Managing the Computer Resource: A Stage Hypothesis

Richard L. Nolan
Harvard University

Based on the study of expenditures for data processing, a descriptive stage hypothesis is presented. It is suggested that the planning, organizing, and controlling activities associated with managing the computer resource will change in character over a period of time, and will evolve in patterns roughly correlated to four stages of the computer budget: Stage I (computer acquisition), Stage II (intense system development), Stage III (proliferation of controls), and Stage IV (user/service orientation). Each stage is described and related to individual tasks for managing the computer resource.

Key Words and Phrases: computer management, computer budget, computer expenditures, stage hypothesis, planning, organizing, control, computer resource

CR Categories: 2.41, 2.43, 3.50

Over the past decade, managements have diligently searched for the key to effectively exploit the computer resource in doing business. They have been quite successful in using the computer in the operating aspects of their businesses. Most firms have effective computer-based logistic and financial systems—such as inventory control, bill of materials, payroll, and accounts receivable. Computer applications for these operational aspects of businesses have been generally successful, even if occasionally marred by higher costs than anticipated. In contrast, managements have had only limited success in using the computer for strategic and higher level decision-making. Computer applications for middle-to-top management have almost always been plagued with incidents of user dissatisfaction [1].

Although "how-to-do-it" heuristics abound for use of the computer resource [2, 3], there is a dearth of generally accepted guidelines for effectively using the computer resource. Indeed, the lack of accepted guidelines for managing the computer resource has resulted in some skepticism as to whether normative theory for the use of computers in organizations is feasible with the current state of knowledge. The obvious complexity of management in general, and computer technology in specific, lends support to the skeptics' arguments. Organization theory eclectically draws upon the foundations of the social sciences, such as psychology and sociology, as well as engineering and biology. The study of the use of computers in organizations is a very recent offshoot of organization theory. At this point, only a rudimentary foundation exists for developing normative theory for the use of computers in organizations. Even the terminology abounds with imprecision. Nevertheless, the need for developing knowledge leading to computer management principles is great.

In spite of the need, however, researchers must carefully guard against pressures to prematurely attempt normative theory formulation. Research activities must first support a formative period where the set of variables exerting major influence on the management of the computer resource is identified, the behavior and interrelationship of the variables are determined, and finally, the generality and the major determinants of the variables are assessed.

Stage Theories

Stage theories have proved to be particularly useful for developing knowledge in diverse fields during their formative periods. For example, they have been used in the early development of knowledge in the study of biological growth and of galaxies. The study of economic development of nations in the 19th century was characterized by stage theory formulations. More specifically, Karl Marx theorized that nations pass through four stages: Primitive Culture, Feudalism, Capitalism, and Socialism or Communism [4]. Careful

This research was done under the auspices of the Division of Research and supported by the Associates of the Harvard Business School. Author's address: Graduate School of Business Administration, Harvard University, Boston, MA 02163.

formulations of these stages represented an important development in the field of economics; the characteristics of the stages and the study of movement through the stages provided a base for prescriptive theory formulation, such as that of John Maynard Keynes in his work, *The General Theory of Employment, Interest, and Money* [5].

Stage theories are based on the premise that elements in systems move through a pattern of distinct stages over a period of time and that these stages can be described. Kuznets states two guidelines for a stage theory: (1) the characteristics of each stage should be distinct and empirically testable; and (2) the analytical relationship of any stage to its predecessor or successor should be well defined—it must be possible to identify what processes cause an element to move from one stage to the next [6].

Two key characteristics of stage theory formulation are (1) the identification of elements and (2) the conception of their growth through time. The concept of an element is that it is generic to a particular field and that it can be specified by a set of attributes. For instance, behavior and physiology are two of the elements for stages of human development. Maternal dependence and communication are attributes which specify the behavior element, while physical size and appearance specify physiology.

The second key characteristic in stage theory formulation, the concept of growth over a period of time, is that the element changes as its attributes expand or contract in number and nature. For example, behavior changes as an individual progresses from only nonverbal communication to a combination of nonverbal and verbal (talking) communication.

