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Decision Production-- A Step Toward a Theory of Managerial Information Requi rements

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ABSTRACT

The lack of a general theory of managerial information requirements is proposed as an underlying cause of the many MIS failures. This paper takes a first step toward developing such a theory. Viewing decision making as a production process (decisions being produced in much the same manner as normal goods or services), microeconomic concepts are employed to provide descriptive and normative guidance for the development of MIS.

INTRODUCTION

Successes notwithstanding, millions of dollars have been wasted in trying to develop information systems to enhance managerial decision making. The view here is that a major reason for these failures is the lack of a general theory of managerial information requirements establishing the relationships between the information provided to management and the resulting decisions (Cooper and Swanson, 1979).

The purpose of this paper is twofold. As a first step in developing a general theory of managerial information requirements, a production theory of managerial decision making is introduced, and its applicability is identified. As a second step, the potential of this view for enhancing the analysis of managerial information requirements is explored.

A logical source of help in developing this theory is the decision making literature; however, a problem arises in choosing among competing descriptive and normative theories. An alternative to wrestling with this choice is to identify a common thread on which further research can be based. Although each of the decision theories indicates different views of how decision making is performed (intuitively, rationally, politically, etc.), there seems to be a common notion of what must be done, that is, the tasks involved. These tasks, then, can serve as the common research thread.

Research relating to decision tasks has tended to gravitate toward frameworks which include such tasks as noticing or searching for environmental signals, identifying a problem requiring a decision, understanding the problem, generating or discovering alternative courses of action, and choosing the appropriate course of action (e.g., Keen 1977, Mintzberg, et al. 1976, Simon 1960). Using these decision making tasks as the common base, we propose a view of decision making which can encompass the political, rational, etc. decision theories. Decision making can be thought of as a production process in which decision tasks are performed by resources such as managers, staff, computers, etc. The exact functional relationships between resources (inputs) and decisions (outputs) may be in accord with any or

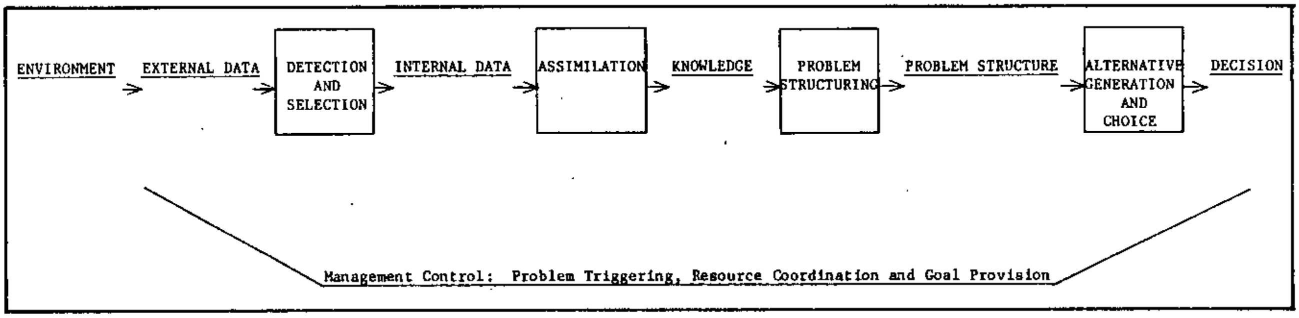

Figure 1. Decomposition of the Decision Production System

a combination of the decision theories.

If this production view is valid, then microeconomic production theory can provide valuable descriptive and normative guidance for developing information systems that enhance managerial decision making. The second through fifth sections develop an intuitive understanding of the decision production model, creating a conceptual link between neoclassical production theory and decision making. The sixth section discusses the effects of neoclassical assumptions upon the model's applicability and the seventh section provides some evidence of the model's validity. The eighth section applies the model to the analysis of managerial information requirements. The last section presents a summary.

INTUITIVE DESCRIPTION

An intuitive description of decision making from a production viewpoint is provided below and depicted in Figure 1. A decision production system (DPS) is postulated to exist, in which a functional relationship linking the use of certain physical resources (computer software, people, communications devices, etc.) with the production of decisions can be identified. As with normal production, a transformation of raw material is said to occur. The raw material of decision production is information, which is transformed from its initial state (data) to its final form (decisions).[1]

Though we postulate that a DPS can be fully described by a single functional relationship, a division of this complex function into smaller, less complex components will aid in the understanding and analysis of decision making. The DPS can thus be viewed as consisting of two components: a Mainline Component and a Management Control Component. The Mainline Component consists of tasks directly related to the transformation of data into decisions. The Management Control Component has a directing and organizing role, which includes triggering the decision making effort (i.e., making the Mainline Component aware of a problem) and coordinating the activities of Mainline Component resources. It is the Mainline Component which will be the focus of discussion. Management Control will be peripherally involved, usually representing exogenous conditions within which the Mainline must operate.[2]

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[1]For our purpose, information will be used to refer generically to the raw material of decision production. This follows from the various definitions of information as provided by, e.g., Davis 1974, Kleijnen 1980, and Machlup 1962.

