# END USER COMPUTING GROWTH AND MANAGEMENT IN ORGANIZATIONS

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**ABSTRACT**

The research reported in this paper involved the study of end-user computing in typical organizational settings. An extensive literature review was conducted and a number of executives consulted about the effects and position of the end user computing phenomenon within their organizations. The data served as a basis for a system dynamics model that focused on the forces that create growth in end-user computing. The "tiered infrastructure" of computing in the organization is demonstrated and discussed. One problem with the study of end-user computing has been the lack of testable theory about it. The majority of research has used case studies or relatively narrow field studies as a methodology. The key purpose in using the system dynamics approach has been to provide a vehicle to capture the ideas cataloged in the various case studies and cast them in the causal map format as a dynamic theory of systems organization and behavior.

## INTRODUCTION

Although the emergence of end-user computing in organizations is a relatively new phenomenon, it has been heralded as "... one of the most significant developments in corporate computing to have taken place in the past decade. In fact, it marks a major transformation of the nature of managerial work and is of growing strategic importance to many corporations." (Henderson and Treacy 1986) This rather imposing statement has been supported by the suggestion by Nolan, Norton & Company that end-user computing has the potential to change the hierarchical pyramid structure of many of today's organizations to a network form that will be more flexible, less bureaucratic, with greater direct communication among employees (Alexander and Connolly 1989).

The growth of end-user computing over the past several years has been overwhelming, outpacing typical data processing systems growth by at least five times. Typical growth rates for end-user computing have been reported to be 50 to 100% per year (Gerrity and Rockart 1986, Sumner 1986). This growth is reflected in the large percentages of capital currently spent on end-user computing. Nearly 45% of all capital spending in the 1980's has reportedly been budgeted to information technology, with 40% of that allocated to office-focused, end-user computing expenditures (Evans 1989).

This phenomenal growth in end-user computing has been referred to as a "mixed blessing" (Guimaraes and Ramanujam 1986) as well as a "double-edged sword" (Leitheiser and Wetherbe 1986b). Although there is no doubt that end-user computing has the potential to provide many benefits to organizations, for many organizations it has been far more costly and far less effective than anticipated. There is no doubt that EUC is presenting new challenges for organizations and that its growth and development must be prudently managed in order to reap the benefits available while avoiding the serious pitfalls that can occur. A major problem with existing research on EUC however, has been the lack of a coordinated view of the phenomena. A model integrating the literature is needed to explain the growth of end-user computing and serve as a vehicle to experiment with policies and procedures that can affect the growth and management of EUC.

The next section will discuss the difficulty in defining EUC. Causal relationships are then explored based on a literature review. The subsequent conceptual and simulation models are discussed, followed by key issues deserving attention. The presentation culminates in some considerations regarding the direction of future research.

**DEFINITION OF END USER COMPUTING**

While there has been much discussion on end user computing, there is not a single agreed upon definition of the concept, with descriptions ranging from narrow to broad interpretations. The following definitions are representative of varied interpretations of end user computing:

* "Having the users develop their own applications" (Alexander and Connolly 1989).
* "The end users are largely on their own to design, implement, modify, and run their own applications" (Doll and Torkzadeh 1988).
* "The creative use of computers by nondata processing experts" (Henderson and Treacy 1986).
* The direct use of, but not necessarily development of, technology by individuals to automate the tasks associated with their jobs (Evans 1989).

Several user classification schemes have been proposed in the literature. Rockart and Flannery (1983b), for example proposed six levels including non-programmer end users, command level users, end-user programmers, functional support personnel, end-user computing support personnel, and DP programmers. Pliskin and Shoval (1987), in a different vein, view Martin's classification of non-programming end users, DP amateurs, and DP professionals in a two dimensional framework based on programming skills and DP professionalism.

