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ASSESSING THE VALUE OF INFORMATION: PROBLEMS AND APPROACHES

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ABSTRACT

Several approaches to assessing the value of information are reviewed and their usability is discussed. The first approach is that used by economists, where the value of information is reflected through market prices and changes in probabilities. It is claimed that the applicability of this approach to information systems (IS) is limited. The second approach is based on measuring the quantity of information and then assigning value to quantity. An example of this approach is the entropy function. It is explained why the use of this method is limited to cases where data capacity or probability changes are the only issues to be considered. Three other approaches that are more useful to IS are discussed: the *normative value*, the *realistic value*, and the *perceived value*. These values are explained and discussed through a review of theoretical studies, real-life cases, and empirical research. The concluding section provides a comparative discussion of the various information values, and suggests the conditions to which each is best suited.

1. INTRODUCTION

Observation indicates that information has an economic value. People are willing to pay for information: they buy newspapers, they install computers and develop computer applications, they protect copyrights, they secure files. In general, it appears that attitudes toward information are similar to their perception of many other commodities, though certain severe problems arising from its singular character impede the precise evaluation of information.

A major problem is the difficulty of distinguishing between data and information. Data of the same size and nature may sometimes be valued as information and at other times become valueless. For example, knowing tomorrow's price of gold today is very valuable, while knowing the price of gold a year ago is an unimportant piece of data. The two data items are very similar in terms of size and memory requirements, but only the future price carries any commercial value.

Another problem is associated with the difficulty of separating information from communication capability. Suppose, for instance, we know for certain what the price of gold will be tomorrow, but we are marooned on an island in the South Pacific where the only means of communication is launching a bottle on the ocean. The value of information here is almost nil because the knowledge cannot be exploited. Hence value should be assigned not only to data but also to the system allowing for its exploitation. In fact, the value of information cannot be separated from the value of an information system for exploiting the information. This principle underlines the discussion through this entire article.

Finally, the value of a piece of information depends very often on the number of persons possessing it. For instance, if only one person knows the price of gold tomorrow, it is worth much more than when this information is available to everybody. (The difference between the private and the public value of information is analyzed in Hirshleifer [1971].)

In summary, the value of information depends on many external factors. It depends on the time the information is provided, the number of persons possessing it, and the circumstances under which the information is available.

The purpose of this article is to discuss various approaches to information evaluation and to attempt to determine which approach is better suited to any given type of problem and circumstance. The next section briefly reviews the approach prevailing in Economics, and explains why this approach has not been adopted by Information Systems (IS) scientists and practitioners. Section 3 discusses a naive approach based on measuring the quantity of information and explains why this approach is limited in its usability. Section 4 portrays the general pattern of an information value function. Sections 5, 6, and 7 describe three approaches that are more common in IS: normative, realistic, and perceived evaluation of information. The last section provides several conclusions as to which approach is more adequate for certain types of information systems and certain types of evaluation problems.

2. THE ECONOMICS APPROACH TO INFORMATION EVALUATION

Economic Theory defines information as data evoking modifications in probabilities assigned by individuals to occurrences of events (see for example Radner 1986a). Hirshleifer (1971) demonstrated this in an analysis of a case where an individual can gain profit from exploiting private information, while, if the same information becomes public domain, commodity market prices will adjust to reflect the public knowledge, and consequently the individual will not have any edge. This prompts the immediate conclusion that market prices reflect information.

Many other studies in Economics have investigated the relationship between information and prices. We will mention here only a few examples. Wilson (1975) examined economies of scale in terms of the capability of large corporations to obtain more information than that available to small firms. Arrow (1975) discussed the informational advantage of a vertical merge of firms. Such a merge enables firms to be mutually informed of transfer prices and production quantities.

Hilton (1981), through a comprehensive synthesis, identified a number of determinants affecting the value of information. He grouped them into four categories: action flexibility, payoff, initial uncertainty, and information system's traits. His major conclusion suggests that out of the four categories, only the information system determinants exhibit consistent directional effect on the value function (i.e., monotonic value function).

Somewhat related to this approach is some of the work done in Agency Theory, where different parties are distinguishable with respect to the information they possess, which may affect the decisions they make and the benefits they gain (e.g., Atckinson and Feltham 1980).

It appears, however, that the Economics approach is not of much use to IS scientists. As mentioned earlier, it is almost impossible to separate the information from the system processing it. Therefore, the major concern of IS theory is how to evaluate information systems. In this respect, scientists would like to investigate the effects of various characteristics of the mechanism of information flow and processing on the performance of decision makers. The Economics approach does not deal with the mechanism but only with its outcomes. It perceives an IS as a black box that affects probabilities and prices. It does not contend with "how" type questions (e.g., how the information is created and transmitted; how it becomes noisy; how to select a certain information technology). The IS discipline wishes to shed more light on the interior of the black box. Therefore, there is not much diffusion between the Economics approach and IS.

The next section presents a totally different approach to information evaluation, based on Engineering tools and Accounting.