A Stage Hypothesis for Use of Computers in Organizations

One of the most interesting phenomena of the use of the computer in business organizations is the behavior of the share of financial resources allocated to using it—roughly quantified by the computer budget. The computer budget typically includes the costs of the physical hardware, software, programmers, systems analysts, and management. It has generally reflected a growth phenomenon. The overall growth of the computer budget itself is not of particular interest given that the use of the computer is an accepted part of doing business and that most established companies have generally exhibited growth in sales and assets over the past 20 years. One would expect the computer budget to grow along with the growth of the company, though the growth might occur as a step function rather than a smooth, steadily increasing function.[1]

What is of interest is the *pattern* of growth for the computer budget and the associated techniques used to manage the computer resource. Figure 1 illustrates the computer budget curve for three companies studied in some depth.[2] The curves are estimates, and certainly there are some consistency problems due to the different account classifications from year to year and poor data for early years. They reflect the effects of many variables, including situational factors such as changes in the scope of the business, impact of centralization/decentralization moves, and major computer acquisitions. Nevertheless, a careful analysis uncovers a crude S-shaped curve behavior. The points of inflection of a generalized S-shaped computer budget curve provided the basis for the stage hypothesis. As illustrated in Figure 2, four stages, delineated by the points of inflection on the generalized S-shaped computer budget curve, are hypothesized: Stage I (slow annual increases after computer acquisition); Stage II (highly increasing annual increases—often over 50 percent per year); Stage III (decreasing annual increases, or even a decrease from the previous year); and Stage IV (slow, even annual increases). Applying the stages to the companies studied—Company A is experiencing Stage II; Company B and Company C are experiencing Stage III.

It is proposed that the computer budget curve will serve as a useful surrogate for representing the growth phenomenon for use of computers in organizations. Further, the *tasks* for managing the computer resource (i.e. planning, organizing, and controlling) are closely aligned with the growth of the computer budget. The tasks are detailed to accommodate the unique characteristics of the set of computer resources to be managed and the objectives to be attained. The stages and the rate of growth of the computer budget affect the way in which the tasks are executed, and determine where in the organizational structure responsibility and authority are centered for carrying out the tasks. Since the ultimate objective of research on computers in organizations is the development of normative theory, the *tasks* of managing the computer resource are the logical choice

[1] Computer systems usually can accommodate increases in volume of data (e.g. inventory orders) without major changes in the system configuration. For example, a supermarket chain increased its volume of business by 25 percent in one year. The centralized EDP department easily handled the increased volume. The effects on the other parts of the business were great: new warehouses, financing, changes in management structure. Growth or changes in applications, however, generally entail changes to the computer system. Of course, overall volume growth will eventually lead to a larger computer system.

[2] It would have been useful to have studied in depth the computer budget behavior of more than three companies. However, it was extremely difficult to find companies that had sufficient records and knowledgeable personnel who could interpret the historical records on the computer budget. The study of each of the companies was preceded by the author's three-year relationship with the managements through involvement in the Harvard Computer-Based Information Systems research report course. The author's on-site study for the actual research consisted of approximately five days at each company.

[3] The term "computer" as used here is meant to broadly include the actual computer and all the resources associated with using it in the organization (e.g. programmers, operations personnel, and materials).

[4] For an extended discussion of an analogy between managing the computer and managing the organization see [2].

Fig. 1. Companies A, B, and C computer budget behavior (annual computer budget dollars).