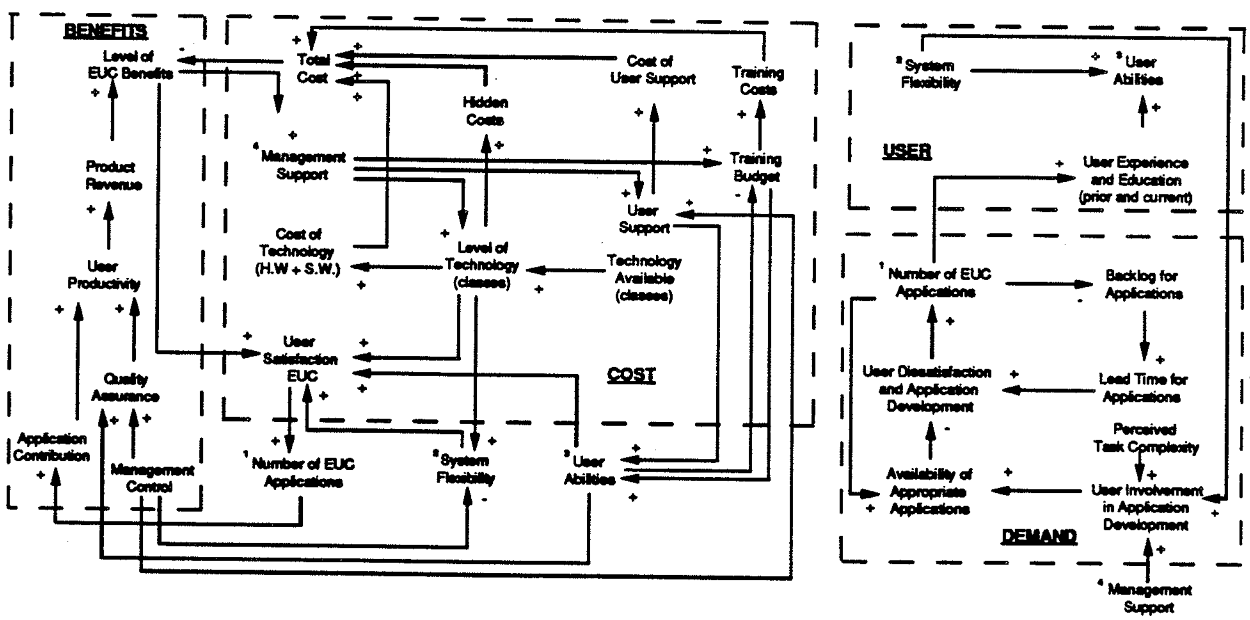
Cotterman and Kumar (1989) provide a more comprehensive framework for defining and classifying end users by identifying three critical dimensions of the EUC phenomenon: end-user development, end-user operation, and end-user control of computer based information systems. In addition, they maintain that the definition of end users can be made more precise by differentiating between the producers, consumers, and producer/consumers of information in an organization. They define end users as those units or individuals who are involved as either consumers or as producer/consumers of information, specifically excluding producers only. The three dimensions of development, operation and control are used to distinguish between various types of end users, yielding eight representative types of end users: user-consumer, user-operator, user-developer, user-controller, user-operator/developer, user-developer/controller,user-operator/controller, user-operator/developer/controller (Cotterman & Kumar 1989). The resulting "user-cube" can then be used to help organize and analyze issues identified in end user computing. Risks and benefits can be identified for each separate dimension, which should aid management in devising strategies for EUC growth and development.

The "user cube" framework proposed by Cotterman and Kumar provides the most comprehensive taxonomy of end users to date and the three dimensions identified provide an effective method for identifying and analyzing critical issues in EUC growth and management. For purposes of definition for this model, we have adopted their taxonomy of end users. This is what we mean when we use the term in our discussion of the causal structure of the system.

**SYSTEM CAUSAL DIAGRAM**

Based on an extensive review of the available empirical and conceptual literature on end user computing, a causal model was developed depicting the factors and relationships affecting the growth and management of end user computing.

**Figure 1. EUC Growth and Management Causal Diagram**




The factors in the model, shown in Figure 1, can be classified into the four distinct sectors of demand, benefits, costs and user issues. The elements and their relationships are discussed next.