3. THE QUANTITATIVE APPROACH

When an accountant wishes to assess the value of an asset, the evaluation process will follow two steps. First, the quantity of the asset is measured; second, the value of one unit of the asset is assessed and multiplied by the total number of units, giving the total value of the asset. This approach was formulated by Ijiri (1967) in a set of axioms from which we cite the second:

> **Axiom of Quantity**: There exists a method by which all resources are uniquely partitioned into a collection of classes so that for each class a non-negative measure is defined." (p. 90)

Information may be evaluated in a similar fashion by first measuring the quantity of information (data) and then multiplying the quantity by the value of one unit of information to get the total value. (Note that this approach does not distinguish between the terms "information" and "data.")

Possible measures for information quantity could be the number of characters, the number of bits, the number of printed lines, or the size of a file. It is obvious, however, that all these measures cannot even be considered as informational units because there is not necessarily any relation between the size and the value of a data set.

A better candidate for measuring information quantity is the entropy function, which is an engineering tool for measuring quantities of data. The entropy function measures the amount of information provided by a source reporting on the occurrence of n events with a priori probabilities $p_i ,..., p_n$. The amount of information is represented by the function

$$H = -\sum_{i=1}^{n} p_i \log(p_i)$$

The entropy function (originally used in Thermodynamics) was first adopted in Communication Theory by Shannon and Weaver (1949) and was found to be useful in measuring the degree of uncertainty of stochastic processes (see Khinchin 1957). The entropy function and many of its "offspring" are widely used in problems related to channel capacity and coding efficiency.

Since information is defined in Decision Theory and Economics as modifications in a priori probabilities, some attempts have been made to exploit entropy to measure the value of information rather than merely its quantity. A notable attempt is Lev (1969), who suggested using the entropy function to measure the informativeness of accounting statements. Mitroff and Mason (1974) employed entropy to assess the effectiveness of the Apollo project.

Such attempts, however, usually confront a deficiency inherent in the entropy function: the function does not account for the meaning of the events but only for the probability of their occurrence. For example, if you toss a balanced coin or if you are told by a surgeon that you have to undergo critical surgery where the chance of survival is 50 percent, the value of the entropy function associated with prior information about the outcomes of these scenarios is the same, but the context is very different. The importance of additional information is certainly different for each scenario.

In fact, Shannon and Weaver (1949 p. 9) warned against entropy "abuse":

> The word information, in this theory, is used in a special sense that must not be confused with its ordinary usage. In particular, information must not be confused with meaning.

This warning was later substantiated in a number of studies. Ronen and Falk (1973) conducted an empirical study of the value of aggregate versus disaggregate information and found that the value does not correlate with entropy except for the case where the reward function resembles a logarithmic function. Arrow (1986) came to a similar conclusion by way of a theoretical analysis where he proved that entropy can serve as a measurement of information value if and only if the utility function of the decision maker is logarithmic. Individuals are not likely to have a logarithmic utility function because it would imply that their decision is motivated only by the probabilities of the states of nature and not by the magnitudes of the payoffs. Therefore it appears that the use of entropy as a measurement for data quantity may be effective, but its use to measure the value of information is quite limited.

We may conclude this section by saying that assigning value to information quantity is not a very promising avenue of research in information evaluation. In lieu of this approach, one should try to bypass the stage of measuring the quantity of information and move directly to value assessment. Three such approaches are discussed later. However, if we wish to bypass the quantity problem and move directly to information evaluation, we need to understand the general pattern of an information value function. This is presented in the next section.

4. THE ATTRIBUTES OF AN INFORMATION VALUE FUNCTION

> Any search for a one-dimensional measure of informativeness is a vain one (McGuire 1986, p. 109).

There have been many attempts to identify and classify the various attributes constituting information value, which, it is commonly agreed, is a multi-attribute function. Some of these attempts are conceptual while other studies are based on empirical research.

The commonly accepted view suggests that the value of information is a function consisting of a number of arguments (attributes) that can be classified into four categories (see Ahituv 1980; Kleijnen 1980):

1. **Timeliness**: attributes related to the time dimension such as recency, response time (Grochow 1972), and frequency.

2. **Contents**: attributes related to the contents of the information such as accuracy, relevance (Feltham 1968), level of aggregation (Lev 1972), and exhaustiveness.

3. **Format**: attributes related to the way the information is displayed to the user, such as media, color (Benbasat and Dexter 1985), graphs versus tables (DeSanctis 1984), sequence of presentation, and batch versus online (Edstrom 1970; Hedberg 1973).

4. **Cost**: attributes related to the cost of providing the information.

The multi-attribute approach incurs certain severe methodological problems that can be classified into the following categories (Ahituv 1980):

1. **Identification**: how to identify the variables pertaining to a certain evaluation problem.

2. **Measurement**: how to measure the variables that have been identified as relevant to the evaluation problem.

3. **Effects on the value**: how to formulate the functional relationship between each individual variable (argument) and the value of information.

4. **Tradeoffs**: what are the tradeoffs among the various variables with respect to the way they affect the value of information.

5. **Function formulation and calibration**: how to formulate a joint value function and how to calibrate variables of different measurements.