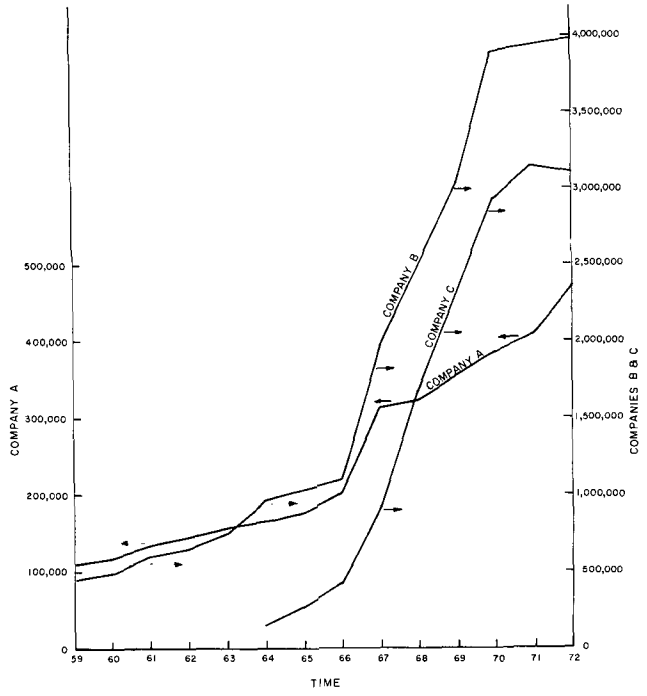
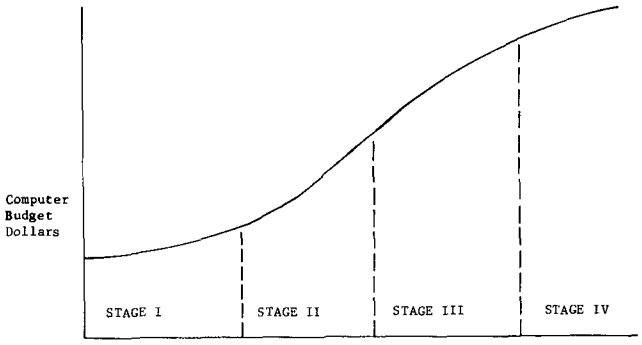


Fig. 2. Stages of computer budget growth.

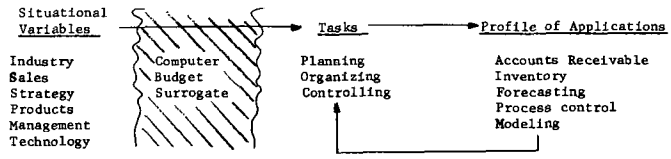


for the *elements* of the stage hypothesis. The tasks are generic to the field of organization theory.

As shown in Figure 3, the computer budget is a surrogate for the collective effect of multiple situational variables, such as industry, dollar sales, products, business strategy, management and technology, which determine the set and nature of the planning, organizing, and controlling tasks for managing the computer resource. The situational variables, together with a given set of tasks and their attributes, result in the profile of computer applications for the organization. Over a period of time, the profile of applications, in turn, influences the tasks.

A complete stage theory for the tasks of managing the computer resource must include an explanation for the effects of situational variables and the recursive effects of existing computer-based applications. Ultimately, it is desirable to functionally relate the situational variables to the tasks, and eliminate the need to

Fig. 3. Process of computer resource allocation.



use the computer budget surrogate. At this point, however, a complete formulation is too ambitious for a "do-able" research undertaking.

A manageable undertaking is to formulate a hypothesis on the relationship of the tasks to the hypothesized stages reflected in the growth of the computer budget. Both situational variables and effects of existing applications are confounded in the budget. However, for the three companies studied, the tasks seemed to be sufficiently associated with the computer budget growth so as not to be overwhelmed by the effects of situational variables or existing applications. The following description is based partially on the three companies studied and partially on generalized experience and discussions with computer managers.

General Description of the Stages for Managing the Computer

The stages for managing the computer[3] are descriptions of central tendencies for the number and nature of planning, organizing, and controlling tasks.[4] By central tendencies, I mean that the nature of the task and its associated attributes seem to be somewhat predictable by stage. Analysis of the computer activity in the three organizations studied indicated that the tasks change character over a period of time and that their attributes evolve in patterns roughly correlated with the computer budget growth. The intent, however, is to describe tasks by stage, and not to assert cause and effect relationships.