**Demand Sector**

The number of end-user computing applications developed will be a function of the rate at which EUC applications are discarded, the demand for EUC applications (Money et al. 1988, Doll & Torkzadeh 1988, Rockart & Flannery 1983a 1983b), and the organization's EUC development capacity. In general, applications will have a limited usefulness, so it is reasonable to expect a normal replacement or discard rate as applications become outdated (Rivard & Huff 1988, Pliskin & Shoval 1987, Gerrity & Rockart 1986).

The demand for EUC applications, which depends on several factors, creates requests for computer applications that generate a backlog of applications. As the rate of system development increases, end-users as people in an Information System will either develop or buy packaged software causing the number of applications on backlog to decrease (Saarinen et al.

1988, Robey & Zmud 1988, Henderson & Treacy 1986). The existence of incredible applications backlogs, reported to range in the average of two to four years, has been a major impetus in the growth of EUC (Cougar 1986, Gerrity and Rockart 1986, Henderson & Treacy 1986, Leitheiser and Wetherbe 1986a 1986b, Sumner 1986, Pliskin & Shoval 1987, Sumner and Klepper 1987, Head 1985, Beheshtian & Van Wert 1987, Gremillion & Pyburn 1983, Jones 1986, Lucas 1986). In addition, Sumner and Klepper (1987), reported that a 1983 study by Alloway and Quillard discovered the "invisible backlog" of systems, those that were needed but not yet approved, was 784% greater than the "official" backlog of approved projects. Not surprisingly, as the number of applications on backlog increases, the lead time for applications development also increases, resulting in user dissatisfaction with current applications development capabilities (Sumner 1986, Leitheiser and Wetherbe 1986b, Rivard 1987, Pliskin and Shoval 1987, Sumner and Klepper 1987, Spence 1988, Doll and Torkzadeh 1988, Robey & Zmud 1988).

Another factor affecting user dissatisfaction with the applications development rate has been the availability of "appropriate applications" (Cougar 1986, Gerrity & Rockart 1986, Leitheiser & Wetherbe 1986a 1986b, Rivard 1987). Miscommunication between users and developers frequently led to inappropriate applications, which increased user dissatisfaction. As dissatisfaction with available applications and application development capabilities grew, end-user computing grew because increasing numbers of end-users discovered they could develop systems themselves that were tailored to their own needs (Head 1985, Rivard 1987). Raymond (1985) found that users in firms that developed a greater proportion of their applications internally were slightly more satisfied than users in firms which relied heavily on external development. O'Donnell and March (1987) report that application "fit" or appropriateness is a function of user involvement in the development process. Several other studies show that application appropriateness is a principal factor in the growth of EUC (Evans 1989, Doll & Torkzadeh 1988, Rivard & Huff 1988, Baronis & Louis 1988, Rivard 1987).

User involvement in the application development process will be a function of several factors, including system flexibility, perceived task complexity, and perceived management support. System flexibility is the amount of control the user can exercise in programming for problem solving, modification, adoption of methodologies, or development of applications. Increased system flexibility will allow for increased user involvement in the applications development process. As perceived task complexity (especially unstructured decision making) increases, the user will attempt to exercise some control over the computing environment through user involvement (Pliskin & Shoval 1987, Junk & Sargent 1987). Head (1985) reports that, regardless of the size or nature of the project, there are two essentials to achieving active and effective end user involvement: easy to use software packages that support user needs and interests and a managerial climate that encourages and supports EUC.

Finally, in the demand sector, the EUC development capacity is a function of the technological capacity of the organization and the abilities of the users. The combination of these elements produce applications that provide an organizational benefit.

**Benefits Sector**

To date, the benefits of end user computing, like most other computing, have been most difficult to quantify. This is a particularly important point because the continuing difficulty of justifying IS investments using a cost-benefit framework. Many, if not all, of the benefits realized by EUC are intangible (Gerrity & Rockart 1986, Henderson & Treacy 1986). Aberth (1986) reported that most people were unable to cite specific dollar figures, only intangible benefits, in response to a request to quantitatively substantiate their investments in applications. He used one example of a 15% across-the-board productivity rise and another in which an application saved J.C. Penny $250,000 by enabling the retention of valuable information when an insurance subsidiary was sold.