The understanding of a system can be enhanced by dividing it into smaller, more fundamental pieces. Therefore, the following example is provided to illustrate the decomposition and viewing of a DPS.

Using decision making tasks commonly referred to in the literature, we start by tracking the form of information as it is transformed from data to decisions.[3] The Mainline Component of a DPS can be viewed as consisting of four different processes (tasks) that result in three intermediate information states and a final product. External Data reflecting environmental events are input to the first process. This process is involved with the detection (sensing or capturing) as well as selection (filtering and aggregating) of the External Data to produce Internal Data. The Internal Data from this Detection and Selection Process are then input to an Assimilation Process. Assimilation includes the interpretation of Internal Data, which results in an updating of Knowledge; that is, Assimilation transforms Internal Data into Knowledge. Knowledge is then the basis (i.e., input) for the Problem Structuring Process. Problem Structuring identifies and organizes (transforms) applicable portions of Knowledge into a Problem Structure. (This Problem Structure is analogous to Simon's problem space, less the operators.) On the basis of this Problem Structure, the Alternative Generation and Choice Process then produces Decisions. (The Detection and Selection and the Assimilation Processes constitute what can be referred to as "Knowledge Production." "Decision Production" can be used to indicate the Problem Structuring and Alternative Generation and Choice Processes.)

ECONOMIC LINKAGE

The DPS described above, its components and processes, are all viewed as productive units, and thus must conform to neoclassical definitions and assumptions. This neoclassical foundation provides both guidance and constraints. The following discussion highlights some of the neoclassical production theory implications for DPS. A definition of production and its assumptions is first introduced, followed by examples of implications from neoclassical economic theory for identifying and measuring inputs and

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[2] Neoclassicial production analyses ignore significant management issues; it is assumed that resources are employed in an efficient manner, and that the manager's goals coincide with those of the firm or owner. These assumptions, however, seem to be important enough to consider explicitly within DPS analysis. The Management Control Component is thus offered as a vehicle to allow the characterization of these management issues of coordination, provision of goals, and problem triggers. Treating management influence as separate from Mainline production also allows the DPS to be analyzed in a traditional neoclassical sense.

[3] It is of interest to identify information states which can be labeled as distinctly different from each other. This is analogous to identifying raw material input, intermediate states (goods in process), and final products in a manufacturing firm. As with manufacturing firms, the existence of specific intermediate information states depends upon the technology (context) involved. For example, the production of knives may be accomplished in a single step with blade and handle produced together, or there may be a two-step process where the handle and blade are made separately and then assembled. In the first instance there is no intermediate state; in the second instance there is.

outputs as well as defining economic efficiency, effectiveness, and optimization.

Production has been defined as the transformation of materials into products by a series of energy applications. In the DPS view it is information which is undergoing these changes; one information state is input and another state is output. There is, however, a basic difference between information and normal production materials, such as steel, as the focus of change. Though each transformation of information results in what may be considered physical changes (change of form), no consumption of the input necessarily occurs. Information exhibits properties of both raw material (consumable) goods and durable goods. As will be seen, however, this duality does not pose problems for economic analysis.

A production function is a description of the relationship between quantities of outputs for given quantities of inputs. Typical neoclassical assumptions concerning this function include: no additive constants, a positive amount of all inputs required for output to occur, continuous functions, technically efficient production, continuous and repetitive production at constant rates during the period, etc. The implications of these assumptions for DPS can be illustrated by the assertion of continuous and repetitive production. This enables production to be considered timeless, with input consumption and corresponding output production occurring during the same period. Thus, since time is not treated as an input, "incubation periods" for decision making are ignored in the DPS model. The sixth section describes the implications of these neo-classical assumptions in more detail.

Two classes of DPS inputs exist: information states (External Data, Internal Data, etc.) and resources (people, computers, etc.). The earlier categorization of information into the five states distinguishes between different types of information inputs (and outputs) in a DPS. Resources can be identified in terms of their "natural" physical distinctions: for example, people as inputs are different from equipment or supplies.

Information states may be measured via a scheme that characterizes information in terms of its age, detail, completeness, language, etc. (these characteriastics are described in the fifth section).[4] Since each state as a whole is being described by these characteristics, characteristic index measurements in terms of averages and associated variances are appropriate. Though this approach works for characteristics that are defined continuously, it will not work for characterisics that are defined nominally, such as language (verbal, pictoral, mathematic, etc.) and medium (report, punched card, magnetic tape, etc.). For the present, such nominal characterizations are assumed to be included in the shape of the production functions.

Measurement of resources will usually be easier than measurement of information states. Once resources are categorized in terms of their "natural" physical distinctions, the amounts used can generally be measured in terms of the units in which they are normally purchased (power in kilowatt hours, paper in pages, labor in hours, computers in connect time, etc.).

DPS outputs are information states from Internal Data to Decisions. Since (in a continuous production view) all outputs are flows, the same methods that are used to identify and measure flow information states as inputs are appropriate for their identification and measurement as outputs. The one state described as a stock is Knowledge, which is not consumed and has constant characteristics throughout the production period. However, since Knowledge obsolescence occurs, output from the Assimilation Process must be used to update Knowledge to keep its characteristics constant. For example, this output must keep average Knowledge age constant. It is the characteristics of this updating flow which can be measured to depict Assimilation Process output.