There is no commonly accepted core of theory on how to deal with these problems. Some attempts (e.g., Ahituv 1980) are based on Multi-attribute Utility Theory (Keeney and Raiffa 1976). Grochow (1972) provided an analytical study of an information evaluation problem that is based on empirical findings. Ahituv (1982a) analyzed the value of a data entry and validation system by means of a multi-attribute function. The whole area, however, is still very much virgin soil for further research which should confront the five problems mentioned above.

Some interim conclusions are:

1. The value of information and the value of an information system cannot be separated.

2. The quantity of information is not likely to serve as an argument in the information value function.

3. The information value function is a multiple attribute function. Its arguments are characteristics of an information system; its results (i.e., dependent variable) relate to benefits.

The next three sections present common approaches to dealing with information evaluation by means of assessing the benefits deriving from an information system. The three approaches differ in the tools they employ. While the first one, the normative approach, is based on analytic tools, the other two approaches are empirical in nature.

5. THE NORMATIVE VALUE OF INFORMATION

The normative approach to information evaluation is based on quantitative analysis of situations in which the IS can be rigorously modeled and the impact of various traits of information on the decision maker's performance can be calculated.

The starting point for a normative evaluation is a set of assumptions (axioms) about the decision maker's behavior and preference function (this will be demonstrated later in this section). For example, one may assume that the decision maker's behavior is rational (Utility Theory) and that he or she wishes to maximize payoffs. Under these assumptions, an information system is rigorously modeled such that the payoffs to the decision maker can be computed for various alternative sets of information that can be examined. The value of information then is reflected in the difference in payoffs yielded from the various alternatives.

The normative approach is purely analytical; it is based on modeling and computation. A number of studies on the normative value of information are reviewed here. The first studies are based on assumptions of rational behavior; it will be shown later how different assumptions may change the results of the analysis.

A typical example of a normative model is shown in Adar, Ahituv and Berman (1985). The study incorporates three types of information systems into an Operations Research model of dispatching servers to calls occurring on nodes of a service network (e.g., ambulance, fire engines). The objective function of the dispatcher is to minimize the expected response time to a call. It is demonstrated how a real-time IS can improve the performance of the network in terms of expected response time relative to two other alternative information systems where the information is delayed.

Several normative models have been developed for inventory management systems. These models explore the impact of various attributes of information on cost and accuracy of inventory management (see Feltham 1968; Stohr 1979; Tapiero 1977). Since models of inventory management are structured in nature, it was possible to analyze the value of information in a rigorous manner.

A general normative model of an IS was developed in Information Economics. It is called the Information Structure model (see Marschak 1971; McGuire 1986). It formulates an IS as a stochastic matrix (Markov matrix) of conditional probabilities that transforms events into signals. A special case of deterministic structures is known as the Information Function model (see Radner 1986a).

The information structure model is highly structured and enables rigorous mathematical analysis. For example, it is possible to impose a partial rank ordering on information structures which will compare the degree of informativeness of various structures. The conditions for the rank ordering are stated in the Blackwell Theorem (see McGuire 1986). Ahituv (1982b) employs the information structure model to illustrate the widely observed phenomenon of an information systems life cycle. He shows that the information structure model can mathematically describe the limited duration of an IS life cycle.

These models are all based on assumptions of rational behavior. However, a normative model does not necessarily have to be based on "classical" Utility Theory. It may assume different patterns of human behavior and consequently develop an information value not exactly equivalent to the one assuming rational behavior. The model is still normative, rather than descriptive, because it asserts what the value *should* be rather than what it is observed to be empirically.

There are few studies that develop normative values that are not based on rational behavior. For example, Prospect Theory claims that humans do not wish to maximize expected utility but rather to maximize a function composed of their subjective value of payoffs and the subjective weights they assign to probabilities of events (see Kahneman and Tversky 1979). Based on Prospect Theory assumptions, Newman (1980) proves that the rank ordering of information structures is not identical to the one imposed by the Blackwell Theorem. Moreover, he illustrates the difference in a case where nil information is preferred to partial information. He constructs a numerical example where a systems designer assumes the decision maker is a rational behavior type while he or she is in fact a Prospect Theory type; hence an inferior system is developed for the decision maker, but neither the designer nor the decision maker will ever be aware of this.

Ahituv (1982b) suggests that decision makers are not perfect operators, namely, they do not necessarily modify a decision rule instantaneously when the structure of an information system is altered, but rather stick to a rigid decision rule at least for a certain learning period. The study shows that, during the rigid decision rule period, the rank ordering of information structures is different from the one imposed by the Blackwell Theorem.

Bounded Rationality is a theory that also deviates from the basic assumptions of rational behavior (Simon 1957). Its main premise is that when humans wish to accomplish a certain goal, they set an aspiration level which is a minimum bound for the desired performance, and they suspend looking for a solution once they have found one that meets the aspiration level. This kind of behavior is called *satisficing* (as opposed to optimizing).

Ahituv and Wand (1984) incorporate Bounded Rationality principles into the information structure model, such that the value of information can be measured by additional variables that are not accounted for in the original information structure model. The major new factor is called "level of risk." It indicates the probability of getting a payoff which is below the aspiration level of the decision maker. This factor should be considered in addition to the traditional measurement of expected payoff.