Computer budget growth	Stage description
Stage I	Initiation (computer acquisition)
Stage II	Contagion (intense system development)
Stage III	Control (proliferation of controls)
Stage IV	Integration (user/service orientation)

Stage I (Initiation). Stage I is brought about by the introduction of the computer in the organization. Typically, the computer is introduced into the organization for one of two reasons. The most prevalent reason is that the organization reaches some critical size in which certain administrative processes can be more effectively accomplished through mechanization. Increasing numbers of business transactions justify the capital investment in specialized equipment. Until recently, computer acquisition, either through purchase or lease, dominated the character of the Initiation Stage. Recently, however, low priced minicomputers, time-sharing, and computer utilities have made the computer resource available to organizations which could not economically justify

using computers for processing their data only a few years ago.

A second main reason for acquiring a computer is computation need. Engineering companies, for example, often acquire a computer to aid in the computational work, constituting the main profit-making activity of the business. In addition to the two main reasons for acquiring a computer, there are a host of less rational reasons: the competition acquired a computer, the desire to maintain an image of using the latest technology, and the belief that "computing is the wave of the future."

Management generally recognizes the fact that the computer will shock the organization. Thus attempts are made to assimilate it into the organizational structure with the least disruption. The original justification for the computer is typically a compelling cost-saving study. It is oriented toward use in one particular system such as payroll, billing, or inventory. The "low-profile" strategy leads to the assignment of responsibility for the computer to the department that performed the original justification (e.g. controller). If the original justification, however, is partially administrative and partially scientific (computation), an organization conflict for control over the computer often arises. In these cases, scientific and commercial programming groups may spring up and may keep the conflict alive through a type of competition for an extended period of time. This situation is more prevalent among firms in the aerospace and petroleum industries than in less scientific-based industries such as banking. It complicates the implementation of control devices like charge-out systems.

A short time into Stage I, it becomes apparent that the computer is a potent "change agent" in the organization. The computer necessitates a rigor and formalization typically never before experienced in the organization. Its high fixed cost structure focuses management attention on rapidly eliminating underutilization.[5] The forces for rapidly developing "production" applications create an environment which discourages planning, cost control, and quality assurance. The only control is imposed by programmers themselves. Organization for the computer grows rapidly and haphazardly. The incorporation of highly trained systems analysts and programmers also imposes on the organization a relatively foreign analytical approach, ridden with cryptic terminology.

Often even the strongest advocates for computing become alienated by it. The forces of a change not guided by planning techniques and constrained by control devices are too radical to be smoothly assimilated by bureaucratic organization. The result is "those who are committed to computing" despite previous experiences and "those who have become alienated by computing." The experiences engender what has come to be known as the "two-culture problem." People who are closely associated with computing recognize that their interests and motivations are basically different than those of operating management. Yet, to make their work purposeful, they are dependent upon effectively communicating with management. Operating management, on the other hand, begins to recognize that the computer resource is different than other resources that they manage. Effective management of the computer is dependent upon an awareness of the nature and potential for computing, which is acquired by working with those associated with computing.

Although senior management by this time has gained enough experience with the new resource to be tempted by the potential power of computing, it is, on the other hand, beginning to become sensitized to its dysfunctional effects: the way of doing business is changing too rapidly to be smoothly assimilated into the organization; tough internal control problems are leading to costly mistakes (e.g. out-of-stock conditions); and technological change on the job is causing human relations problems. Nevertheless, the managerial tendency is commitment to computing. The fallacy and realism of sunk cost seems to play no small part in the commitment. The computer is acquired, and old systems are converted to computer-based systems; the skills required to operate the old manual systems disappear. This managerial commitment (in one way or another) marks the transition from Stage I to Stage II. A manifestation of the transition is often an increase in the responsibility and reporting level of the manager of the computer resource. Assignment of responsibility for computing to a specific function, such as accounting, usually is attributed to be the cause of many of the planning and control problems. Raising the responsibility and reporting level is also a common technique used by senior management for reacting to problems.