The production of each information state can be viewed as joint production, where the change in a single input can affect all the characteristics of an information state. This type of function can be depicted as $F(S_1^O,\ldots,S^O;r_1,\ldots,r_m;S_1^I,\ldots S_n^I) = 0$, where S_i^O is the amount of information state characteristic i output, r_j is the amount of resource j input, and S_k^I is the amount of information state characteristic k input. This formulation works for characteristics which can be measured continuously. Nominal characteristics such as language and medium are assumed to be implicit in the functional shape.

Using economic optimization techniques to increase the efficiency and effectiveness of decision making is a major goal of the DPS view (and is addressed in the eighth section). Efficiency, or "doing the thing right," can be operationalized in terms of constrained cost minimization. Effectiveness, or "doing the right thing," can be operationalized in terms of constrained revenue (or benefit) maximization. The combination of efficiency and effectiveness leads to DPS optimization.

In order to use these techniques, inputs must be associated with their costs. In the short run, costs of fixed or capacity inputs are not an optimization issue.[5] Though these costs are important in determining profitability, they do not enter into marginal analysis. Costs of nondurable inputs are the purchase prices measured as a constant flow per time. Similarly, costs of variable durable inputs, such as labor, are calculated in terms of the purchase of their service flow per time. In the long run, with all inputs variable, a

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[4] The durability of information states plays an important part in their measurement. At one extreme, nondurability implies that consumption occurs contemporaneously with output production, and the problem becomes one of measuring a flow of input per unit time. At the opposite extreme, durability implies that no consumption occurs during production, and measurements characterize a stock of input which is assumed constant during the production period.

Initially, all information states except Knowledge are assumed to be nondurable. Consumption of, say, Internal Data occurs as its usefulness is used up. Once Internal Data has been entered into the Assimilation Process, it is assumed to no longer have value for the DPS. Knowledge will generally have a variably durable nature. That is, it can be incrementally increased and is not used up during Decision Production. It will, however, lose its value at rates that depend upon such things as environmental stability. For example, if the environment is rapidly changing, the value of a specific Knowledge state will rapidly diminish. This loss of value can be thought of as Knowledge obsolescence.

[5] Note that switching costs for fixed or capacity inputs are applicable in the short run.

steady-state production flow is assumed. Thus, discontinuous purchases of durable (capital) inputs can be made commensurate with the continuous flow of nondurable inputs by using a present value strategy.

Using costs and the production function, efficient input allocations can be determined. To identify effective production requires some notion of Decision value. If the firm as a whole can be viewed as a production system, then the DPS output (Decisions) is just another class of inputs to this greater productive process. The Decision characterization scheme can then be used to determine the marginal benefits (in monetary tems) of a Decision stream, allowing DPS effectiveness to be determined. This effectiveness, combined with efficient input allocations, will lead to optimal DPS performance.

AN INVENTORY ORDERING EXAMPLE

This section describes an inventory ordering decision scenario, and then maps it into a DPS model. The purpose of this exercise is to provide the reader with a better understanding of DPS concepts, and to lay a foundation for further illustrations.

Consider an automated inventory ordering system which is used at a retail store. Algorithms in this system relate inventory needs to sales forecasts, which are based upon prior sales. When these needs are combined with current inventory levels, as well as ordering and storage costs, decisions are made as to the amount and timing of inventory orders. Current inventory levels are computed from past levels, sales, and shipments received. Sales and shipments received are recorded manually on sales receipts and shipment invoices at the points where the transactions occur. Twice a week, these documents are sent to a data entry clerk at the computer center who enters the information into the computer system, updating current inventory and sales levels. Once a week, the inventory ordering program is run to examine the current inventory level for each item and decides how much of the item to order.

This example is now mapped into the four-task structure provided above (see Figure 2). External Data (environmental signals of goods sold and shipments received) are transformed into Internal Data (sales receipts and shipping invoices) by multiple processes consisting of, e.g., a person with supporting equipment and supplies. Internal Data are picked up twice weekly from the sales and shipping locations and delivered to a data entry clerk. This clerk and the data entry and update portion of the computer system are included in a process within the Assimilation Task. This task transforms the Internal Data into Knowledge by updating inventory and sales levels within the computer system. Knowledge, then, consists of inventory and sales levels as well as models (embodied in algorithms) relat-