More commonly reported are perceived benefits (Money et al. 1988) such as increased efficiency and effectiveness (Gerrity & Rockart 1986, Cougar 1987) which result in enhanced productivity, stemming from improvements in speed, cost or yield (Rivard & Huff 1985, O'Donnell & March 1987, Colligan & Allman 1986, Alavi 1985, Rivard 1987). The change in the level of benefits (and hence, perceived benefits) attributed to EUC, therefore, is a function of the revenue generated by the "usability" of EUC applications minus the costs associated with development.

Application usability is a function of the quality of the application (Spence 1988) and the contribution that the application may make to solving organizational problems and contributing to revenue. A number of authors agree that there are many possible risks that threaten quality assurance and therefore require strict management controls (O'Donnell & March 1987, Harrison & Dick 1987, Alavi 1985, Rivard & Huff 1985, Sumner & Klepper 1987, Cougar 1987, Mayo 1986, Colligan & Allman 1986, Beheshtian & Van Wert 1987, McFarlan & McKenney 1983, Gremillion & Pyburn 1983, Blank 1986, Sumner 1986, Metz 1988, Wilkinson 1988, Bairstow 1988). Alavi and Weiss (1985) present one of the most comprehensive lists of risks by identifying where they might appear throughout the development cycle. Potential risks include wasted monetary resources, incompatible end-user tools, threats to data security and integrity, over analysis or insufficient analysis of the problem, solving the wrong problem, using the wrong analysis technique, inadequate documentation, insufficient application testing, inefficient expenditure of people's time, redundant development efforts, and the failure to keep applications current. White and Christy (1987) report that appropriate security and controls in microcomputer environments are inadequate or nonexistent. Burns (1985) reinforces this and believes that the dispersal of users throughout the organization is a major reason for it. Sumner (1986) theorizes that since user developers are not data processing professionals, they are not aware of the need for nor do they feel responsible for providing accurate documentation and may not be aware of security issues. Another potential problem pointed out by Sumner is the reliance on end-user generated data, regardless of whether or not adequate validation, testing, or maintenance of the programs have been performed.

These potential risks and their potential effects on quality assurance point out the strong need for management controls and policy guidelines. Alavi and Weiss (1985) suggest that this does not imply discouraging or inhibiting EUC, but rather guiding, directing, and encouraging its effective use. Cougar (1987) suggests the use of both "hard" and "soft" controls in order to provide standards and guidance to enhance quality assurance. Hard controls suggested include limiting hardware selections to compatible PCs, standardization of operating systems, applications packages, and fourth generation language tools, and the installation of chargeback systems to users to encourage efficient use of EUC resources. Soft controls would encourage users to follow established standards and policies by providing maintenance for recommended PC types only; centralized purchasing and quantity discounts on suggested brands of hardware and software; selective training on software, fourth generation languages, and applications development methodology; and by offering to evaluate and install approved new software for all interested users. Cougar also points out that soft controls permit more individual creativity and are a more practical approach.

Other examples of management control would be reviewing and approving requests for computing resources, coordinating applications development, and controlling mismatches between hardware capacity and software requirements (Guimaraes and Ramanujam 1986, Henderson and Treacy 1986, Leitheiser and Wetherbe 1986a 1986b, Sumner 1986, Dearden 1987, Pliskin and Shoval 1987, White and Christy 1987). As management control of EUC increases, quality assurance also improves (Guimaraes and Ramanujam 1986, Henderson and Treacy 1986, Pliskin and Shoval 1987, Leitheiser and Wetherbe 1986a 1986b, Sumner 1986, Sumner and Klepper 1987a 1987b, Dearden 1987, White and Christy 1987, Doll and Torkzadeh 1988).

Another factor that affects quality assurance is user abilities. As user abilities increase and users become more knowledgeable about security and integrity issues, quality assurance improves. Rivard (1987) and Mayo (1986) report that user experience enhanced by training and documentation skills led to quality application development.