Stage II (Contagion). Stage II is characterized by a managerial climate of concern for strategies to encourage alienated users to investigate the potential for computing. Generally impressive cost savings in clerical areas, as well as a few of the inevitable "spectacular successes" reported in the trade journals, give a "time is of the essence" element to the movement.

A number of characteristics designed to "spark" wide computer applications are observable during Contagion (Stage II). The need for emphasis on planning tasks is still not recognized. The job of the moment is to use up the capacity of the existing computer. (In extreme cases, studies are initiated on the economics of

[5] Upon acquiring a computer, a company usually does not have enough programs immediately developed to keep the computer busy. It is not unusual during the first six months to operate a new computer less than one shift.

[6] Professor Neil C. Churchill and I explored the Stage Hypothesis together in the spring of 1971. At that time we did not completely agree on the characterization of Stages III and IV. Professor Churchill characterized Stage III as the turning point where general management learns to manage *with* the computer, and computer management learns to *manage* the computer resource. Stage IV, then, was the maturing of that process. Professor Churchill preferred to characterize Stage III as the Restraint Stage, and Stage IV as the Control Stage.

selling on the outside the excess capacity.) Inducements include a general lack of project control and budgetary control. Once computer projects are initiated, the management posture is supportive, even if relatively high computer budgets must be absorbed in the process. In fact, most computer projects are noticeably devoid of any project control devices such as PERT or cost/benefit analyses. Centralized systems analysis and operations research groups often render nonchargeable services to user groups.

Inevitably, the capacity of the current computer becomes saturated. The seemingly continued burst of new applications leads to larger and expanded computer systems. More sophisticated computer systems lead to needs for greater specialization in the areas of operations, systems programming, applications programming, and management. Recruiting highly-trained, specialized people in a limited supply market results in a host of high salaries. The budget for the computer organization increases exponentially, and quickly soars to a point of crisis concern for management.

Stage III (Control).[6] Stage III is entered into as a result of the crisis. Management mobilizes a set of tasks to control expenditures for computing. Inefficiencies in computer applications are the most obvious and are usually the first target. Planning tasks are initiated in all aspects of the computing organization. A senior management steering committee is established to evaluate the systems plan and to establish priorities for future system development. Organization of the steering committee is accompanied by the increase responsibility of the EDP manager, which is often at the director or vice-president level. The tendency is to recentralize the computing activity. By this stage there has been a general realization of the potential effectiveness of computing in certain areas. The result is a high level of competition for the relatively scarce systems personnel. Budgetary controls and overall cost justification somewhat contain the competition. Nevertheless, the problem that prevails can only be accommodated by a higher level managerial committee for establishing priorities.

Formal project management and management reporting systems are instigated during Stage III and provide for the beginning of effective management of the computer resource. The existence of these systems leads to the need and development of standards for programming, documentation, and operations. Often there is also a shift to a user charge-out system for computer services. In the extreme case, the computer organization may be assigned profit center responsibility. Stage III, characterized by a myriad of control devices, is often an overreaction, with strong forces toward centralization.

Stage IV (Integration Stage). Stage IV is marked by the refinement of the control tasks and the elimination of the more arbitrary ones. There is an overall maturation of the tasks for managing the computer resource. Notably, the project control system and the management reporting system become integral components of the management function. Planning tasks become more comprehensive and are effectively linked to the budgeting process and the corporate formal planning activity. The EDP director may spend up to 30 percent of his time in planning.

The most dominant characteristic of Stage IV is a rethinking of the role of the computer resource in organizational goal achievement. The rethinking process is manifested by an upsurge of user empathy and by the need to create an organizational design which effectively "taps" user needs and brings about reconciliation of user needs to the unique comparative advantages of computer processing over other alternatives. The alternatives are evaluated in a manner which incorporates the economic concepts of out-of-pocket costs, opportunity costs, and cost/benefits.