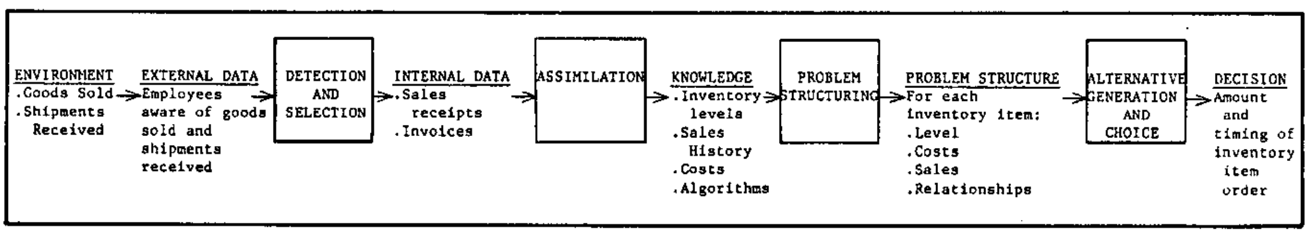

Figure 2. Decomposition of the Inventory Ordering Example

ing sales levels, inventory levels, and ordering and storage costs to firm performance. Firm performance is indicated by total inventory-related costs, including stockout penalties. Once a week, the Problem Structuring and the Alternative Generation and Choice Tasks are performed for each inventory item by a single process consisting of the computer system (hardware, software, operators, etc). The Problem Structuring Task chooses the appropriate models, sales levels, and storage and ordering costs for each inventory item. This model provides a Problem Structure for determining the optimal amount and timing of inventory orders. This determination is provided by the Alternative Generation and Choice Task which produces inventory ordering Decisions.

The Management Control Component is involved with providing resource coordination, problem triggers, and Mainline Component goals. In the inventory example, Management Control's coordination role includes: invoking the correct computer programs in the correct sequence (e.g., Problem Structuring before Alternative Generation and Choice); assuring that appropriate inputs are available (e.g., transporting sales and shipping documents to the data entry clerk and assuring that current rather than outdated documents are used as input); and running the weekly Decision Production programs only after the Knowledge Production programs. Problem triggering consists of running a program each week to focus on each inventory item and to determine if any ordering should occur. Note that problem triggering actually starts Decision Production (the Problem Structuring and Alternative Generation and Choice Tasks), while Knowledge Production may occur independent of specific triggers. Provision of goals for evaluation is illustrated by the example criterion of least inventory cost.

MODEL DETAIL

A closer look can now be taken at the various information states. Moreover, since each task can be defined in terms of changes to information states, the following examination will also serve to increase an understanding of tasks. Where appropriate, illustrations based upon the inventory ordering example are included.

<u>External Data</u> are defined as stimuli reflecting events occurring in the DPS environment. These stimuli can be manifest in many forms, including visual (e.g., reports), verbal (e.g., conversations), electronic or magnetic (e.g., computer input), etc. In the inventory ordering example, visual stimuli indicating the actual sale of an item was one form of External Data.

<u>Internal Data</u> are nonrandom representations of events "owned" by the DPS but lacking a cohesive problem solving organization. For example, Internal Data may be stored chronologically by date received, stored randomly, batched by event, etc. The DPS has no ability to recall these data in a cohesive fashion when responding to a problem. Sales receipts and shipping receipt invoices represented forms of Internal Data in the inventory ordering example.

<u>Knowledge</u> is an understanding of reality, an understanding of the levels of variables and the causal relationships between them. Knowledge need not be in the form of a comprehensive and cohesive scheme. It may take the form of overlapping, contradictory models stored apart from each other and from their associated variable levels. What differentiates Knowledge from Internal Data is the overall retrieval structure allowing relatively immediate recall of appropriate models and variables for a given problem. As Machlup notes, knowledge need not be knowledge of certified events and tested the-

ories; it includes conjectures and hypotheses no matter what their state of verification (1962, p. 23). Updated inventory and sales levels, as well as the models relating these levels and ordering and storage costs to total inventory costs, were included in the inventory ordering system's Knowledge.

A Problem Structure is an organized subject of Knowledge consisting of variables and models related to a specific problem. A goal of this Knowledge reorganization is a synthesis of, or arbitrary choice between, conflicting and overlapping models. In the inventory ordering example, a Problem Structure was created when the current inventory level of each item along with its sales history and ordering and storage costs were "loaded" into its associated model to predict total inventory costs.

Decision is a commitment to the action that has been chosen as a solution to a problem (Mintzberg, et al., 1976). Note that this includes what may be considered temporary or non-solutions, such as deciding that no action or change in current action is necessary. Decisions can be examined in terms of the alternative chosen (a description of reality) or in terms of the prescribed set of actions (implementation orders). The concern here is with the alternative chosen. Thus, a Decision information state consists of a description of reality and the corresponding predicted effects of variable changes implied by the alternative chosen. In this light, Decisions in the inventory ordering example consisted of the model of reality used, including the amount of inventory ordered and its predicted effect upon total inventory costs.

A general characterization scheme for information states is presented in Figure 3. This scheme is important because it serves as a basis for measuring the amount of an information state that is produced or input. Thus, the rules for creating a characterization scheme are the same as those for defining economic productive inputs. For example, characteristics must be independent of each other and of their effects upon outputs. This requirement allows input-output relationships to be experimentally determined rather than assumed within the definitions. At the same time, however, only those characteristics which have an effect upon production are of interest.[6] No claim is made that the characterization scheme offered is complete. Rather, it should be viewed as a partial shopping list of information state characteristics. The actual scheme chosen will depend upon the specific DPS (technology) and the specific information state being examined.