All the aforementioned approaches center on individual decision makers. Assessing the value of information for group decision-making processes is much more involved, due to the following distinctions:

1. Members of the group may observe different "parts" of the relevant world

2. Members of the group may communicate partial information (or not communicate any information)

3. Members of the group may have different sets of actions at their disposal

4. Members of the group may have different preferences.

Constructing a normative model for information evaluation under the above conditions is almost impossible (see the General Possibility Theorem in Arrow 1963, p. 59). However, when the fourth condition is omitted, and it is assumed that group members share the same preferences, normative models of information evaluation can be developed to a certain extent. Such attempts have been made in Team Theory (see Marschak and Radner 1972; Radner 1986b).

The major deficiency of Team Theory is that it has never been able to produce general analytic results to solve team problems. Most of the studies culminate in a solution by enumeration. Such methods limit the size of the problems that can be resolved and provide no real "intellectual" challenges. This is the reason theoretical research in Team Theory has been diminishing and its application to real-life cases is very rare. For two applications of Team Theory, see Beckmann (1958) and McGuire (1961).

The normative approach to information evaluation can be viewed as a "ranking box." The input to the box consists of information systems; the output is a rank ordering and evaluation of IS; the mechanism inside the box is a set of assumptions that constitutes an approach, e.g., Utility Theory, Prospect Theory, Bounded Rationality. Once the mechanism is replaced, a new rank ordering may emerge.

Normative approaches embody certain severe research and technical problems. First, it is hard to model a real life IS; it requires formulation of all the relationships among the system's components, including human-machine interactions. Second, even if the mathematical relationships are well defined, it is very difficult to calibrate the model, that is, to introduce real figures into the theoretical model. Third, many models become so complex that they are not likely to be resolved analytically, and even heuristics or enumeration may be beyond the capacity of current computing technology.

In the concluding section of this review we shall touch on the applicability of normative evaluations. For additional discussion on normative models of information evaluation the reader is referred to Kleijnen (1980) and Chapter 3 of Ahituv and Neumann (1986). The next two sections depart from normative models and discuss empirical approaches to information evaluation.

6. THE REALISTIC VALUE OF INFORMATION

The realistic value of information is derived from measuring differences in the decision maker's performance when provided with different information sets. The basic premise is that information affects performance: changing some characteristics of information pertaining to a certain decision problem will cause variations in the outcomes (i.e., the performance). The value of information derives from differences in outcomes.

The object of the research is an information system that can be prototyped or actually implemented while its characteristics can be monitored and controlled. The approach is empirical in nature: measurement is performed by comparison of outcomes.

Studies of the realistic value can be divided into two categories: real-life cases and experiments. The study of a real-life case requires that the performance of a decision maker (or an organizational function) be measured prior to the introduction of a new information system and thereafter be compared with the performance after the system has been installed and reached a "steady state." Such studies are rare because organizations seldom maintain controlled data on "before and after the fact" performance. It is also difficult to isolate the effects of the information system on organization performance from the effects of other exogenous factors. For a discussion on measuring the benefits of real-life information systems, see King and Schrems (1978).

Many experimental studies of the realistic value of information have been reported. They are usually based on controlled experiments where experimentees are presented with various information sets and their decisions and actual performance are recorded.

A notable series of such studies was carried out in Minnesota during the mid-1970s. The series, known as The Minnesota Experiments, were reviewed by Dickson, Senn and Chervany (1977). The studies were based on business games where the information provided to the players was modified according to the research objective of each study. Some of the information attributes that were measured were level of aggregation of data, graphic versus tabular presentation of data, on-line versus batch processing, and presentation of raw versus processed data. The principles of systems analysis and design are being influenced by the findings of these studies to this day. For example, in the design of DSS and Expert Systems it is common to present processed data to the user but to maintain an option for the user to trace back the raw data. These practices are based on the findings that although the realistic value of information improves when processed data are presented to the users, the confidence of the users (which is associated with the perceived value of information) decreases when they are unable to retrieve the original preprocessed data.

One of the first experiments in this area was conducted by Mock (1969, 1971). He measured how the recency of data affects the performance of decision makers in production decisions and managed to assess the realistic value of information derived from providing decision makers with more recent data. Hedberg (1973) and Edstrom (1973) measured the effects of online systems on decision makers' performance and found that online facilities improve managers' performance.

Recent studies in this area tend to center on the effects of the mode of presentation on user performance. Such studies are usually conducted in a microcomputer environment where the mode of presentation (e.g., graphs versus tables, color versus monochrome) can be easily monitored. Examples of such studies are Benbasat and Dexter (1985), DeSanctis (1984), Dickson, DeSanctis and McBride (1986), Lucas (1981), Lucas and Nielsen (1980), Vogel, Lehman and Dickson (1986).

The major problem one faces when measuring the realistic value of information is the accuracy of the measurement. Figure 1 portrays a general schema of a study of an information system value. According to this schema, data are generated by the real world (or a simulation of the real world) and then relayed to an IS, which, in return, provides information to the decision maker. The decision maker produces decisions and actions whose impact is reflected through outcomes and performance. The object that we wish to manipulate is the IS, but the measurement instrument is located at the outcomes. The distance between the object under investigation and the point of measurement might be too remote to guarantee accurate results. In other words, it is hard to control all sorts of noises and exogenous factors that might interfere on the way from the IS to the outcomes. This is difficult to do in an experiment and it is even harder when a real-life case is being examined.