It is expected that all applications will not contribute equally to usability in an organization. The contribution made by each application will be a function of several factors. Because more than one user will likely use an application, the number of users per application will contribute to usability. Some applications are more critical to organizational operations and goals than others. The greater the criticality, the more contribution a particular application makes. The greater the frequency of use of the application by the user(s) the more its contribution. Finally, because some applications will be more complex than others, an application's complexity will affect usability. Complexity is defined by Franz (1985) as the number of procedures and exceptions in processing and the need to integrate and control them. Size and element interaction in application code also are components of complexity.

**Cost Sector**

The management of limited resources can enhance or stifle the benefits derived from end-user computing. Management support for end-user computing is based on the perceived benefits directly gained from user-developed applications. The degree of management support appears to be related to the stage of end-user involvement in application development. After conducting interviews with information center and microcomputer managers, Karaten (1978) pointed out that management support is usually high at the initial stage of involvement in end-user computing. Over time, diminishing support is reflected by restrictions on spending, smaller budgets, inadequate facilities and staffing. Tait and Vessey (1988) found the chances of system failure increase as resources are constrained. Inconsistent levels of support and unclear policy were attributed, by Benson (1983) to a top management team that is ignorant or indifferent about end-user developed applications.

Management support, therefore, strongly controls the rate of system development (Panko 1987, McGovern 1988, Scheier 1988, Currid 1989) and influences the subsequent benefits gained. The rate of system development increases proportionately with management's commitment to end-user computing.

With more resources available to the end-user, the timeliness of applications improves (Mayo 1986, Rivard 1987, Cougar 1987, Saarinen et al. 1988). In short, as the rate of system development increases (due to management support) the backlog of applications decreases (Saarinen et al. 1988, Robey and Zmud 1988).

If a reduction in benefits is perceived, management withdraws support by reducing allocations to the various budgets. This has a rippling effect throughout the system. At some point marginal revenues equal marginal costs and an optimum level of end-user computing is reached for the corporation at a particular point in time. The total benefits perceived to have been derived from end-user computing are modified by a percentage of total perceived benefits. This percentage, termed the benefits modifier, is what management is willing to reinvest in the end-user computing budgets given past system performance.

Financial resources dedicated to the EUC budget are divided among three areas: technology and the associated hidden costs, the training of users, and user support services. The technology budget represents the portion of the total end-user computing budget allocated to hardware acquisition. The improved price-performance ratios of personal computers over mainframes have contributed to the growth in end-user computing.

Leifer (1988) discusses four classes of computer-based information systems based on architecture or topology: centralized systems utilizing a mainframe or central processor; distributed peer to host systems; decentralized systems such as peer networks, LANs, and e-mail; and stand alone systems consisting of individual personal computers. Connolly and Barney (1986-87) believe personal computers will account for most of the future growth in computing. Alexander (1989) projected that in 1990 forty to fifty percent of the Fortune 1,000 companies will downsize from mainframes and minicomputers to personal computers. This projection represents a dramatic increase over the twenty to twenty-five percent of earlier projections.

Investment in technology is a limiting factor in end-user computing. Without the appropriate technology and flexibility in utilizing the technology, end-user computing is stifled. The level of technology fluctuates with the acquisition of new technology and the obsolescence of technology previously acquired. Decisions regarding the type and amount of technology investment guide the level of end-user developed applications. To capture the varying degrees of technology advancements, technology is broadly categorized into the three classes of microcomputers, minicomputers and workstations, and mainframes (networks with servers).

The number of units per class of technology is multiplied by the respective price per unit to get an aggregate price for the technology desired. If the aggregate price (cost) is more than what is budgeted for equipment, only the dollar value budgeted can be spent. If the price is less than budgeted, the entire amount can be purchased and added to the level of technology investment. If management reduces support (monetary allocations), less technology can be acquired and the level of technology investment is reduced by depreciation and obsolescence.

Hidden costs are directly a result of the investment in technology. Such costs include peripheral and ancillary hardware, software, employee wages, supplies, overhead and data proliferation. Cougar (1987) points out that data proliferation can be the most insidious and costly of the hidden costs, adversely affecting productivity as decision making is clouded.