Note that characteristics are not viewed as descriptions of specific portions of information states (e.g., a datum in Internal Data), but as depictions of the aggregate information state. That is, one can think of the Figure 3 characteristics as averages during a production period.

MODEL APPLICABILITY

Thus far, the DPS model has been described as a system of neoclassical production units involved in transforming External Data to Decisions. Due to its neoclassical foundation, certain DPS assumptions restrict the range of decision contexts in which

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[6]Characteristics were developed on the basis of referents external to the Mainline Component. Three referents were used: the environment (reality), the Management Control Component (problem trigger), and physical descriptions such as volume, language, and medium.

CHARACTERISTICS APPLICABLE TO ALL INFORMATION STATES INCLUDE:

- Age: the length of time between the occurrence of an event and its appearance in the information state. For example, if sales occur evenly throughout the week and are entered once a week into a computerized inventory control system, then the average age of sales levels in, say, Knowledge is 3.5 days.

- Replication: the repetition of the same information in an information state. For example, multiple copies of a sales invoice.

- Conflict: the amount of contradicting descriptions in an information state. For example, two invoices depicting the same sale but indicating different quantities sold.

- Completeness: the closeness with which an information state tracks reality. The most complete would be continuous tracking, where variables are monitored constantly. Completeness in the inventory ordering example would include a measure of sales and receipts which occurred but were not stored.

- Detail: the lack of aggregation in the information state. For example, storing sales information as average daily sales would be less detailed than storing information on each sale.

- Scope: the portions of reality being described. In a temporal sense, large scope may include historical and forecast as well as current information. In a spatial sense, increasing the factors evaluated in forecasting inventory requirements to include, say, GNP and demographic items would increase the scope of the inventory ordering DPS information states. Note that aggregate information may have the same scope as detailed information. Visualizing an aggregation pyramid, where the same event is described by successively less volume of information, the same scope is evident at any level.

- Bias: the systematic error of information state descriptions when compared to reality. For example, if a data entry program truncates numbers it processes.

- Reliability: the lack of random error in information state descriptions when compared to reality. For example, transposition errors during data entry reduce information state reliability.

- Precision: the "exactness" of a description. For example, storing the average sales as a point estimate ($1,300) instead of as an interval estimate (between $1,000 and $2,000).

- Access time: the elapsed time required for resources to recall a portion of an input information state. Access time for Knowledge (stored in a computerized data base) in the inventory ordering example may be less than a second.

- Language: the symbolic way information is expressed in an information state. Examples include mathematic, pictorial, and verbal (English, French, etc.). The language in the inventory ordering system's Internal Data was mathematics and English.

- Medium: the physical substance within/on which the information is stored (e.g., paper reports, magnetic tape, human minds). Internal Data in the inventory ordering example was on paper reports.

- Volume: the size or rate of an information state. For states such as External Data, Internal Data, and Knowledge, volume can be measured as the number of symbols (forms, words, letters, bits, bytes, etc.) of which they are composed. For states such as Problem Structures and Decisions, the number of structures or decisions themselves may be counted. (Note: this is not the same as Shannon's measure of information in terms of bits per second: 1949.) For example, the volume of Internal Data in the inventory example may include the number of sales invoices and shipment receipts per week.

CHARACTERISTICS APPLICABLE ONLY TO DECISIONS INCLUDE:

- Decision response time: elapsed time between the problem trigger and its associated decision. In the inventory ordering example, the trigger for each inventory item occurred once a week and response time consisted of the computer processing time required to decide how much of that item to order. (Note that with the neoclassical assumption of continuous production, Decision response time is inversely related to Decision volume.)

Figure 3. Information State Characterization

this view is applicable. The following discussions examine important DPS assumptions in light of MIS research, to identify appropriate decision contexts. We will find that the DPS view is applicable to contexts that are more programmed, oriented toward management or operational control, and in a steady state with relatively high decision volume.

Simon's (1960, p. 5) notion of decision programmability provides a structure which can be used to identify decision contexts in accord with DPS (neoclassical) assumptions. As indicated by Thompson (1967, p. 134), Simon's continuum is a synthesis of the decision maker's certainty concerning beliefs about cause/effect relations and the decision maker's certainty concerning beliefs about cause/effect relations and the decision maker's certainty of preferences concerning possible outcomes. In this view, programmed decisions are those where cause/effect relations are known and preferences are well defined.

In neoclassical economics, optimization is the ultimate goal (Cyert and Hedrick, 1972). Optimization is conceptualized as profit maximization with subordinate goals of cost minimization and revenue maximization. Preferences associated with this view are thus nonconflicting and certain. In addition, it is assumed that the environment is deterministic; all future cause/effect conditions are known with certainty.

These goal and environmental assumptions seem to make the DPS (neoclassical) view more appropriate for describing programmed rather than nonprogrammed decisions. This limitation is somewhat mitigated when simple modification of the neoclassical structure is allowed. For example, if the goal of expected profit maximization is used (Hawawini, 1978), then an uncertain environment can be accommodated.