Another problem encountered in realistic value measurement is that it requires an implemented system to exist before any measurement can take place, that is, the value is assessed ex-post rather than ex-ante, while managers and systems analysts always wish to evaluate a system before it is implemented. This problem is partly alleviated by the use of application generators and fourth generation software that expedite the construction of prototype systems that can be demonstrated to the decision makers to illustrate what the real system can do.

The realistic value of information is likely to be the most preferred approach to information evaluation because it reflects actual performance. However, its use is limited due to the problems mentioned above. We shall discuss the applicability of the realistic evaluation in the concluding section of this article. We turn now to another empirical approach involving the perceived value of information.

7. THE PERCEIVED VALUE OF INFORMATION

The perceived value of information is based on subjective evaluation performed by users of an IS. The basic premise of this approach is that users can recognize the benefits they gain from an IS and transform these either to monetary terms or to ranking scales.

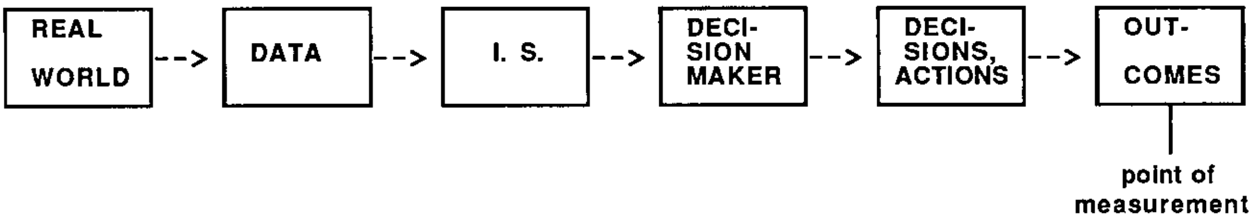

Figure 1. Measuring the Realistic Value of Information

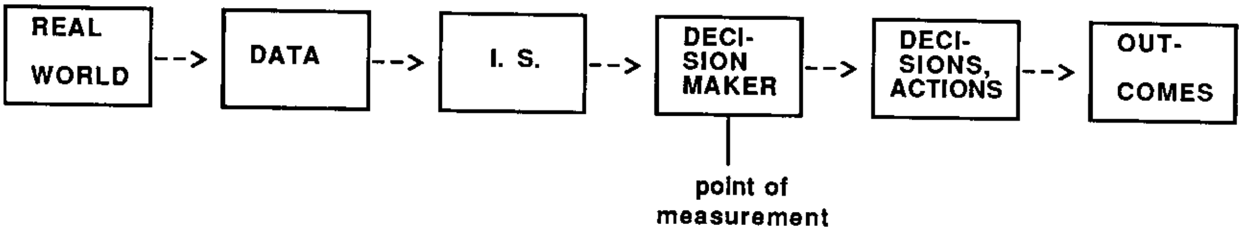

Figure 2. Measuring the Perceived Value of Information

The object of the research is an information system that can be prototyped or actually implemented while its characteristics can be monitored and controlled. The approach is empirical in nature: measurement is performed by questioning the users on the value they assign to the system or to some of its traits.

There are few methods by which the perceived value can be investigated. The first method is called "monetary equivalent" or "willingness to pay." In this method, users are asked how much they are willing to pay in order to maintain a certain system intact and to continue to receive its output. By comparing the willingness to pay for alternative systems or alternative features of a system one can assess the value the users associate with the system and its features. Studies of this nature were performed by Ronen and Falk (1973), Gallagher (1974), and Zmud (1978).

A second method to investigate the perceived value is based on semantic scales. In this method, users are asked to mark their reaction to certain features and attributes of a system on semantic differential scales (usually, but not necessarily, ranging from 1 to 7). By analyzing the ranking, one can obtain some knowledge on how the users appreciate the system and its features and how they rank order alternative systems and alternative features.

Studies of this nature were reported by Munro and Davis (1977), Neumann and Segev (1979), and King and Rodriguez (1978). Gallagher (1974) employed both methods (willing to pay and semantic scales) and compared the results which were found to be quite consistent.

An expansion of the subjective scaling method can be performed by using the Analytic Hierarchy Process (AHP) developed by Saaty (1981). This technique requires hierarchically decomposing a problem into elementary components. When this is performed, the evaluator makes pair comparisons among the components. An application of AHP to the evaluation of an accounting IS is reported by Arbel and Seidmann (1985).

There is also an indirect method to assess the perceived value of an IS. This can be done by observing the intensity of use of an IS. It is assumed that users tend to use a system more frequently if they believe it is of value to them (see Ein-Dor and Segev 1981). This measurement, however, is better suited to voluntary systems where users may opt to withdraw from using the system. It is hard to assign any value to the frequency of use of mandatory systems.

It should be noted that, except for the monetary equivalent method, none of the above methods provides a monetary or any other performance measure of the system under investigation. Hence, it is hard to relate perceived values (or, more precisely, perceived rank ordering) to cost or other monetary measures. Therefore, direct cost/benefit analysis of an IS is not likely to be obtained through probing the perceived value.