One-third of information system spending is attributed to end-users. Elliot (1986) reported sample hidden costs in one organization to include $514 million annually for the space required for end-user equipment, $325 million for daisy print wheels, and $3.9 million for printer forms. As hidden costs increase, the marginal benefit associated with end-user computing is reduced and management will tend to withdraw support for end-user computing.

As noted earlier, there is a positive relationship between the level of technology and the maximum capability of developing end-user applications given the technology. Lucas (1986) reports that the technology available, particularly more powerful application packages, has increased users' abilities to develop applications. Faster application development results in greater user demands propagating the growth of end-user computing. As new products for automating parts of applications development are introduced (Jones 1986) end-users are able to produce more in a day than in the past (Aberth 1986). Familiarity with the technology is another factor that leads to increased development capacity (Benson 1983).

The amount and type of training associated with end-user computing is often an elusive figure. A KPMG Peat Marwick study noted in MIS Week (1989) reported that computer training expenditures declined seven percent from $6.5 million in 1988 to $6.1 million in 1989. The training budget for most organizations is approximately ten percent of the hardware budget. Yet this figure may be understated as there is a trend to deflect support and training costs back to the department, in effect treating training costs as hidden costs.

The KPMG study also reported that the investment in user support increased from $20.8 million in 1988 to $22.4 million in 1989. User support includes the availability of expert personnel inside and outside of the organization. A variety of support mechanisms have been reported, such as technology assistance, training, consulting, problem solving, mainframe-micro connections, hot-line access, and personal computing libraries. An example is the information center concept promoted by IBM in the mid 1970's to provide resources to help users meet their own information needs.

Total cost is an aggregate measure of all of the costs associated with end-user computing. The primary control mechanism limiting growth is the implicit and explicit costs encountered. Forty to fifty percent of data processing resources are used for end-user computing. The continued strength of the explosion of EUC is apparent as dedicated resources are expected to rise 50 to 90 percent annually (Saarinen et al. 1988). The KPMG Peat Marwick study of 1989 concluded that total EUC expenditures increased from $123.4 million in 1988 to $130 million in 1989. This increase is even greater when one notes that technology advancements have brought down the cost of hardware and software (Rivard 1987).

As management allocates more dollars to support end-user computing, end-users are encouraged to be more involved in application development. Perceived management support relates monetary commitment to user involvement. Yaverbuam (1988) reported that the use of computing resources by nonexpert users is growing at a rate of between 50% and 90% annually. As management support increases, perceived management support by end-users increases and in turn is reflected in an increase in user involvement in application development. The role of the user is, of course, a major focus of this research and will be reviewed in the next section.

**User Sector**

One element contributing to the growth in end-user computing is the flexibility of the system. System flexibility is driven by the level of technology employed and is defined as the amount of control the user can exercise in programming for problem solving, modification, adoption of methodologies, or development of applications. One benefit in downsizing and EUC focus is the added system flexibility (Alexander 1989).

Flexibility is limited by management policies. The more centralized computing is in the organization, the more control the information center or management will exercise in deciding system design, software, access methods, and the mode of decision making (Mayo 1986, Rivard 1987). As management control increases, user control decreases. This has serious implications considering user satisfaction is positively related to the user's perceived control over his or her computing environment (Clark 1986, Mayo 1986, Panko 1987, Rivard 1987, Saarinen et al. 1988, Robey and Zmud 1988).

An increase in the amount of training and the number of users trained also leads to a more positive user experience (Nelson & Cheney 1987a 1987b, Rivard 1987, Cougar 1987, McGovern 1988, Saarinen et al. 1988). The number of users that can be trained is a function of the dollars management dedicates to the training budget. The amount of training is modified by individual learning differences, user expectations about computers, retraining needs, and a general increase in the support staff that may be required (Karaten 1987). The number of users trained contributes to an aggregate measure of user abilities. The more users trained in application development and use, the higher the level of user ability in the organization.

