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THE DYNAMICS OF CHANGE IN COMPUTING USE: A THEORETICAL FRAMEWORK

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INTRODUCTION

The use of computing in organizations has undergone extraordinary change since it began three decades ago. From its beginnings as a province of a few people in the accounting and billing operations, computing has evolved to the point that it is now an essential component in nearly all aspects of modern organizations. What accounts for this phenomenal change, and what has been its effect on organizations? Understanding the change of computing in organizations is important not only to help explain the present but it is essential for improving our ability to predict the future of information systems. This paper discusses change in computing in terms of two theoretical perspectives on the dynamics of computing, and concludes with an analysis of the forces affecting the dynamics of computing constructed by combining these perspectives.

THEORETICAL PERSPECTIVES ON THE DYNAMICS OF COMPUTING USE

Two theoretical perspectives are common in accounting for dynamics in computing use: rapid *changes in technology* leading to new and useful capabilities; and *changes in organizations* that use computing which alter the context within which computing takes place. We describe these two basic classes of change underlying the dynamics of computing in organizations, then discuss the interaction of these to develop a more complete picture of the complex set of phenomena that make computing dynamic.

The technological perspective

It is a commonly held view in the computing field that computer technology creates new capabilities and new enconomies that "drive" the use and evolution of computing in organizations. Consequently, much attention is devoted to research, development and diffusion of new physical technologies and processes for use of those technologies, which together provide the infrastructure of computing in organizations. Change in the technological infrastructure of computing can be usefully characterized in four areas: theory, physical devices, software, and methods for use. Each is summarized in Fig. 1.

The various components of computing technology shown in Fig. 1 are separated for explanatory purposes, but computing technology consists of all these components in systematic interaction. To understand change in computing technology, the interactions of the components must be recognized and understood. Four important interactions can be observed. First, there is a precedence in development that is common across the components. Major advances in theoretical computer science generally precede new advances in physical devices and software. Often, new advances in software are stimulated by the capabilities and constraints provided by new physical devices. And methods tend to follow other areas of development in the effort to improve the organization's means of utilizing and exploiting the advances made in those areas. As a general rule, then, advances in computing use follow a long history of theoretical and engineering advances made in the other areas of computer technology. While application environments provide the "proving ground" of advances in computing technology, and often suggest new directions for

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Major areas	Components	Primary directions of change	Features of change
Theory	Materials and electronics, algorithms and procedures, data structures and complexity analysis	New capabilities Optimization Increased peformance	Breakthroughs can really make a difference Considerable lag between new theory and application
Physical devices	Processors, RAM memory devices, secondary and mass storage devices, communications pathways and switches, sensors, and actuators	Increased performance Reduced production cost Greater integration for general- and special-purpose uses Greater standardization and interface	High leverage from change Changes are "discrete" Considerable time lag between laboratory and consumer applications
Software	Operating systems, utilities, data management systems, communications systems, applications systems.	Greater use of machine capabilities Greater flexibility and utility for users Increased use of standard, turn-key applications	Flexibility makes standardization difficult to achieve Tailoring reduces transferability
Methods	Information systems analysis and design	Automation and integration of techniques Expedite production of software Package and distribute computing tools to users	Life-cycle management of software

Fig. 1. Changes in technological infrastructure of computing.

research by highlighting needs, actual development proceeds toward application and not the other way around.

Second, this precedence of development and the characteristics of the different technology components combine to create a substantial time lag between advances and innovations and their incorporation. Theoretical proposals often take years to test and utilize, while the constraints of economic production in the creation of physical devices sometimes results in useful innovations never being made available to the market. This explains in part why there is such a substantial discrepancy between the "state of the art" in computing and the "state of the practice" in computing use. At the other end, in the user organization, the adoption and incorporation of a specific set of technology components often "freezes" the organization into those components for a considerable period of time. The investment must be amortized and paid off, and the costs of major changes to new components must be carefully weighed before they are adopted. This natural process of delay in organizational adoption and use of innovations also helps account for the difference between the state of the art and the state of the practice in computing.

Third, the process of change in the component areas often occurs across as well as within the areas. A prime example of this is the relationship between advances in physical devices and software, where many routines done by hardware have been taken over by software, and vice versa. Many of the major improvements in system performance of the past few years have come about by building hardware that incorporates specific features of given software systems, thus enabling more rapid execution of tasks. The creation of the Lisp Machine for using the Lisp programming language is a good example of this shift.

Finally, the changes in technological infrastructure illustrate that the goals guiding developments often embody trade-offs that cannot be easily resolved. For example, creation of more efficient software tools to make better use of hardware frequently constrains the utility of such software for users and programmers, while development of more user-friendly software usually places greater demands on hardware resources. There are ongoing efforts to create efficient systems that avoid this trade-off, but the task is difficult and compromises must be made. The fact that the goals for improvement vary from situation to situation means that there can be no universal solution to developing the "best" configuration of computing components.

The technological infrastructure for computing is perhaps the most widely investigated aspect of computing, and certainly is the aspect of most concern to those in the production end of computing technology. Many discussions of the growth and change in computing focus exclusively on changes in technological infrastructure. Such changes are fairly easy to identify and trace because they involve relatively discrete entities—new pieces of equipment, new programming languages, new releases of operating systems, new concepts for structuring data, or new means for controlling the development of software, or new applications for users.

Change in the technological infrastructure of computing plays a critical role in the overall change of computing use in organizations by altering the perceptions of organizational actors about the "possibilities" of computing. With each advance in technological infrastructure, and especially when such changes are integrated into existing packages of technology, new capabilities for applications emerge and new economies for using the technology are revealed. Over the past three decades, capabilities have increased dramatically, while costs as a function of capabilities have declined dramatically. This has continued to stimulate considerations of what is possible with computing in organization, and accounts for much of the growth in computing during that time. But technology alone cannot account for the success of computing, nor will an exclusive focus on technology reveal the dynamics of computing. In order to understand the dynamics of computing in organizations, therefore, it is also necessary to investigate the human and organizational contexts within which computing takes place.

The organizational perspective

The organizational perspective is relatively new to the computing field and largely the result of empirical social science analyzes of computers and information systems in real organizations [1]. In contrast to the technological perspective, it posits that organizational factors are the key drivers of change in computing. Organizations adapt the technology to fit their routine processes and the interests and agendas of key actors; they usually do not change to fit the technology. From the organizational perspective, changes in computing correspond to changes in organizational routines and the interests and agendas of key actors. Computing is used to create new opportunities and to respond to changes in organizational contexts.