Another problem arises from the location of the point of measurement. Figure 2 duplicates the IS schema presented in Figure 1, the point where the value is measured being now marked at the decision maker square. On the one hand, the point of measurement is now closer to the object to be measured (i.e., the IS) so it is easier to control the experiment and to associate the value with the information attributes. On the other hand, the point of measurement is now remote from the real outcomes and it might very well happen that the perceived value will have nothing to do with the real value. The users might believe that a certain system is good for them but the truth is that other systems may do better. A phenomenon of this kind was reported by Chervany and Dickson (1974) where managers had less confidence in their decisions when they were provided with aggregate rather than raw data, though their real performance improved.

Despite its limitations, the perceived value is very instrumental in assessing the value of an IS that supports unstructured decisions where the outcomes are somewhat intangible or planned for the long range. In such cases, neither the normative nor the realistic value is likely to be formulated and measured. The concluding section compares the various approaches to IS evaluation and elaborates on the usability of each.

8. DISCUSSION AND CONCLUSIONS

The preceding sections have outlined a number of approaches to IS evaluation. The Economics approach is not very applicable to IS researchers and practitioners since it overlooks the mechanism that generates the information and centers only on the outcomes in terms of probabilities and prices. The "naive" quantitative approach is usable in cases where the capacity of data is to be examined (e.g., channel capacity) or where the only thing that matters is the change in probabilities while the titles of the events and the payoff values are unimportant. Such circumstances are rare.

Three evaluation approaches remain for consideration: normative, realistic, and perceived. With respect to these three, we shall elaborate on two questions:

1. Is there any relation between the values emerging from the various approaches?

2. What are the circumstances under which each of the approaches is applicable?

The perceived value is totally subjective; it reflects the individual's view on the benefits to be derived from an IS. Perceived value may, then, be higher, equal to, or lower than either of the other two values. In other words, there is not necessarily any relation between the perceived value and either the normative or the realistic value. This has been recognized empirically in a number of studies (e.g., Chervany and Dickson 1974).

Unlike the perceived value, the normative and the realistic value can be related. In a way, the normative value can be considered as an upper bound for the realistic value, that is, if the decision maker is perfect, his or her performance should get very close to the normative value. However, the decision maker can never exceed the optimal value derived from a normative analysis (note that this statement refers to expected values). This was empirically validated by Mock (1969).

For the above assertion to be true, one has to assume that the decision maker behaves in accordance with the same set of assumptions that engender the normative value. For instance, if rational behavior is assumed, then the normative value calculated under rational behavior limits the realistic value gained by decision makers behaving in the same manner. However, if one claims that decision makers act as satisficers or under Prospect Theoretical assumptions, there will not be any clear relation between the realistic value and a normative value calculated under rational behavior assumptions (see Newman [1980] and Ahituv [1981] for expositions of this point).

Regarding the applicability of the three values, it should first be noted that ideally the realistic value is the most preferred one since it reflects the real performance of a decision maker while using a certain IS. Unfortunately, the realistic value is the hardest one to measure because of the many obstacles (discussed in Section 6).

Table 1 designates the conditions under which each approach can be useful (see also Ahituv, Munro and Wand (1981) for a related discussion). The left column of Table 1 presents the four tiers in the organizational hierarchy (see Ahituv and Neumann 1986, Chapter 5; Anthony 1965): Operations, Operations Control, Management Control, and Strategic Planning. The second column lists the information systems that are usually employed by the corresponding tiers along the organizational gamut (see Ahituv and Neumann 1986, Chapter 6). The last two columns distinguish between the existing IS and an IS that is only on the drawing board and designate which type of information value is most adequate to each case.

Table 1. The Applicability of the Various Information Values

ORGANIZATIONAL LEVEL	TYPE OF IS	STATUS OF THE IS: EXISTING IS	PROPOSED IS
Operations (OP)	Transaction Processing Systems (TPS)	realistic	normative
Operations Control (OC)	Structured Decision Systems (SDS)	realistic or perceived	perceived
Management Control (MC)	SDS and Decision Support Systems (DSS)	realistic or perceived	perceived
Strategic Planning (SP)	DSS	perceived	perceived

Table 1 reflects the following ideas and thoughts:

1. The higher the organizational level, the more difficult it is to formulate a normative model and to measure tangible performance; thus the perceived value becomes more essential.

2. Realistic value is obtainable only from examining changes in real outcomes before and after the installation of an IS. Therefore the realistic value is feasible mainly for existing systems (prototyping of a proposed system is considered an existing system).

3. The normative approach is feasible mainly for low level systems that are designed to support structured decisions and structured processes. In such cases, modeling is more likely to be possible.

It should be noted that, unlike the discrete classification in Table 1, reality is continuous; hence the table reflects a spectrum of possibilities rather than clear-cut distinctions.

To sum up, it appears that all three values are applicable depending on the circumstances. The normative value is more accurate but requires formal models; the realistic value is the most preferred but hard to measure; the perceived value is easier to assess but questionable with respect to its utility. As the focus of MIS research and practice moves towards unstructured decisions and high level IS, it seems that the perceived value will capture more attention in the near future, until scientists are able to formulate more rigorous approaches to information evaluation.