The more applications an end-user works with and the number of times each application is used enhances the user's experience. Saarinen et al. (1988) demonstrated a positive relationship between user experience and the level of end-user computing applications in their exploration of critical issues in EUC. The correlation between a user's experience and his or her learning curve is positively and directly related.

A study of personal computer users in twelve organizations found that users with stronger backgrounds in computers, use personal computers to a greater extent than do users with weaker computer backgrounds (Lee 1986). Henderson and Treacy (1986) report that background and experience of end users result in differing levels of user abilities, which in turn require different levels and types of user support. Information system personnel spent fifteen percent more time on hardware support from 1987 to 1988 and twenty-five percent less time on formal end-user training (McGovern 1988). A survey on microcomputer support revealed that staffing levels for microcomputer support personnel lags behind growth in the installed base of corporate and institutional microcomputers. In 1986 there were 15.5 support people per 1,000 workers. In 1987 that ratio was 13.5 support people per 1,000 workers, dropping to 12.9 in 1988 (Stromer 1988).

Most end-users can not achieve a desirable level of proficiency in application development if left strictly on their own. In organizations with an information resource center, the center must offer not only hardware and software, but must provide expert and sympathetic technical assistance. A field study of personal computing in 173 corporations demonstrated that the greater the control over acquisition matters exercised by the information center, the greater the level of user support provided. The support appeared to be more readily extended by the information center when they have a clear say in personal computer acquisitions (Guimaraes and Ramanujam 1986). This is in keeping with the view that the role of the information center is evolving into a support function for end-user development of applications (Rivard 1987, Cougar 1987, Bridges 1988, Scheier 1988).

An increase in user support will lead to an increase in user abilities (Cougar 1986, Guimanaes and Ramanujam 1986, Henderson and Treacy 1986, Lee 1986, Leitheiser and Wetherbe 1986a 1986b, Sumner 1986, Nelson and Cheney 1987a 1987b, Sumner and Klepper 1987, White and Christy 1987, Robey and Zmud 1988, and Evans 1989). Guimaraes and Ramanujam (1986) found that managers identified the lack of user education as the most critical personal computer problem. Sumner (1986) also found user support to be particularly critical.

User ability, therefore, is a function of previous ability and current changes in ability. Here it is considered an aggregate measure for the entire organization. User training, support, experience, and system flexibility are all taken into consideration as they affect the users' rate of change. The users' confidence and attitude about their ability has a direct effect on their perceptions of end-user computing (Mayo 1986).

User abilities in application development are affected by the amount of user support the end-user receives if needed, training, experience in developing and using applications, and the flexibility of the system. Each factor is derived from management support. As management support is withdrawn there is little change in user abilities. User experience may continue to increase, but the other components of user abilities will eventually cease. Management support becomes critical as user experience is enhanced by training and documentation (Mayo 1986, Rivard 1987) skills which lead to quality application development.

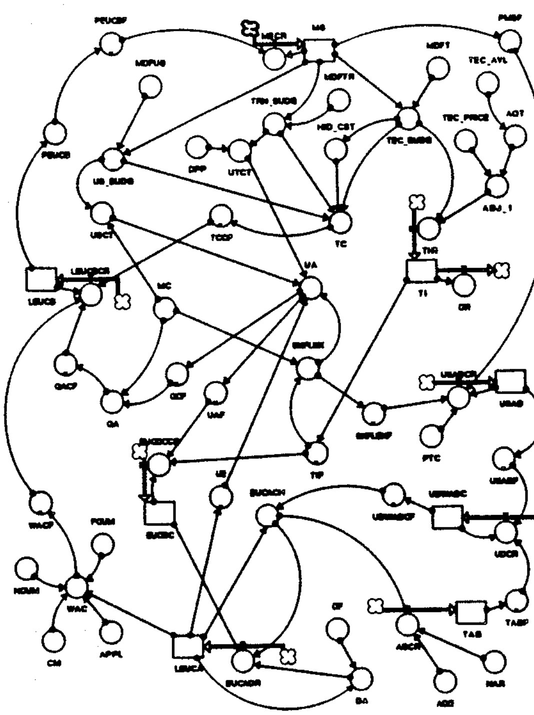
**PARAMETRIC MODEL**

Based on the causal model presented, a working computer simulation model was built using Stella to produce the diagram shown, Figure 2. However, the model was programmed in Professional Dynamo Plus in order to take advantage of the flexibility and power provided by the simulation language as well as the extremely fast processing time afforded by the hardware configurations available.