Modern complex organizations share several key elements. First, they are purposive. Second, they produce most of their goods and services for external clientele. Third, they organize their work through a variety of specialized groups and explicit divisions of labor. These work organizations reflect both the demands of production and the results of critical negotiations about the distribution of resources. Fourth, they are work systems in which participants make decisions in and around their work rather than decision systems in which work is incidentally done. Thus, the physical work with and around computers influences what computing is done and how computing is used. Fifth, their participants are constrained by resources and organizational routines that are defined outside the formal boundaries of the organization. Sixth, their participants operate in a larger political and economic ecology that encourages them to select computing arrangements that give leverage to their negotiations in this larger ecology. Finally, organizations differ substantially in the nature and configuration of these elements—in purpose, in products, in the structure of work and decision making, in the nature of resources and other constraints, in their political and economic ecology, and in the role of computing. Thus, the number of factors that influence organizational differences are great, and each has its particular effect on changes.

Organizations experience a variety of different kinds of change, but only a few of these kinds of change are relevant to consideration of change in organizational computing.† Long-term trends and cycles are important, of course, but they are important to every aspect of organizations. Their special importance to organizational use of computing is too bound up in larger changes to be easily identifiable. Our concern must therefore rest with the more endemic and cyclical changes organizations undergo in the relatively short term (e.g. 20 yr), set against the background of major trends and cycles such as increasing technical and scientific knowledge and economic advances and declines. For this reason, we confine our concern to changes in organizational contexts for computing use.

The configurations of the foregoing key elements, both in time and organizational space, constitute the organizational contexts of computing. That is, they constitute the larger situations in which individuals and groups carry out their on-going concerns while they engage with computer-based technologies [2]. These organizational contexts influence the kinds and quality of computer technologies that organizations adopt, use and evolve. For example, organizations with critical on-going negotiations with outsiders might seek to develop computing arrangements to enhance their bargaining positions. In developing such arrangements, their choices might be limited by factors outside the organization's control such as labor markets, vendor supply practices, or competition from other organizations.

†We identify four different kinds of change: endemic, episodic, trend, and cycle changes. Endemic change is change that is a consistent feature of the organization. Most obvious here are changes in personnel. Few individuals spend more than 50 yr in any one organization, and most spend considerably less. Aside from death, which is the ultimate arbiter of organizational tenure, individuals leave organizations for many other reasons such as a career change, health problems, family reasons, or just personal preferences. And even when an individual stays with a single organization for many years, the roles they play in the organization change as they move from task to task and role to role. Other endemic changes organizations experience are fluctuations in the organization's fortunes as the environment around the organization changes. A good example of this would be the depletion of the resources of a mining company as it extracts minerals from the mines it owns. Other economic forces such as the fluctuating business cycle, economic dislocations, changes in labor markets and demographics, and changes in social conditions of business also affects the fortunes of organizations on a regular, although often intermittent, basis.

Second, there are major episodic changes, such as upheavals resulting from large-scale warfare, natural calamities, political and social revolutions, and economic disasters such as the Great Depression.

Third, there are major change trends that organizations tend to experience. These are longer in duration than the endemic changes, and for many organizations they are prevalent throughout the life of the organization. Good examples of such changes are sustained periods of national economic growth (e.g. the industrial growth from the end of the second world war to the present in many industrialized countries), improving technical and educational conditions, increasing governmental activity in the affairs of the private sector, continued growth in world population, and the long-term depletion of certain important resources. These changes can involve decline as well as growth, as with the dissolution of the British Empire from 1850 to 1950.

Fourth, there are change cycles that affect organizations. Good examples are cyclical changes in population demographics (e.g. the "baby boom"), changing political orientations of government (e.g. conservative to liberal), and over the long run, the rise and fall of national powers.

From the standpoint of the dynamics of computing, then, relevant changes in an organizational context include:

Change in mission—the kinds of functions and tasks that the organization performs; the purposes individuals bring to their actions.
Change in operations—the size, scope, or critical timing of the tasks it performs; the structure of work and decision making; the common practices and procedures of the organization.
Change in learning and knowledge—individual and institutional memories and capabilities.
Change in social relations—political coalitions, conflict and cooperation; leadership styles, ideology, power bases.
Changes in resources and constraints—economic fortunes; competition.

There is no uniform way to describe the dynamics of organizational change. Changes are not monolithic or monotonic. Organizational change is unlike changes in technological knowledge, which, barring exceptional circumstances (e.g. the decline of technically sophisticated cultures periodically through history), are unidirectional toward greater knowledge. Individual organizations, and even whole organizational sectors, can come and go relatively quickly.

Accounting for organizational change requires attention to the characteristics of the specific organizations. Organizations in the same locale, doing the same kinds of things, using similar technologies, and with similar goals can be radically different in their behavior and in their success at accomplishing their goals. There is as yet no uniform means of specifying organizational change. Nevertheless, we identify six factors that seem to influence the success with which organizations can adopt and utilize computing technology. These are:

Size—the larger an organization, the greater the likelihood that it can afford to adopt new technologies, although there is also a greater likelihood in some cases that innovations cannot be adopted and implemented rapidly due to prevailing organizational inertia.
Wealth—wealthier organizations are much more likely to be able to afford adoption of, experimentation with, and routinization of new technologies.
Complexity—the greater the complexity of an organization (in either the things it does or in the means with which it does them), the greater the difficulty in adopting technology uniformly. However, there is also a greater likelihood that specific innovations will be adopted readily by decentralized organizational units.
Longevity—the longer an organization has been around, the greater the likelihood that it will be able to adopt and implement new technology. However, it is also likely that such organizations will be comparatively slower to adopt than new and innovative organizations.
Innovative style—an organization that embodies a faith in technology and innovation will be much more likely to adopt and implement such technology and innovation.
Technological dependency—organizations that depend heavily on the use of particular technologies to carry out their objectives will be much more likely to adopt future innovations in these and other technology areas.

The key issue in determining which aspects of organizational context will influence the use of computing technology, and thus affect changes in use of the technology, is identifying the means by which choices among various technological opportunities are made, implementations are designed, and control over uses of the technology are established. To investigate these issues we will next review several models of the growth of computing in organizations.

MODELS OF CHANGE IN COMPUTING

The basic issue in integrating the technological and organizational perspectives is to determine the processes of change and the drivers of change in computing use in organizations. Processes of change can be identified by historical analysis of the ways in which computing technology has been adopted and used in organizations. From these accounts, and the factors that underlie change in each account, we can develop models of the drivers of change. We review here three models of change in computing in organizations taken from the literature of computer science, information systems and social science that concentrate on (1) the growth of systems in use, (2) the