In an attempt to distinguished between different types of managerial activities, Anthony, Dearden, and Vancil (1972) provide a three-level managerial hierarchy. These levels are subdivisions of a continuum running from strategic planning, through management control, to operational control.

Among the many characteristics describing each hierarchy level, those of greatest interest are indications of the regularity with which problems are encountered and the elapsed calendar time between problem triggers and decisions. Anthony, et al. (1972, pp. 6, 7), indicate that while strategic planning is essentially irregular ("Problems, opportunities, and bright ideas do not arise according to some set time table..."), movement along the continuum toward management control and operational control increases problem regularity ("...follow a definite pattern and timetable, month after month and year after year"). This description of management control and operational control more closely fits the image provided by the neoclassical assumption of continuous and repetitive production, where outputs (here, decisions) are assumed to be produced at a constant rate. The long-term nature of strategic planning (Anthony, et al., 1972. p. 9) is also at odds with neoclassical assumptions. The longer elapsed calendar time (vis-a-vis management or operational control) brings into question changes in decision making technology, for the neoclassical view assumes that technology is constant during the production period; the "technical description" of resources employed, and the types of resources employed, must not change.

Keen and Scott Morton have combined the dimensions provided by Simon and Anthony to form a taxonomy of decision contexts. This taxonomy, shown in Figure 4, is reproduced from Keen and

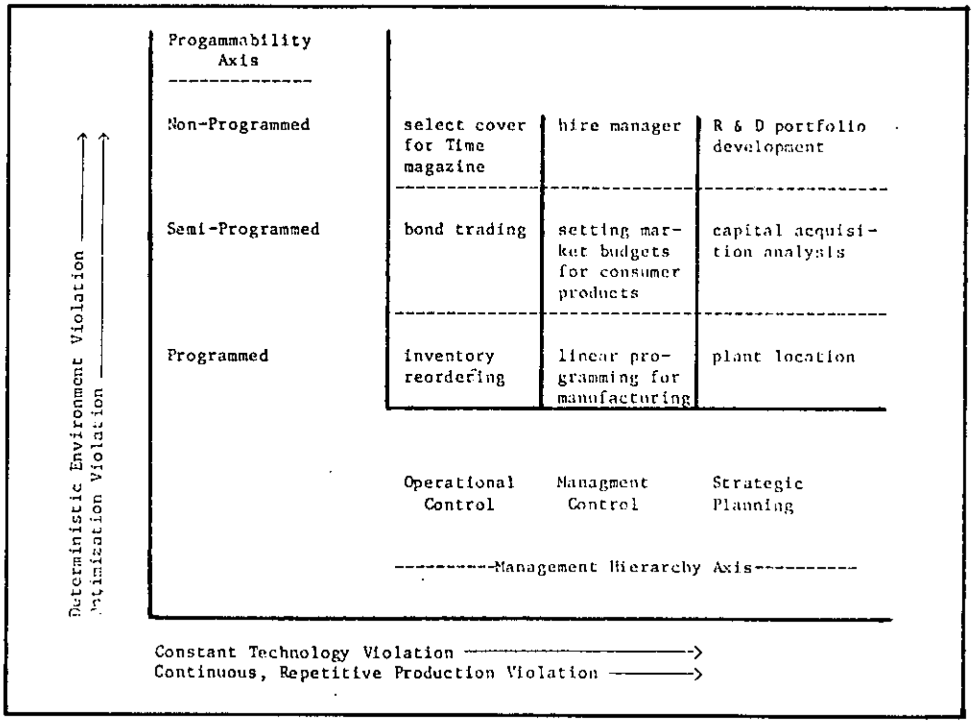

Figure 4. Keen - Scott Morton Framework And DPS Assumption Violations

Scott Morton (1978, p. 87), and will be used to summarize the appropriateness of DPS in terms of decision programmability and management hierarchy. Note that the programmability axis used here retains Simon's nomenclature for his continuum rather than adopting Keen and Scott Morton's equivalent continuum in terms of structuredness. Added below and to the left of the figure are neoclassical assumptions which are increasingly violated along each axis.

As illustrated, in terms of an accord with neoclassical assumptions, decisions such as inventory reordering are much more appropriate for DPS analysis than, say, R & D portfolio development. However, it does not necessarily follow that the DPS framework should be totally rejected for nonprogrammed and/or strategic planning decisions. There are at least two issues to consider. First, as Keen and Scott Morton indicate (1978, p. 92), there is a historical shift of problems toward the programmed end of the programmability dimension; as management science grows, more and more decisions are becoming programmed. Second, current work in microeconomic theory (e.g., including uncertainty and reducing dependence on profit maximization [Cyert and Hedrick 1972]) is decreasing or eliminating the effect of violations of neoclassical assumptions.

Two additional DPS assumptions potentially restrict DPS applicability. First, it is assumed that the DPS is in a steady state; the assumption of constant input and output levels and descriptions indicates that learning or improvement in the problem solving abilities of resources may not occur during the production period. This also implies that there is no interaction between problems; the order of problem solution does not affect production. Second, the assumption of a smooth production function indicates perfect divisibility of the number-of-decisions output. Though this is an obvious simplification, it is acceptable when a high production volume is being considered (Debreu, 1959, p. 30).