In support of user-orientation, charge-out systems that may have been implemented in earlier stages may be modified to partial charge-out systems, or eliminated entirely. Systems analysts may be moved out into the functional user departments. There is an overall concern for effectively accommodating centralization and decentralization in the organizational philosophy and business strategy.

The transition into Stage IV is more subtle than transitions into the other stages. The computer budget continues to grow as more applications are developed and new technology is integrated, but the growth is slow and even. In addition, the efficiency of using the computer resource increases at a greater rate than the incremental dollars allocated to the computer resource.

General Task Descriptions for the Stages

Further analysis of the generic tasks for managing the computer activity and their relative existence and degree of sophistication for the three companies studied leads to the generalization for finer breakdowns of controlling, organizing, and planning tasks, shown in Tables I, II, and III, respectively. Rough descriptors are deduced for the attributes of the subtasks associated with the stages. Since none of the companies studied was considered to be in Stage IV, Stage IV descriptors are fully extrapolated. Although an underlying growth sequence is suggested, it is likely that a particular organization will find itself lagging or leading a stage for several attributes of the tasks.

Table I shows the *control* tasks and subtasks. In general, control tasks are at a rudimentary state or nonexistent (NE) in Stages I and II. During Stage III, the tasks initiated in the earlier stages become formalized, and new ones are initiated. Finally, in Stage IV, the control tasks are refined and reconciled with the organization's goals. Reconciliation with organizational goals is indirectly manifested. For example, system objectives are made more explicit and are developed in close conjunction with users. Users express support and respect for the systems organizations.

Table I.

Task	Stage I	Stage II	Stage III	Stage IV
Table I. Control Tasks and Stages.				
Priority setting	FIFO	Broad guidelines	Arbitrary	Estab. policy
Budget	NE*	Communication	Control	Control
Computer operations				
a. Scheduling	FIFO	Broad guidelines	Job shop	Job shop
b. I/O control	User†	User	Policy	Cent. policy‡
c. Security	NE	NE	Policy	Policy/stds.
d. Training	Apprentice	Apprentice	Prereq.§	Internal‖
Programming control				
a. Documentation	NE	NE	Initiation	Std. policy
b. Standards	NE	NE	Initiation	Std. policy
Project management	NE	NE	Initiation	Std. policy
Mgt. reporting system				
a. Project plan	NE	Informal	Formal	Formal
b. Project performance	NE	Informal	Formal	Formal
c. Customer service	Informal	Informal	Formal	Formal
d. Personnel resources	Informal	Formal	Formal	Formal
e. Equipment resources	NE	NE	Formal	Formal
f. Budget performance	NE	Initiated	Formalized	Formal
Data base policies	NE	NE	NE	Established
Chg. out/non-chg. out systems	Nonchg. out	Nonchg. out	Chg. out	Best system
Audits	NE	NE	Initiated	Formal
Quality control				
a. Computer system	NE	Initiated	Established	Sophisticated
b. System design	NE	NE	Initiated	Established
c. Programming	NE	Initiated	Broad policy	Standards
d. Operations	NE	NE	Initiated	Established
Manual systems and procedures	NE	NE	NE	Standards

Table II shows the *organizing* tasks and subtasks. Three growth characteristics of organizing tasks are important: (1) EDP director's organizational position, (2) steering committee, and (3) specialization. The EDP director's organizational position initially is relatively low, and EDP constitutes only a part of his functional responsibility. As EDP grows both in commitment of financial resources and diversity of computer applications, the EDP responsibility rises to higher levels in the organization. Generally the first move is to assign to higher level managers in the functional area a full-time responsibility. The progression then may continue to the establishment of a director outside a functional area with a title such as Technical Services Director or Administrative Services Director. In some organizations, the responsibility has risen to the level of the vice-president with titles such as Vice-President for Information Systems.

The steering committee consisting of higher level management is indicative of an awareness of the potential and importance of the computer resource. Typically, steering committees are initiated at Stage III, and at Stage IV they become a refined device for ensuring efficient resource allocation in respect to organizational goals.