	Evolution of Administrative and Business Systems			
Application characteristics	Least complex ---→ Most complex			
Category of hardware system	Basic batch electronic unit record plus magnetic tape	Expanded batch electronic unit record, magnetic tape, small capacity disk storage	On-line inquiry electronic unit record, larger disks, typewriter, and CRT terminals	Distributed computing, large disks, remote terminals (minicomputers, CRTs), data communications devices
Cost to develop an application system	Less than $50,000	---- increasing to ---		→ $000,000's to millions
Time required for development	Several man months	---- increasing to ---		→ Several man years (2–5 plus)
Degree of integration with other application systems	Low, normally one department served	More than one department served	Several departments served	High, many departments served
Degree of difficulty of development and implementation	Simple, mostly internal to data processing dept.	Relatively simple, some technical problems	Relatively difficult, operational problems in manipulation	Difficult, often large operational as well as technical problems
Criticality of computerized system to departmental operation	Low, manual backup always possible	Medium, manual backup usually possible	Medium, manual backup difficult	High, manual backup almost impossible
Organization level at which commitment needed for development and implementation	Manager of department requesting the system	Manager of department requesting the system	Vice president	President, top managing executive
Type of benefit	Clerical savings	Primarily clerical savings, some improvement in management control	Improved customer service, improved management control	Cost reductions, improved service, improved management control
Magnitude of benefit	Small, but demonstrable and immediate	---- increasing to ---		→ Large, difficult to quantify in advance, gained over time
Amount of user participation required in systems development	Limited, generally not critical	Needed in design phases	Needed in all phases	Extensive, critical to project success
Amount of user participation required in systems operation	None	Limited to coding of input data	Moderate, for inquiry operation	Extensive, user runs the system from terminals
Response time of system to user request for information	Week(s)–days	Days	Minutes–seconds	Minutes–seconds
Historical time frame of first systems	Early 1950s	Mid 1950s	Late 1950s	Late 1960s

Fig. 2. The GTS model. Source: Glaser *et al.* [3].

characteristics of systems in use, (3) the uses to which the systems are put, and (4) the factors that influence the changes in each of these.

Three models

The three models we use are those of Glaser *et al.* [3] Nolan [4–6], and Kraemer and King [7]. Although these three models are not the only models present in the literature (see e.g. [8–13]), they are the most representative of classic differences in theoretical perspectives on the dynamics of computing in organizations. Each is briefly described next and then compared and contrasted for what they reveal about the dynamics of computing.

The GTS model [3] posits that computer use in organizations "has followed the expanding hardware and software capabilities of the computer" (p. 26). It is clearly rooted in the technological perspective, and in technological determinism. Four broad stages (which are shown in Fig. 2) characterize computing's development in organizations:

> *Basic batch*—the least complex level of computer processing where application systems are made up of small programs that are run through the computer one by one and which process transactions only from sequential files.
> *Expanded batch*—a somewhat more complex level of computer processing where programs are larger and involve further automation of manual functions, perform complex computations and produce reports that analyze performance (not just report it as in basic batch), and where a small capability exists for processing transactions in random sequence.
> *On-line inquiry*—a level of computer processing that results from adding to expanded batch systems the capability to access immediately, by terminal, any record that is stored in the computer's disk files and the capability to process transactions that are not in a numerical sequence.
> *Distributed computing*—a level of processing where systems consist of combinations of large central computers, data communications networks, and remote terminals that enable terminal operators located remotely from the central computer to carry out complete operations [3, p. 26].

According to the GTS model, growth in the use of computing is a function of the organizational benefits derived from the technology's use and the continuing underlying advances in the technology itself.† It is the advances in the technology which set the stage for the organizational benefits. Specifically, it is the interacting phenomena of increasing capability and facility at decreasing cost per unit that are at the heart of the positive economics of computer use and that produce the benefits of both efficiency and effectiveness for users. Thus, it is technology which sets the stage for organizational benefits derived from computing, and it is continuing advances in technology which enhance the benefits derivable from each successive stage of computing's evolution.

In contrast to this model based primarily on technological determinism, Nolan's "stage theory" of computing posits is that organizations *selectively adapt* to changes in the technological infrastructure of computing in response to features of their internal and external environment. To capture the characteristics of change in computing, Nolan made the assumption that changes in budgets for computing can serve as a surrogate measure for change in a wide variety of environmental and technical variables, including changes in industry conditions, corporate sales, organizational strategy, management practices, and uses of computer technology. Plotting the changes in budgets for computing in a number of firms revealed that budgets seemed to grow according to an S-shaped curve. This led to a second major assumption: that the turning points in the budget curve (shown in Fig. 3) are transition points between stages of growth. The turning points A, B, and C in Fig. 3 break the S-curve into four stages. From here Nolan made a third

†Chief among these are technical advances in: (1) computer performance per dollar; (2) operating systems software; (3) application development facilities, notably programming languages and aids; (4) purchasable ready-to-run application packages; (5) communications technology; (6) terminals, both for human and machine interconnection; (7) data processing capabilities furnished by outside specialists such as service bureaus and remote computing services; and (8) education of developers, users and managers [3, p. 24].

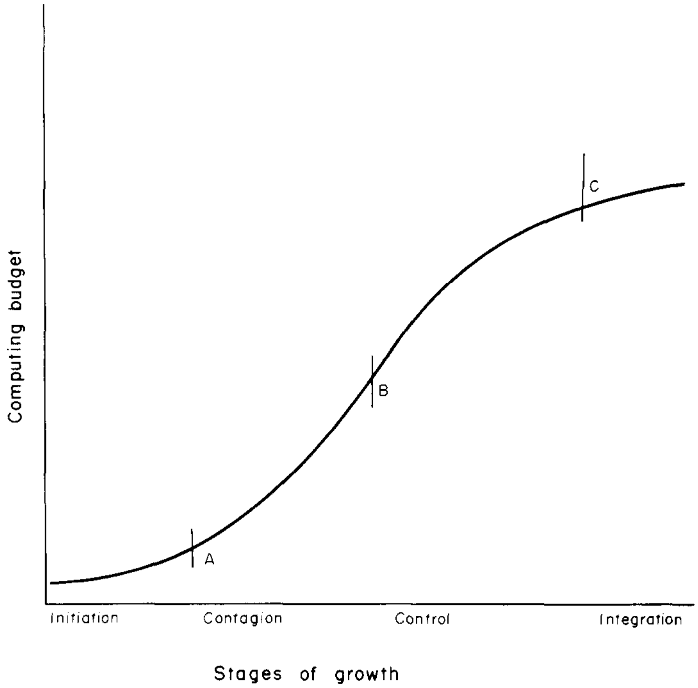

Fig. 3. The Nolan basic model.

major assumption: that these stages "capture the central tendencies" of the major tasks in the management of computing: planning, organizing and controlling.

Working backward, the logic of the model runs as follows: the major activities in the management of computing are identifiable in stages that correspond to periods of stability along the growth path of computing use; the stages can be traced by change in computing budgets which acts as a surrogate measure of environmental and technical variables that make up the computing phenomenon in an organization. Management practices related to computing are thus explained as responses to environmental and technical changes. The four stages from Nolan's early model [4] are as follows:

Initiation—introduction of computing into the organization to meet basic needs; slow growth in use; beginning of problems caused by computing's role as a "change agent"; little management response to these problems; decentralized control of computing and minimal planning.

Contagion—top management commitment to exploiting computing's potential plus great expectations among users brings major growth in computing; costs rise rapidly; a cost crisis stimulates top management to search for controls to contain costs; centralization of computing begins; planning remains weak.

