the complex Bayesian revision process adopted by information economics.

5. Multiple Decisions Over Time

How do managers deal with information over time? The economics models assume that all future decision problems have been designed at the beginning of a finite time horizon.[18][19] In this context, an information source is valued as the present value of the expected stream of outcome improvements gained by a decision maker using information signals optimally. The solution to this problem can only be derived using dynamic programming, for one must consider the impact of each signal in all future decisions as well as in the present decision. It is not the reuse of the information source, but of the particular information signals that makes the structure of the model so absurdly counter to intuitive notions of managerial behavior.

The economists appear to have been trying to model the use of historical information in decision making. This might be accomplished much more simply if we do not distinguish historical information. In this way, the new information signals may embody historical information and the overwrought complexity of the problem disappears.

The other major modification of the multiple decision problem has already been suggested in an earlier section. Decision problems cannot be defined and enumerated at the beginning of any period of time. They must be discovered, selected, or assigned with little forewarning. We have suggested that this problem identification issue can best be described by adding an intelligence phase to the model.

CONCLUSIONS

We have examined the standard economic models of information value and suggested five major areas of revision that would move the models toward a behaviorally-grounded theory of information value. Our suggestions are not radical. These modifications would alter the underlying assumptions about decision making and human information processing, without abandoning the general economic framework of information valuation.

The review of work in the five major revision areas reveals that descriptive theories of decision making and human information processing are not well understood. Competing and conflicting theories abound, each with its own proponents and its own relevant domain of managerial behavior. This may lead some to be skeptical of success in building a revised model and to retreat to standard economic models, but there can be no safe refuge in theory which is built upon a weak foundation of invalid assumptions.

Rather than retreat, what is necessary is that information theory be constructed for particular classes of decision making or managerial action. Then, one need use only descriptive theory relevant to that domain. The resultant model will not achieve universal applicability, but it may provide the theoretical underpinnings to the solution of an MIS problem. Specialization should also alleviate some of the operational difficulties encountered whenever economic models of information value have been applied. After all, our implementation studies have highlighted the advantages of tailor-made solutions. It's time to tailor-make some theory.

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