In summary, appropriate decision contexts tend to be those which are more programmed and more oriented toward management or operational control. In addition, steady-state production of a relatively high volume of decisions is assumed. Though this seems to restrict the applicability of DPS analyses, as Machlup notes (1955, p. 15), "When a simpler hypothesis, though obviously unrealistic, gives consistently satisfactory results, one need not bother with a more complicated realistic hypothesis." Thus, contexts violating DPS assumptions should not be rejected outright.

MODEL VALIDATION

A step toward validation of the DPS view resulted from a study of decision making during a simulated business game. The study and its results are briefly explored below. (A detailed discussion is in Cooper [1983].)

As part of an advanced marketing course at UCLA, MBA students participated in a computer marketing strategy game called MARKSTRAT (Larrache and Gatignon 1977). This game provides a business environment within which students compete against each other in producing and selling consumer goods. An indicator of student performance was devised by course instructors, and took the form of a stock price reflecting market share, current profit, and profit trend. Decisions required by MARKSTRAT can be characterized as relatively programmed and oriented toward management control, and thus, as discussed in the sixth section, fall within the purview of DPS analysis.

Because it is so robust (Intriligator 1978, pp. 276-278; Kimbell and Lorant, p. 49) and embodies neoclassicial attributes, the Cobb-Douglas function was used to describe MARKSTRAT data. Four functions were estimated. The first two were shadow functions, describing the Assimilation Task. Inputs to these functions were two characteristics of Internal Data derived from market research reports purchased by the students. Internal Data scope was measured as the variety of report types purchased, while Internal Data completeness was measured as the average number of times various reports were purchased. The outputs from these Assimilation Task functions were two Knowledge characteristics: Knowledge scope and Knowledge accuracy. Estimates of these characteristics were derived from self-administered questionnaires. (Note that Knowledge accuracy and Decision accuracy, mentioned below, are composite characteristics consisting of age, conflict, bias, etc.) Inputs to the third function, Decision Production, were Knowledge scope and Knowledge accuracy, and the output was Decision accuracy. Decision accuracy was derived by comparing students' forecasted stock prices with actual stock prices. The fourth function described firm production in general; Decision accuracy and Budget level were input and stock price was output. Budget level was used to represent all other firm resources. These four functions were estimated, and the results are depicted in Figure 5.

The research hypothesis for this study proposed that the DPS view could adequately describe MARKSTRAT decision making. The following two subhypotheses were used to test this research hypothesis:

H_1: The system of Assimilation, Decision Production, and firm production functions represents an appropriate decomposition of MARKSTRAT decision making.

Estimated Function	R^2	Significance	N
Assimilation:			
$K_1 = 5.03\ I_1^{.39}\ I_2^{.07}$	.30	.01	28
(.01) (.01) (.72)			
$K_2 = 14.97\ I_1^{.12}\ I_2^{-.02}$	.04	.60	28
(.00) (.34) (.91)			
Decision Production:			
$D = .001\ K_1^{2.35}\ K_2^{.81}$	.28	.03	24
(.10) (.02) (.50)			
firm production:			
$S = 1.34\ D^{.12}\ B^{.79}$	.78	.00	24
(.34) (.27) (.00)			

where:

- I_1 and I_2 are Internal Data scope and completeness, respectively.
- K_1 and K_2 are Knowledge scope and accuracy, respectively.
- D is Decision accuracy.
- B is firm budget.
- S is firm stock price.

(Note: Significance of t statistics for estimated parameters are indicated parenthetically beneath the functions.)

Figure 5. Estimated MARKSTRAT Production Functions

H_2: Each estimated function conforms with neoclassical assumptions.

Here, H_1 considers the overall appropriateness of the DPS view, and H_2 addresses the applicability of neoclassical assumptions. As described below, MARKSTRAT data were encouraging: H_1 was supported, while conclusions concerning H_2 were indeterminate.

H_1 was tested by comparing a directly estimated "complete" MARKSTRAT function with an indirectly estimated complete function. A complete function is one relating ultimate output (Stock Price) to initial inputs (Internal Data scope and completeness, and Budget). Direct estimation was performed by regressing Stock Price upon Internal Data scope and completeness and Budget. Indirect estimation was obtained by estimating each of the four separate functions, and then combining them algebraically to form a complete function.

H_1 is supported if the coefficients of the two complete functions are not significantly different. In fact, tests comparing the two functions did not indicate significant differences ($F_{3, 21} = 1.43$ a = .26).

The indeterminate conclusion for H_2 was reached using an approach described in Dayton (1979, p. 347) for combining a series of experiments. Briefly, the probabilities of a Type I error for all experiments are combined and evaluated as a chi-square. Here, each estimated function was viewed as an experiment.