Control—top management institutes cost control measures; planning becomes a major priority; the computing function is centralized; the DP manager's position is raised in the organizational hierarchy; priority setting is mandatory; standards are established for programming, documentation and operations; chargeout systems are adopted to impose market-like constraints on use; controls often prove to be too stringent, resulting in failure to exploit the potential of computing or to meet user expectations.

Integration—controls refined to allow exploitation of computing without runaway costs; planning is well established; users are more knowledgeable and capable in their uses of computing; cost-benefit analysis is used to set priorities for new systems; chargeout systems modified to ease restriction on use; system analysts sometimes decentralized to encourage improved systems development; centralization/decentralization decisions now made in light of organizational and business strategy; growth of computing slows markedly, but new investments bring greater marginal benefits.

Characteristics	Stage of development: Introduction and conquest	Experimentation and expansion	Competition and regulation	Reassessment and consolidation
Type of policy and major issue	Constitutive policy—How set up framework for computing? Whom should it serve?	Distributive policy—How distribute computing among other departments in the government?	Regulatory policy—How regulate competing demands for service and for priority?	Redistributive policy—How reallocate computing services to ensure attention to government-wide priorities? How share data?
Nature of EDP	Initial adoption of computing in larger governments; computing resources plentiful; uses involve large volume routine clerical tasks which are merely "computerized"	Early development of computing; few applications extant; expansion outside finance to utilize resources and to justify more resources	Middle stage of development; applications in many departments; high demand; limited resources to satisfy demand; regulation needed to sort out demands; uses more advanced and sophisticated than earlier	Mature stage of development; re-examination of application development patterns; emphasis on government-wide priorities; emphasis on top management uses; new technology; integrated data bases
Participants and basis for coalition	Top management and finance department; joint interest in revenue maximization/cost savings and/or financial reform	Users in all interested departments; log-rolling; everybody gets some share in computing	Multiple user departments; users begin to to see their interests as aligned with others	User groups organized along lines of big users and small users; chief executive's interest in government-wide database joined with "data have-nots" and analytic types to foster integrated systems
Political interactions	Finance department defines the criteria for computer use; all would-be users must deal with finance	Each use or application is developed independent of one another; users do not interfere with one another's activities; coalition of users with finance to expand EDP	Conflicts arise over priorities for development and operation; small users unite against big users; no stable power structure	Structure of computing is stable but new conflicts arise over data sharing and use; cooperation demands increase among data providers and data users
Locus of decision	Finance department with top management assent	Individual departments indicate their needs	Top management; computing centralized in an EDP department under the chief executive	Chief eecutive and inter-departmental user committee
Decision-making process	First priority given to finance applications	Decisions made without regard to limited resources; departments get what they ask for	Multi-department user committee established to regulate demands and priorities; planning, charging and other mechanisms instituted to regulate demand; decisions involve choice about who will be indulged and who deprived	Proposals for computing use scrutinized from perspective of contribution to top management and government-wide needs
Political impacts	Resources shift to the finance department; other departments dependent upon finance department for computing whereas previously they had been independent	Every interested user gets some computing; those who control computing (finance) get more	EDP department gains status, prestige, and some measure of independence due to its monopoly of expertise; regulation directly raises costs of computing in terms of time and money; regulation expands the alternatives for some users and reduces them for others; competition means that departments must develop some independent capability	Computing reinforces the existing patterns of power and influence in the government; potential for political impacts from the differential ability of departments and top management to use information in computerized systems

Fig. 4. The KK theoretical model. Source: Kraemer [14].

Growth stage	Computing environment	Computing impacts	Computing problems	Management policies	Illustration
I Introduction and conquest	Recent adopters Low local computing capacity and staff expertise Few applications, usually batch, in a few departments Slow application growth Computing located in finance department, a shared facility, or a service bureau Functional decentralization	Some impacts of improved speed and accuracy in routine data processing applications, and in cost avoidance	Moderate to major problems with responsiveness, staff, support and knowledge	No local policy board Low or "remote" manager and user involvement Low orientation and training for managers and users Control of computing is in the hands of the "owner" of computing resources Use shared facility, service bureau or small local installation	Smaller OECD cities with shared computing
II Experimentation and Expansion	"Middling" adopters Moderate local computing capacity and staff Slack computer resources Rapid application growth and expansion to many departments Computing located in finance or independent department	Established improvements in speed, accuracy, and cost avoidance in routine applications New capabilities for improving service delivery being explored Very early management and planning applications yield minor decision-making improvements	No problems or moderate problems with EPD staff, technology, responsiveness and resources	No local policy board Low to moderate involvement of users Low to moderate orientation and training of managers and users Technology expanded and moderately upgraded Control of computing under the chief executive	Small and moderate-sized URBIS cities
III Competition and regulation	Early adopters Large sophisticated computing capacity and technical staff; being overloaded Many sophisticated applications in many departments Application growth is marginal, in areas already developed Extensive demand for maintenance and modification of equipment, software applications Computing located in an independent department	No new improvements in speed, accuracy or cost aviodance for routine applications, and in some cases reduced payoffs due to system obsolescence; impacts on decision-making and planning more common from management and planning applications as applications expand	Moderate to major problems with EDP staff, technology, and resources No support problems	Use policy board or interdepartmental committee Centralize computing in a local installation High management and user involvement Intensive management and user orientation and training Control of computing shared between chief executive and policy board Advanced technology is used	Larger URBIS and OECD cities

Fig. 5. The KK empirical model. Source: Kraemer and King [7].

In contrast to the foregoing two models, Kraemer and King's model assumes that the organizational context rather than technological infrastructure is the driving force behind the evolution of computing in organizations. Their theoretical model [14] uses an underlying tenet of the other two models, namely the growth of computing can be usefully portrayed as a series of stages, but the key feature of their model is that organizational policy and politics drive the evolution of computing. Four types of policy and political relationships are defined as relating to various stages: constitutive, distributive, regulatory, and redistributive policy. Briefly, constitutive policy is concerned with setting up a system, distributive policy with husbanding a system, regulatory policy with regulating the system, and redistributive policy with manipulating the existing system to achieve greater equity. Their theoretical model with four stages is shown in Fig. 4.

Their empirical research [7] describes the characteristics of cities in three of the stages as follows (see also Fig. 5):

Introduction and conquest—recent adoptors with little computing capacity and staff expertise; basic-mode computer applications serving only a few departments; experience slow application growth due to limited development funds and lack of local knowledge about the technology; demand for computing is low and centered primarily around the perceived needs of resource controllers (finance and administrative uses); have problems generating support for the technology, communicating with users, and responding to users' needs; primary payoffs are in speed and accuracy of operations and cost avoidance.

Experimentation and expansion—middling adoptors with moderate computing capacity and staff expertise, recently upgraded hardware capacity, slack computing resources relative to current demand, extensive applications development underway in many departments, and utilizing a newly formed independent computer department; relatively few operational or user problems; experienced users satisfied with service and new users enthusiastic and promotional about developing applications; slack computing resources allow handling increased demand; payoffs arise from further integration of applications into the organization's operations and from primitive applications to planning and management.