Growth processes universally result in increasing specialization, and this is true for use of the computer resource. Specialized groups are formed for systems programming, application programming, operations, maintenance, and management.

Table III shows the *planning* tasks and subtasks. Virtually no planning takes place during Stages I and II, with the exception of conventional budgeting. During Stage III, relatively widespread planning is initiated, which becomes refined in Stage IV. At Stage IV, planning plays a dominant role in shaping management processes for using the computer resource into their "ideal" form in respect to organizational objectives.

Tables II and III.

Task	Stage I	Stage II	Stage III	Stage IV

Table II. Organizing Tasks and Stages.

Steering committee	NE*	NE	Initiation	Established
EDP Director's position	Functional area	Greater respon.	Director	Vice-president
Degree of specialization	Low	Medium	Medium	High
Research	NE	NE	Conducted by S.A.**	Separate function
Program maintenance	Haphazardly done	Loosely organized	Dominant activity	Well defined
Technical services	NE	Initiated	Established	Defined role
Modeling	NE	Initiated	Limited	Well defined
User/analyst teams	NE	NE	Encouraged	Organized for
Centralization/ decentralization	Decent.	Decent.	Cent.	Hard, cent.; S.A., decent.‡
Data base	NE	NE	Initiated	Important activity
Manual systems & procedures	NE	NE	NE	Incorporated‡‡

Table III. Planning Tasks and Stages.

Financial plan and budget	Part of other budget	Loose budget	Budget	Budget & plan
Technological forecasting	NE	NE	Initiation	Developed
Systems plan	NE	NE	Initiation	Developed
Operations and programming plan	NE	NE	Initiation	Developed
Equipment plan	NE	NE	Initiation	Developed
Personnel plan	NE	NE	Initiation	Developed
Conversion plan	NE	NE	Initiation	Developed

* NE, nonexistent
† User, no formal controls: left to user judgment
‡ Cent., centralized: Decent, decentralized
§ Prereq., prerequisite minimum standards
‖ Internal, internal training groups
** S.A., systems analysts
†† Hardware centralized and systems analysts decentralized
‡‡ Incorporated into the EDP system

Conclusion

The study of the use of computers by organizations is in a formative period. The existence of the formative period is evinced by the imprecise terminology in the area and by the lack of an accepted body of knowledge for effectively managing the computer resource. In recognition of this, the stage hypothesis is presented, not as a prescription for computer management, but as a plausible description of the process of using the computer resource in the organization.

The stage hypothesis is based on the expenditure patterns of an organization over a period of time. The expenditure patterns are quantified by the computer budget. While the computer budget measurement is crude at best, it does have the virtues of being quantitative and of being a reproducible measurement. It is a surrogate for the situational variables that directly determine the nature of the planning, organizing, and control tasks for managing the computer resource. Hopefully, the description of the tasks for managing the computer resource and the logic of their association with the computer budget behavior are strong enough to permit others to formulate empirically testable hypotheses on the determinants, development, and attributes of the individual tasks, which will ultimately provide the base for normative theory formulation.

Received February 1972, revised March 1973

References

1. Swift, R., Mack, M., and Descarpentries, J.M. *Unlocking the Computer's Profit Potential.* McKinsey, New York, 1969.
2. Ditri, Arnold E., Shaw, John C., and Atkins, William. *Managing the EDP Function.* McGraw-Hill, New York, 1971.
3. Wight, Oliver. *The Executive's New Computer: Six Keys to Systems Success.* Reston Pub. Co., Reston, Va., 1972.
4. Marx, Karl. *Das Kapital.* Regnery, New York.
5. Keynes, John Maynard. *The General Theory of Employment, Interest, and Money.* Harcourt, Brace, Jovanovich, New York, 1936.
6. Kuznets, Simon. *Economic Growth and Structure: Selected Essays.* W. W. Norton, New York, 1965, pp. 213–216.