9. REFERENCES

Adar, Z.; Ahituv, N.; and Berman, O. "The Value of an Information System for a Service Network." *Computers and Operation Research*, Volume 12 (1985), Number 1, 1985, pp. 71-85.

Ahituv, N. "A Comparison of Information Structures for a Rigid Decision Rule Case." *Decision Sciences*, Volume 12, Number 3, July 1981, pp. 399-416.

Ahituv, N. "A Systematic Approach Towards Assessing the Value of an Information System." *MIS Quarterly*, Volume 4, Number 4, December 1980, pp. 61-75.

Ahituv, N. "A Theoretical Framework for Cost/Benefit Analysis of Data Entry and Validation Systems." *Proceedings of the Third Annual International Conference on Information Systems*, Ann Arbor, Michigan, 1982a, pp. 47-55.

Ahituv, N. "Describing the Information System Life Cycle as an Adjustment Process Between Information and Decisions." *International Journal on Policy Analysis and Information Systems*, Volume 6, Number 2, 1982b, pp. 133-145.

Ahituv, N.; Munro, M. C.; and Wand, Y. "The Value of Information in Information Analysis." *Information and Management*, Volume 4, Number 3, July 1981, pp. 143-150.

Ahituv, N., and Neumann, S. *Principles of Information Systems for Management*, Dubuque, Iowa: W. C. Brown, Second edition, 1986.

Ahituv, N., and Wand, Y. "Comparative Evaluation of Information Under Two Business Objectives." *Decision Sciences*, Volume 15, Number 1, Winter 1984, pp. 31-51.

Anthony, R. A. *Planning and Control Systems: A Framework for Analysis*, Division of Research, Graduate School of Business Administration, Harvard University, Boston, Massachusetts, 1965.

Arbel, A., and Seidmann, A. "Designing a Multi-Micro Distributed Accounting Information System." *Human Systems Management*, Volume 5, Number 4, 1985, pp. 283-291.

Arrow, K. J. *Social Choice and Individual Values*, New Haven, Connecticut: Yale University Press, Second edition, 1963.

Arrow, K. J. "The Value of and Demand for Information." In C. B. McGuire and R. Radner, Editors, *Decision and Organization*, Minneapolis, Minnesota: University of Minnesota Press, Second edition, 1986, pp. 131-139.

Arrow, K. J. "Vertical Integration and Communication." *The Bell Journal of Economics*, Volume 6, Number 1, Spring 1975, pp. 173-183.

Atckinson, A. A., and Feltham, G. A. "Information in Capital Markets: An Agency Theory Perspective." W.P., Faculty of Commerce, University of British Columbia, July 1980.

Beckmann, M. "Decision and Team Problems in Airline Reservation." *Econometrica*, Volume 26, 1958, pp. 134-145.

Benbasat, I., and Dexter, A. "An Experimental Evaluation of Graphical and Color-Enhanced Information Presentation." *Management Science*, Volume 31, Number 11, November 1985, pp. 1348-1364.

Chervany, N. L., and Dickson, G. W. "An Experimental Evaluation of Information Overload in a Production Environment." *Management Science*, Volume 20, Number 6, June 1974, pp. 1335-1344.

DeSanctis, G. "Computer Graphics as Decision Aids: Directions for Research." *Decision Sciences*, Volume 15, Number 4, Fall 1984, pp. 463-487.

Dickson, G. W.; DeSanctis, G.; and McBride, D. "Understanding the Effectiveness of Computer Graphics for Decision Support: A Cumulative Experimental Approach." *Communications of the ACM*, Volume 29, Number 1, January 1986, pp. 40-47.

Dickson, G. W.; Senn, J. A.; and Chervany, N. L. "Research in Management Information Systems: The Minnesota Experiments." *Management Science*, Volume 23, Number 9, September 1977, pp. 913-923.

Edstrom, O. *Man-Computer Decision Making*, Gothenberg Studies in Business Administration, Goteborg, Sweden, 1973.

Ein-Dor, P., and Segev, E. *A Paradigm for Management Information Systems*, New York: Praeger, 1981.

Feltham, G. A. "The Value of Information." *The Accounting Review*, Volume 43, Number 4, October 1968, pp. 684-696.

Gallagher, C. A. "Perceptions of the Value of Management Information System." *Academy of Management Journal*, Volume 17, Number 1, March 1974, pp. 46-55.

Grochow, J. M. "A Utility Theoretic Approach to Evaluation of a Time-Sharing System." In W. Freiberger, Editor, *Statistical Computer Performance Evaluation*, New York: Academic Press, 1972.

Hedberg, B. *On Man-Computer Interaction in Organization Decision-Making. A Behavioral Approach*, Second Edition, Business Administrative Studies in Gothenburg, Gothenburg, Sweden, 1973.

Hilton, R. W. "The Determinants of Information Value: Synthesizing Some General Results." *Management Science*, Volume 27, Number 1, January 1981, pp. 57-64.

Hirshleifer, J. "The Private and Social Value of Information and the Reward to Inventive Activity." *The American Economic Review*, Volume 61, September 1971, pp. 562-574.