Competition and regulation—early adoptors of computing with large, sophisticated computing capacity and technical expertise in a single central installation and many sophisticated applications serving many departments; computer and staff capacity overloaded by maintenance demands and development demands; communication problems between DP and users; competition among departments for available computing resources; interdepartmental boards and committees to resolve conflict and problems; managers and users become more involved in DP decision making; effectiveness payoffs derive from applications of computing to planning, management and control.

A number of significant differences in perspective are evident in these three models. The GTS model focuses on technical characteristics, especially on the nature of computer processing and by inference, the integration of computing into user tasks. The Nolan model focuses primarily on the growth in use of computing within organizations from the perspective of organizational exploitation of computing potential and control over computing costs. The KK model focuses on the political/economic relationships within user organizations governing the amount and kinds of computing activities that take place.

The GTS model generally ignores organizational context. It focuses instead on the emergence of technological capabilities and their subsequent adoption by organizations, with consequent effects on the way organizations use computing in their operations. The Nolan model incorporates both technological change and organizational context, but mainly from the view that technology changes rapidly while organizations change more slowly and essentially adapt to the technology. Moreover, organizations learn how to accommodate changes in technology in a manner that facilitates realization of organizational goals. The KK model concentrates primarily on the organizational context of computing growth, taking the technology largely as given. Some change is recognized, particularly change in the "affordability" of computing for the organization. But the major focus of the model is on the political/economic factors of adoption and deployment decisions.

Model	Focus	Theoretical perspective	Primary drivers of change	Key concepts
GTS model	Integration of computing into organizational tasks	Technological imperative	New technological capabilities that correspond, by implication, to organizational needs	Growth in computing A function of organizational benefits derived Organizational benefits enhanced by technology advances
Nolan model	Growth in the use of computing in organizations	"Adaptation" of organization to technological change	New technological capabilities that meet expressed organizational needs	Long-standing, clear-cut organizational needs drive growth of computing Resource constraints place limits to growth Management control matches needs with resource constraints Organizational learning permits control to become finely tuned
KK model	Dynamics which govern computing use in organizations	"Interaction" of organizational context and technology	Interests and agendas of dominant organizational actors are served by adoption of technical capabilities of computing	Routine organizational information processing activities create endemic demand for computing Critical negotiations among actors generate demand for computing as a strategic affective resource Allocation of computing capacity to demands follows political/economic ecology of the organization

Fig. 6. Comparison of models of change in computing.

None of these models are comprehensive explanatory theories. They are descriptive accounts of the changes in computing over time. However, we can use these models to develop insights into the characteristics of computing.

Characteristics of computing dynamics from the models

These three models provide different views on the characteristics of computing dynamics. Most importantly, each offers a different perspective on the *drivers of change* in computing. The GTS model focuses primarily on changes in physical devices of computing technology and on instruction sets that control these devices: processors, communications, control software, data management capabilities, and applications software. The fact that organizations have adopted and implemented these technological changes is taken as given, and the implication is that the changes in technological infrastructure result in their adoption and use. Of course, it is implicitly assumed that these technological advances are adopted for some reason by the organizations that use them, but the reason is not specified. Technological infrastructure in this model is the primary, if not the sole, driver of change in computing in organizations.

The Nolan model incorporates organizational context as well as technological infrastructure in its characterization of change, but it also sees change in technological infrastructure as the primary driver of change in computing organizations. Growth in the use of computing is explained as a process by which the opportunities created by a new technological capabilities are exploited by organizations to meet endemic and long-standing needs. However, given the constraints of resources in organizations such growth must be limited. The Nolan model therefore addresses the additional question of how and why limitations on computing growth come to pass. The mechanism is a simple one: given a finite amount of resources to devote to computing, the organization must select the "best" configurations and applications of the technology, which is done through a process of experimentation and building upon increasing organizational knowledge. Technological infrastructure changes are the basic drivers of change, while organizational adaptations to use of the technology are reactions to this change. One such adaptation is the quest for productive exploitation of the technology in light of prevailing organizational goals.

The KK model pays less attention to the technological infrastructure, and concentrates instead on the prevailing political/economic decision-making patterns within the organization. Technological change is recognized as a factor in making new opportunities available to the organization, but many such opportunities arise from a variety of sources (e.g. new markets to exploit, growth opportunities). Technological change is only one of several change factors affecting the political/ economic equilibrium of organizational decision making.

Implicit in the KK model is the presence of an endemic bias toward exploiting new opportunities within the prevailing constraints of budget and other resources. Initial adoption and expansion of computing is relatively easy, but when the demands of computing use begin to affect the political/ economic context of deployment decisions in the organization, well-established mechanisms of resource allocation begin to emerge to govern computing decisions.

In the KK model, then, the primary driver of change is the continuing organizational *demand* for exploitation of new opportunities, of which computing is one. The process of computing growth proceeds from this demand, and is dramatically influenced by changes in technological infrastructure because such changes continually upset the equilibrium of political/economic allocation decisions. The means by which the organization copes with such changes are highly dependent on bureaucratic processes and the ideology of key organizational actors. Overall organizational goals are not assumed to be static and consensual. Rather, goals are in a state of constant flux as new opportunities become available and the perspectives of key organizational actors regarding the leverage potential of computing changes.

Each of the above perspectives on the drivers of change will lead to different theories about the growth of computing in organizations. The GTS model suggests that as long as technological changes continue toward increased capability and economy there will be steady growth in the use of computing. The Nolan model assumes that continued change in technological infrastructure requires continued change in organizational knowledge about how to exploit the technology, and that organizational learning facilitates exploitation of the technology to achieve organizational goals within the constraints of organizational resources. The KK model assumes that the primary causes of change in computing are the continual shifts in the political and economic fortunes of organizational actors who recognize and exploit changes in computing technology opportunities in order to accomplish their personal and institutional objectives within the constraints of organizational resources.

The GTS and Nolan models are relatively simple, which makes their use in explaining the dynamics of computing easy and straightforward. However, we find them to be weak descriptors of the actual experiences of organizations in adoption and use of computing. They are also very weak as bases for predicting changes in computing over time. The KK model incorporates a broader view of organizational context, and downplays the role of change in technological infrastructure, but it is more difficult to implement as an explanator of change in organizational use of computing. In order to make use of these various perspectives on the dynamics of computing, we must develop a framework that allows us to select from each its most useful features. This requires development of a general characterization of the major forces in the adoption and use of computing innovations.

FORCES AFFECTING CHANGE IN COMPUTING USE

We can factor the major forces behind computing adoption and use into two classes.† First are "supply–push" forces. These include changes in technological infrastructure, especially the improvements in capabilities and price/performance ratios so evident in the recent history of the infrastructure for computing. Also included in supply–push forces are two which are not as commonly recognized: the concerted marketing efforts of suppliers and vendors of the technologies, which in some cases actually can fabricate demand; and longer-term business strategies of suppliers that eliminate support for older technologies and force migration to new ones.