Since the functions estimated were Cobb-Douglas, H_2 implies that all function coefficients should be between zero and one. The chi-square statistic testing whether all coefficients were between zero and one was 2.12, with eight degrees of freedom. This does not allow rejection at the .10 level, indicating support of H_2. However, since this test involves the comparison of estimates with an interval rather than a point, classical statistical testing is not very powerful. Therefore, a second, very conservative test was performed to evaluate whether all coefficients lie in a range <u>other than</u> zero to one. The resulting chi-square statistic was 1.34, with eight degrees of freedom, which does not allow rejection at the .10 level. It is the inability to reject this very conservative hypothesis which results in the indeterminancy surrounding H_2.

IMPLICATIONS FOR THE ASSESSMENT OF MANAGEMENT INFORMATION REQUIREMENTS

As stated earlier, a motivating force behind this paper comes from the multitude of MIS failures. One problem cited for these failures is the lack of a general theory of managers' information requirements. If a general theory addressing the interaction of MIS and managers were known, the following questions about the assessment of management information requirements could be answered:

- MIS Problem Identification - Does a problem or opportunity exist that would indicate MIS change is appropriate.
- MIS Understanding and Alternative Generation - How do MIS and managers interact, and what are viable MIS alternatives for the context being examined?
- MIS Requirements Choice - Given the context, which MIS alternative should be developed?

The following discussion illustrates some ways in which the use of a DPS theoretical perspective can facilitate answers to these questions. Note that the DPS view deemphasizes distinctions between "information systems" and "decision makers." Thus, guidance for assessing management information requirements is interpreted in terms of the allocation and use of decision resources and information state characteristics. Because of space limitations, implications for MIS problem identification and MIS requirements are briefly addressed first, followed by a fuller discussion of contributions to MIS understanding and alternative generation.

As described in Cooper (1983, Chapter 5), MIS problem identitifcation can be aided through the use of productivity and efficiency indices. These indices provide an indication of how productive and/or efficient decision making is compared to other decision making units (i.e., compared to a benchmark) or compared to cost-minimizing pinciples. Poor index evaluations point to potential DPS problems.

On the basis of neoclassical cost minimization, revenue maximization, and profit maximization, three DPS criteria for MIS requirements choice are proposed. As defined in the section entitled Economic Linkage, these neoclassical concepts translate to DPS efficiency, effectiveness, and optimality, respectively. The optimality criterion requires knowledge of DPS and firm production functions as well as associated costs and revenues. In situations where all this information is not available, the lesser (but consistent) criteria of efficiency and/or effectiveness can provide guidance.

MIS understanding and alternative generation can be enhanced as follows. With a DPS function describing a decision making context, one can determine the relative impact of a DPS input (decision resource or information state characteristic level) upon DPS cost, DPS output, and the productivity of other DPS inputs. In addition, if the firm production function is known, the effect of DPS input upon firm activities, costs, and outputs can be ascertained. With this knowledge, alternative DPS configurations can be evaluated in light of choice criteria, such as those presented above.

Even when specific DPS and firm production functions are not identified, the DPS view can provide more general insight into the assessment of management information requirements. Of significant value is the explicit recognition of planning and control (i.e., decision making) systems as an integral part of an organization's physical production process. Implicit in this view is not only the typical causal connection from planning and control to physical production, but also the converse: physical production systems affect planning and control. This bidirectional link, combined with microeconomic principles of resource substituion, reveals the potential of input substitution, both within and between physical and planning control systems. An example of this is described in Cooper (1983, Chapter 6), where inventory investment and planning and control inputs are shown to be substitutable in a manufacturing environment.

It is this more general view which provided a framework for constructing a predictive model of MIS use in a manufacturing context. The model was based upon a comparison of the conditions affecting the long-run average costs of producing production and inventory control decisions, using alternative MISs. The following is an example of what was found. A firm which can be characterized as having continuous production to stock, relatively simple product structure, and high production volume has an 80 percent better chance of implementing a useful material requirements planning information system than a firm characterized by job shop making to order, more complex product structure, and low production volume (Cooper 1983, Chapter 7). Providing the foundation for studies of this type is valuable for a better understanding of management information requirements.

In addition, DPS does not consider decision inputs as inherently productive.[7] This provides a less biased view of the critical interactions among all decision inputs. One implication of this view is a reduction of the traditional focus upon humans as decision makers. For example, it may be more appropriate to hire a new manager who is "compatible" with existing computer systems than to develop new computer applications.

CONCLUSION

This paper has briefly described a model that views decision making as a neoclassical production system. Though behavioral issues were addressed, this was no an attempt at behavioral modeling. That is, the DPS view is not what Leibenstein (1979) would call a micro-micro theory of economics, where the influence of individuals upon firm behavior is studied. Rather, DPS at-

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[7]This is in accord with Stabell (1982), who observes that computer systems are too often inappropriately assumed to be productive.

tempts to recognize decisions as merely another processing factor, much the same as power or steam, which has heretofore been unrecognized. Benefits of this view are both descriptive and normative. In a descriptive sense, this model provides a framework for examining and better understanding the decision making process; this allows a much more informed assessment of managerial information requirements. In a normative sense, this model provides guidance for evaluating the efficiency and effectiveness of information systems. As resources in the DPS, information systems can be evaluated in light of their productivity both within the specific DPS in which they are employed, and within the greater firm production system.

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