Ijiri, Y. *The Foundation of Accounting Measurement*, Englewood Cliffs, New Jersey: Prentice-Hall, 1967.

Kahneman, D., and Tversky, A. "Prospect Theory: An Analysis of Decision Under Risk." *Econometrica*, Volume 47, Number 2, March 1979, pp. 263-291.

Keeney, R., and Raiffa, H. *Decision with Multiple Objectives: Preference and Value Tradeoffs*, New York: John Wiley, 1976.

Khinchin, A. I. *Mathematical Foundations of Information Theory*, New York: Dover Publications, 1957.

King, J. L., and Schrems, E. L. "Cost-Benefit Analysis in Information Systems Development and Operations." *Computing Surveys*, Volume 10, Number 1, 1978, pp. 19-34.

King, W. R., and Rodriguez, J. I. "Evaluating Management Information Systems." *MIS Quarterly*, Volume 2, Number 3, September 1978, pp. 43-51.

Kleijnen, J. P. C. *Computers and Profits: Quantifying Financial Benefits of Information*, Reading, Massachusetts: Addison-Wesley, 1980.

Lev, B. *Accounting and Information Theory*, American Accounting Association, Sarasota, Florida, 1969.

Lucas, H. C. "An Experimental Investigation of the Use of Computer-Based Graphics in Decision Making." *Management Science*, Volume 27, Number 7, July 1981, pp. 757-768.

Lucas, H. C., and Nielsen, N. R. "The Impact of the Mode of Presentation on Learning and Performance." *Management Science*, Volume 26, Number 10, October 1980, pp. 982-993.

Marschak, J. "Economics of Information Systems." *Journal of the American Statistical Association*, Volume 66, Number 333, March 1971, pp. 192-219.

Marschak, J., and Radner, R. *Economic Theory of Teams*, New Haven, Connecticut: Yale University Press, 1972.

McGuire, C. B. "Some Team Models of a Sales Organization." *Management Science*, Volume 7, 1961, pp. 101-130.

McGuire, C. B. "Comparisons of Information Structures." In C. B. McGuire and R. Radner, Editors, *Decision and Organization*, Minneapolis, Minnesota: University of Minnesota Press, Second edition, 1986, pp. 101-130.

Mitroff, I. I., and Mason, R. O. "On Evaluating the Scientific Contribution of the Apollo Moon Missions Via Information Theory: A Study of the Scientist-Scientist Relationships." *Management Science*, Volume 20, Number 12, August 1974, pp. 1501-1513.

Mock, T. J. "The Evaluation of Alternative Information Structures." Unpublished Doctoral Dissertation, University of California, Berkeley, 1969.

Mock, T. J. "Concepts of Information Value and Accounting." *The Accounting Review*, Volume 46, Number 4, October 1971, pp. 765-778.

Munro, M. C., and Davis, G. B. "Determining Management Information Needs: A Comparison of Methods." *MIS Quarterly*, Volume 1, Number 2, June 1977, pp. 55-67.

Neumann, S., and Segev, E. "A Case Study of User Evaluation of Information Characteristics for System Improvement." *Information and Management*, Volume 2, 1979, pp. 271-278.

Newman, D. P. "Prospect Theory: Implications for Information Evaluation." *Accounting, Organization and Society*, Volume 5, 1980, Number 2, pp. 217-230.

Radner, R. "Normative Theory of Individual Decision: An Introduction." In C. B. McGuire and R. Radner, Editors, *Decision and Organization*, Second Edition, Minneapolis, Minnesota: University of Minnesota Press, 1986a, pp. 1-18.

Radner, R. "Teams." In C. B. McGuire and R. Radner, Editors, *Decision and Organization*, Second Edition, Minneapolis, Minnesota: University of Minnesota Press, 1986b, pp. 189-215.

Ronen, J., and Falk, G. "Accounting Aggregation and the Entropy Measure: An Experimental Approach." *The Accounting Review*, Volume 28, Number 4, October 1973, pp. 696-717.

Saaty, T. L. *The Analytic Hierarchy Process*, New York: McGraw-Hill, 1981.

Shannon, C. E., and Weaver, W. *The Mathematical Theory of Communication*, Urbana, Illinois: University of Illinois Press, 1949.

Simon, H. A. *Models of Man*, New York: John Wiley, 1957.

Stohr, E. A. "Information System for Observing Inventory Levels." *Operations Research*, Volume 27, Number 2, 1979, pp. 242-259.

Tapiero, C. S. "Optimization of Information Measurement with Inventory Applications." *Infor*, Volume 15, Number 1, February 1977, pp. 50-60.

Vogel, D.; Lehman, J.; and Dickson, G. W. "The Impact of Graphical Display on Persuasion: An Empirical Study." *Proceeding of the Seventh International Conference on Information Systems*, San Diego, California, December 15-17, 1986, pp. 240-254.

Wilson, R. "Informational Economics of Scale." *The Bell Journal of Economics*, Volume 6, Number 1, Spring 1975, pp. 184-195.

Zmud, R. W. "An Empirical Investigation of the Dimensionality of the Concept of Information." *Decision Sciences*, Volume 9, Number 2, February 1978, pp. 187-195.