Second are "demand–pull" forces. These include the implicitly recognized endemic demand for computing recognized in all three models above. Endemic demand would include standing organizational needs for faster and more accurate means of doing routine information processing tasks such as printing of bills, managing accounts, and keeping records. Also included would be the endemic demand for improved means of dealing with environmental uncertainty in planning and management. Any computing innovation that meets these endemic demands within affordable means is likely to be adopted. Demand–pull forces also include some things not normally recognized: institutionalized demand, which refers to the need to continue to support and improve the use of a practice or technology once it has been adopted (i.e. dependency on the technology that creates ongoing demand); and affective demand which includes created demands for use of computing that are not normally recognized as "legitimate" in the sense of organizational welfare (e.g. to exploit the entertainment value of computing, to capitalize on the leverage computing provides in other resource allocations, or to use computing to increase perceived status).

In using these factors to understand the change of computing in organizations, a first question is "which is the dominant force?" This is a difficult question to answer. Yet we must accept as a working hypothesis that one or the other is dominant to develop a causal model. Most models of computing change assume that supply–push factors are dominant. Clearly, GTS and Nolan models above do so. However, we make the assumption that demand factors are dominant because demand factors are fundamental within the organizational context of computing use. Organizations existed long before computing emerged, and would be present without computing. Yet computing would not be present in more than an academic sense without the presence of organizational demand for it. Therefore, we assume that endemic demand precedes the supply–push factors of computing, and indeed it is this demand that makes computing possible in organizations.

This assumption has important ramifications for understanding the dynamics of computing. First, it suggests that organizational context will be more influential than technological infrastructure in determining the growth and use of computing in organizations. This seems to be the case if we examine the differences between the "state of the art" in computing and the "state of

†The two forces of "supply–push" and "demand–pull" noted here are discussed at considerable length in [15]. See also [16].

practice" in computing use. Actual use of computing in most organizations substantially lags the state-of-the-art in computer science knowledge, the state-of-the-art in computer technology, and the state-of-the-art in leading-edge organizations. Techniques and technologies that most computer scientists consider archaic constitute the vast majority of computing activities in many real organizations. Many organizations still operate batch applications in primitive languages such as Autocoder, even though they run them on modern computing hardware. They simply run them under emulation. The endemic demands of the organization are met by such "old fashioned" means. Eventually it might become desirable or even necessary to update systems and methods, but only when the organization's demands themselves make this sensible.

Second, it suggests that the speed of change in computing in organizations will be controlled by organizational demand forces. It is the speed with which computing-related change is occurring within an industry sector and/or organizational function, the relative role of computing in that change, and the saliency of both of these factors to key organizational actors that determines the speed of change in computing in organizations. Of course, changes in technological infrastructure will influence perceptions of demand in important ways. Changes in what is possible and what is affordable will certainly alter organizational perceptions about what "should" be done with computing. This is clearly happening now as we see the adoption of small computers for specialized tasks that simply would not have been computerized before such computers became available and affordable. But the question of whether to adopt and use such technologies will be answered on more complex grounds than whether the technology exists. The technology must exist to make the question sensible, but the answer to the question will depend on the nature of the organization at that time.

Third, it suggests that the task of understanding the dynamics of computing will require much more careful study of the organizational context of computing use than has been the case in the past. Most analyzes of computing change have focused on the technological infrastructure of computing, and this is the easiest approach to take because changes in the infrastructure are easy to trace. But if we are to understand the nature of computing in organizations we must study computing as it actually happens in organizations. This is a more demanding challenge by far, since it requires us to investigate a much wider array of factors affecting change.

Finally, it suggests that we must further factor our analyzes of computing change according to those things that are internal to the organization from those that are external, in the sense of being controllable versus uncontrollable by the user organization. Changes in core technologies of computing are largely external to most user organizations, and even to many manufacturers of computing equipment. They emerge from research and development sites such as universities and industrial laboratories. The influences of user organizations on the activities of such research and development centers are often indirect, and it is uncommon for any given user organization to have much direct effect on what gets developed. Similarly, any given organization will exist within an environment that critically affects its operations and its welfare. For example, local governments exist within complex intergovernmental networks in which many situations that local governments must cope with originate outside the government's control.

Nevertheless, there also are important aspects of computing growth that occur as a result of deliberate actions of organizations. Suppliers of technology actively market their products to user organizations; user organizations actively investigate new technological possibilities and make decisions about adoption and use of technologies. To understand the dynamics of computing we must understand more about the nature and interactions of both the external forces in using organizations. By developing an accurate model of computing evolution in organizations it is possible to tie together the experiences of organizations to date. More significantly, such a model enables more accurate predictions about the future of computing in organizations. The ideas here build on the concepts presented above to create a framework for assessing the forces that give rise to the observed dynamics of computing. We do so by adding a third dimension in our developing framework by differentiating the major organizational loci of change. Our basic focus has been on the organization, but many drivers of change come from outside the organization. For this reason we make a distinction between "internal" factors in computing use, and "external" factors that affect computing use. The boundary between "internal" and "external" is the boundary of the organization itself in the context of its environment. With the addition of this distinction, we

	Locus of activity: Internal	Locus of activity: External
Technological infrastructure	Current physical systems Current software systems Kinds of uses of systems Volumes of system useage Applications (basic kinds) Technical knowledge	Scientific and technical knowledge Technology of production Mechanisms of market delivery Organizing concepts for technology use
Organizational context	Nature of policy leadership Organizational structure Prevailing political coalitions Managerial style(s) Disposition toward use of technology Policies for management of technology Applications (specific tasks) Personal networks/organization behavior General knowledge about how to use technology	Legal constraints on operation Mandates for operation Prevailing economic conditions Sectoral trends (e.g. centralization/ decentralization; inter-organization relations; reforms) Vision of sectoral organization/ purposes

Fig. 7. Basic organizing framework of variables affecting computing dynamics.

can begin to develop a picture of the "pathways" whereby factors influencing change make their effects felt.

A basic framework

The basic framework for analyzing the pathways of change is shown in Fig. 7. The two perspectives "technological infrastructure" and "organizational context" are shown down the left margin, while the distinction of "internal" and "external" loci of activity is shown across the top. The four cell matrix produced by this framework allows us to fill each cell with the factors that we believe to be important in the evolution of computing. The primary classes of variables we are now investigating in our research are shown in the cells.

Having established our basic framework, more difficult issues arise. Have we included all the significant variables? Are the variables correctly arrayed among the four cells? What weighting should be given to each of the variables? Would the weighting given to each variable change from organization to organization, or from time to time? Perhaps most importantly, can any systematic relationship among the variables be seen over time, in all the organizations studied? These are the fundamental questions of our current research, and since we have only embarked on our studies we do not yet have answers to these questions. Nevertheless, we can utilize existing research, as well as the experience of others, to make some initial guesses about the forces that most dramatically influence the evolution of computing in organizations, and the ways in which they do so.

The variables shown in Fig. 7 are the major factors that can and do change over time. The primary objective in determining the course of evolution among these variables is to establish the dominance, direction, and pace of change among the variables. Dominance of change refers to the fundamental importance of each of the variables, and in turn the cells of the matrix, in stimulating and constraining change. The direction of change refers to the pathways of change among the variables and cells within the matrix. Pace of change refers to the speed with which changes take place within and between the cells.

Dominance. As we noted earlier, we believe that organizational context is the dominant force in the evolution of computing. By this we mean that the prevailing organizational conditions that computing can affect are more powerful determiners of whether and how much computing will be used than are the components of technological infrastructure. Regardless of the significance of new technological developments from the standpoint of innovation or opportunity, such developments will not be incorporated into organizations unless prevailing organizational commitments permit and encourage their adoption. Using our supply–push/demand–pull explanatory model, it is the forces of demand within the organization that are the ultimate arbiters of whether and how technologies are adopted and used. This hypothesis is based on several observations, the most important of which is the fact that there is considerable lag between the introduction of new technologies in the marketplace and their eventual adoption by large segments of the market. If changes in technological infrastructure were dominant, adoption of new technologies could be expected to be very rapid.

Our generalization about the dominance of organizational context is not sufficient to deal with the matrix in Fig. 7, however, since we must also consider the internal/external dimension of change. Here we posit that external forces are ultimately the dominant forces in change. By this we mean that individual organizations, which will be represented by the "internal" column, will eventually follow the "lead" of environmental forces external to the organization. Changes in external technological infrastructure eventually compel changes to be made in internal technological infrastructure. For example, the decision of a manufacturer to drop support for a given system (an external event) eventually results in most organizations eliminating that system from their internal technological infrastructure. Similarly, changes in external organizational context will eventually compel changes in internal organizational context, as happens when a major change in the mandates governing local governments forces those governments to change their operations.

We should note here that the prevailing dominance of organizational context and external forces in evolution does not imply that such forces are always dominant. In a sense, the question of dominance is circular. For example, the prevailing practices of the set of organizations taken as a whole constitutes the "environment" within which each individual organization exists. And more importantly, changes that emerge to become a feature of the environment often begin in a single organization and spread to others. Similarly, technological infrastructure can have major effects on organizational context, even to the point of stimulating significant changes in organizational structure and behavior. In some cases, the influences of technology are extremely powerful, to the point of overcoming endemic organizational resistance. Thus, we stress the fact that dominance in our use refers to prevailing forces of change. It is perfectly possible that in some circumstances technological infrastructure and internal forces are dominant factors in specific instances of change.

This definition of dominance results in the model depicted in Fig. 8. Each of four cells is labeled with respect to its relative dominance in the processes of change in computing use in organizations. The most dominant force is external organizational context, for this constitutes the environment within which the using organization exists, and provides the rules within which it must operate. The next most powerful forces are internal organizational context and external technological infrastructure. We do not identify here which of these is the "most" dominant, however. As the discussion of directions of change below will show, these two forces interact primarily through the remaining cell, internal technological infrastructure. This final cell is the least dominant, being affected by all three of the other cells either directly or indirectly.

Directions of change. The identification of the relative dominance of the four cells shown in Fig. 8 leads immediately to the hypothesis that directions of change tend to flow from the most dominant forces to the least dominant forces. Thus, we see the relationships shown in Fig. 9, where the primary directions of change are from external technological infrastructure to internal technological infrastructure; from external organizational context to internal organizational context; and from internal organizational context to internal technological infrastructure.

The relationship between external technological infrastructure and external organizational context is a bit ambiguous. By our basic definition of relative dominance, we would postulate that external organizational context dominates external technological infrastructure. This will certainly be the case if our definition of external organizational context embraces all organizations, including those of computing manufacturers. But if we restrict the use of the term to denote a subset of organizations (e.g. local governments), the relationship between these two cells becomes blurred inasmuch as those organizations tend not to exert powerful influence on the directions taken by computer scientists or equipment manufacturers. For this reason we suggest that change runs strongly in each direction, although by broadening our definition of what is included in the external

	Internal	External
Technological infrastructure	Least dominant	Somewhat dominant
Organizational context	Somewhat dominant	Most dominant

Fig. 8. Relative dominance of the major factors in the framework.

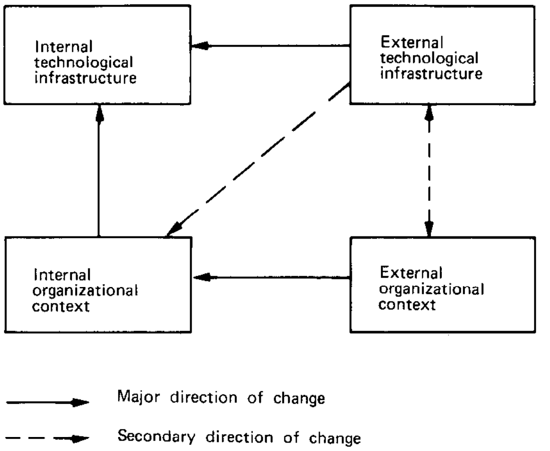

Fig. 9. Primary directions of change among the factors.

organizational context cell we can strengthen that cell's dominance and change will flow from that area.

The relationship between internal organizational context and external technological infrastructure is indirect in our model, but some important aspects of this relationship should be noted. Our studies and those of others suggest that decisions regarding computing within organizations are strongly affected by decision makers' views of what is happening in the larger field of computing. In this sense, changes in external technological infrastructure can influence internal organizational context directly, by-passing the intermediate cell of internal technological infrastructure. This is illustrated by the dashed arrow between these two cells.

We do not perceive a direct connection between external organizational context and internal technological infrastructure. We believe that most influences emerging from external organizational context affect internal technological infrastructure only through the pathways of external technological infrastructure and internal organizational context. Changes in external organizational context either create the perception of emerging demand, thus stimulating the proactive creation of a supply response from external technological infrastructure (which then influences internal organizational context and internal technological infrastructure); or they directly create new demands within the internal organizational context that are made manifest by stimulating change in the internal technological infrastructure.

As the discussion of dominance above, these prevailing directional pathways should be seen as the primary pathways, not as the exclusive pathways of change. In some circumstances changes will emanate from within organizations that affect the external dimensions, thus running in "reverse". This is certainly the case when striking innovations are made by individual organizations which are then picked up by other organizations (e.g. computer manufacturers, national associations) and actively promoted. But this happens relatively rarely, and most changes follow the pathways we specify.

Pace of change. Unlike the models depicted for the dominance of forces in change and pathways of change, the pace of change is uniquely influenced by the particular differences between technological infrastructure and organizational context. Specifically, the pace of basic change within the field of computing technology is so rapid that it eclipses change in other areas. For this reason, we hypothesize that the most rapid change occurs in the cell of external technological infrastructure. The primary effects of this fast pace are felt through the pathways to internal organizational context and internal technological infrastructure. The second most rapid pace of

	Internal	External
Technological infrastructure	Somewhat rapid	Very rapid
Organizational context	Somewhat slow	Generally slow

Fig. 10. Pace of change among the major factors.

change occurs in the internal technological infrastructure cell, as new capabilities are exploited and forced upgrades take place. Change is slightly slower in internal organizational context, since the variables contained in this area are embedded in the traditions and practices of the organization, which generally resist rapid change. The slowest pace of change is in external organizational context. The collective behaviors of organizations and the prevailing traditions of the larger environment change very slowly in comparison to the other cells. These hypotheses about the pace of change are shown in Fig. 10.

Interpreting the model

The model we offer here provides a general interpretation of the course of change in computing in organizations. Change is basically stimulated by the rapid pace of change from within the cell of external technological infrastructure. New capabilities produced within this cell create new opportunities for organizational actors. These opportunities might offer the ability to do something truly new and useful, in which case they act as "attractors". They also might offer a means of escaping from a current condition that cannot be tolerated (a "detractor"), and be adopted for that reason. The pace of change within the external technological infrastructure cell is important in the evolution of computing use because it sets the pace of "opportunity change" adopting organizations must deal with.

It might seem from this assessment that the fundamental driver of evolution is technical change, but this is not the case. The stimulus for change in organizational use of computing often originates from change in external technological infrastructure, but we must reject the notion of a "technological imperative" compelling organizations to adopt new innovations. Rather, we believe that organizational actors decide whether, when and how to adopt innovations. In this way, the organizational context of computing application is the control point in change. By excluding a technological imperative, we hypothsize that the basic determiner of evolution is the selection process whereby organizations choose to adopt or reject specific innovations.

The choices organizations make in adopting or rejecting a given innovation are strongly influenced by internal and external organizational conditions. Developments in the external technological infrastructure offer new means of dealing with perceived needs arising from both internal and external organizational context, but they do not compel adoption of these means. Even in cases where generators of new technology pursue new developments because of perceived demand in using organizations, it is this perceived demand that is in fact driving the development. In many cases perceptions of demand are incorrect, and innovations are developed that are never adopted. Similarly, there are probably cases (these are more difficult to identify) where real demand is overlooked and innovations to meet the demand are not developed.

It is here that we begin to perceive the basic forces behind change in computing in organizations. Changes are constantly occurring in external technological infrastructure (e.g. new developments), internal organizational context (e.g. new leadership, changing organizational fortunes), and external organizational context (e.g. new mandates for organizational activity, major economic change). Thus both the "demand side" and the "supply side" of computing are undergoing change. Changes in external technological infrastructure sometimes occur independently of perceived demand, as when a basic scientific breakthrough with practical application potential is made. But the important changes for the evolution of computing in organizations always relate to some demand within using organizations. Changes in organizational context frequently occur without regard for changes in technological infrastructure, and many such changes are not influenced by technology at all.

The important nexus of these forces in the evolution of computing use is the point where demand and supply intersect. In our model, this occurs along the pathways between internal organizational context, internal technological infrastructure and external technological infrastructure. The powerful forces of external organizational context alter organizational perceptions of what is needed, but these changed perceptions relate to the adoption of new technology only in the context of the perceptions of individual organizational actors, who (with help from marketers of technology) connect organizational needs with possible technological solutions. When the demands of organizations become linked, in the minds of organizational decision makers, with technological innovations that offer some fulfillment of those demands, the process of adoption begins.

To this point the model is conservative, adopting the perspective of rational economic decision making. But this is too strict an interpretation of our model. Several important things differentiate our model from this rational viewpoint. First, we have a loose definition of "demand" that includes many motivations not customarily included in models of organizational rationality. We recognize and include rational demands, such as a proven organizational need for a faster means of processing accounts payable that might facilitate the decision to buy a computer system to accomplish this. But we also include less "rational" demands such as the desire of a departmental manager for a computer system in order to increase the status of his department, compete with another organizational unit, or simply obtain the opportunity to play around with computers.

Second, we explicitly recognize an important link between perceptions of technological capabilities and the fabrication of demand to take advantage of them. This is especially important in computing change, where many computer procurement decisions are made because decision makers think the systems they buy can do things they cannot (or cannot easily) be made to do. It is also important in the context of complex inter-organizational relationships, such as those that exist among governments within a country. Demands can be made by one organization that affect another organization based on expectations about the affected organization's ability to meet the demands. For example, reporting requirements imposed on local governments by central governments will be affected by the central government's perception about local ability to comply with the demand. Prior to the advent of computer systems, certain kinds of reports were much more difficult to produce than they are today. If the central government believed that local governments could not comply with their demands, it would not make the demands (or would soon retract them). But if computer systems make it possible for local governments to comply with the demand, a major logistic barrier to the demand is removed. We believe there is a strong connection between the proliferation of central government reporting requirements and the growth of computer-based reporting capabilities in responding organizations.

Finally, our model does not assume that people know the facts or always tell the truth. Many decisions to adopt computing are made on erroneous information, and many claims are made by vendors of technology that bear little relation to the truth. The result is that the marketing of technology to possible users goes far beyond the "provision of information for purchase decisions" usually ascribed to the marketing function by neo-classical economists. Marketing efforts are sometimes undertaken with the fundamental intent of altering peoples' perceptions of reality. Take for example the current advertizing for office automation equipment that claims this technology to be "inevitable" and "essential" for organizations. Neither claim is true. Widespread adoption of office automation technology is no more inevitable than was widespread adoption of supersonic transport technology or the picture-phone. Similarly, it is not correct to claim that a particular technology is essential to organizations that are getting along without it. The purpose of these ads is to get possible buyers to accept the proposition that they must buy this technology or suffer dire consequences. The importance of this for our model is that concerted marketing efforts can affect the nature of demand, even though demand ultimately exerts the dominant influence in the supply/demand relationship.

CONCLUSION

The basic model presented in this paper draws together the foci of previous models of information system growth in organizations. It integrates the fundamental perspectives of technological and organizational change, and attempts to divine the basic relationships between these kinds of change both internally to the organization and externally to the organization. We believe the utility of this model is its inclusion of a wider array of factors that influence the timing and form of growth in computing use that occurs in complex organizations.

This model alone cannot provide a detailed description of the actual processes of change, however. Research to specify and track the changes in individual variables listed in Fig. 7 is required to verify the model's accuracy as a general description of the forces of change involved, and to determine whether the relationships among the four cells of the model posited in fact proved to be true. We are currently engaged in research that will evaluate this model, and encourage others interested in the processes of computing growth in organizations to evaluate it as well.†

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†We are currently engaged in two major research efforts that will provide information to evaluate our basic mode. One study consists of a set of detailed case studies in 10 local government agencies. These case studies will construct, together with data from earlier studies, a comprehensive and retrospective history of the process of computing growth on each site. The other study replicates major portions of the 1975 URBIS study [17] of 400 cities' use of computing to assess the changes that have taken place between 1975 and 1986.