In accordance with the guidelines suggested by Richardson and Pugh (1981), suitability tests for model structure, including structure verification, parameter verification, extreme conditions, boundary adequacy, and dimensional consistency, were performed during the model development process. Suitability tests for model behavior included both parameter and structural sensitivity experiments.

Consistency tests for model structure, including face validity and parameter values, and model behavior, including boundary adequacy tests focusing on behavior, also were performed. In addition, the appropriateness of the structure for the audience was assessed, considering model size, degree of complexity, and level of aggregation of detail. Necessary adjustments were made and the final structure was compared to the theory derived from the literature review. The behavior of the model appears adequate given its purpose to offer an explanation of EUC growth and to provide a structure for policy analysis in this area.

**Figure 2. EUC Growth and Management Flow Diagram**



| | |
|---|---|
| ABCR | Application Backlog Change Rate |
| ADE | Applications Developed Elsewhere |
| ADJ1 | Adjustment ($) |
| AOT | Amount of Technology |
| APPLC | Application Complexity Rating |
| CM | Criticality Modifer |
| DA | Discarded Applications |
| DPP | Dollars per Person |
| DR | Discard Rate |
| EUCACH | End-User Computing Application Change |
| EUCADR | End-User Computing Applicaation Development Rate |
| EUCDC | End-User Computing Development Capacity |
| EUCDCCR | End-User Computing Development Capacity Change Rate |
| FOUM | Frequency of Use Modifer |
| HID_CST | Hidden Costs |
| LEUCA | Level of End-User Computing Applications |
| LEUCB | Level of End-User Computing Benefits |
| LEUCBCR | Level of End-User Computing Benefits Change Rate |
| MC | Management Control |
| MDFT | Management Discretionary Factor for Technology |
| MDFTR | Management Discretionary Factor for Training |
| MDFUS | Management Discretionary Factor for User Support |
| MS | Management Support |
| MSCR | Management Support Change Rate |
| NAR | Number of Applications Requested |
| NOUM | Number of Users Modifier |
| PEUCB | Perceived End-User Computing Benefits |
| PEUCBF | Perceived End-User Computing Benefits Factor |
| PEUCD | Perceived End-User Computing Delay |
| PMSF | Perceived Management Support Factor |
| PTC | Perceived Task Complexity |
| QA | Quality Assurance |
| QACF | Quality Assurance Conversion Factor |
| QCF | Quality Conversion Factor |
| SXFLEX | System Flexibility |
| SXFLEXF | System Flexibility Factor |
| TAB | Total Application Backlog |
| TABF | Total Application Backlog Factor |
| TC | Total Cost |
| TCCF | Total Cost Conversion Factor |
| TEC_AVL | Technology Available |
| TEC_BUDG | Technology Budget |
| TEC_PRIC | Technology Price |
| TI | Technology Investment |
| TIF | Technology Investment Factor |
| TIR | Technology Investment Rate |
| TRN_BUDG | Training Budget |
| UA | User Abilities |
| UAF | User Abilities Factor |
| UDCR | User Dissatisfaction Change Rate |
| UDWADC | User Dissatisfaction with Application Development Capacity |
| UDWADCF | User Dissatisfaction With Application Development Capacity Factor |
| UE | User Experience |
| UIIAD | User Involvement In Application Development |
| UIIADCR | User Involvement In Application Development Change Rate |
| UIIADF | User Involvement In Application Development Factor |
| US_BUDG | User Support Budget |
| USCT | User Support Conversion Table |
| UTCT | User Training Conversion Table |
| WAC | Weighted Application Contribution |
| WACF | Weighted Application Contribution Factor |

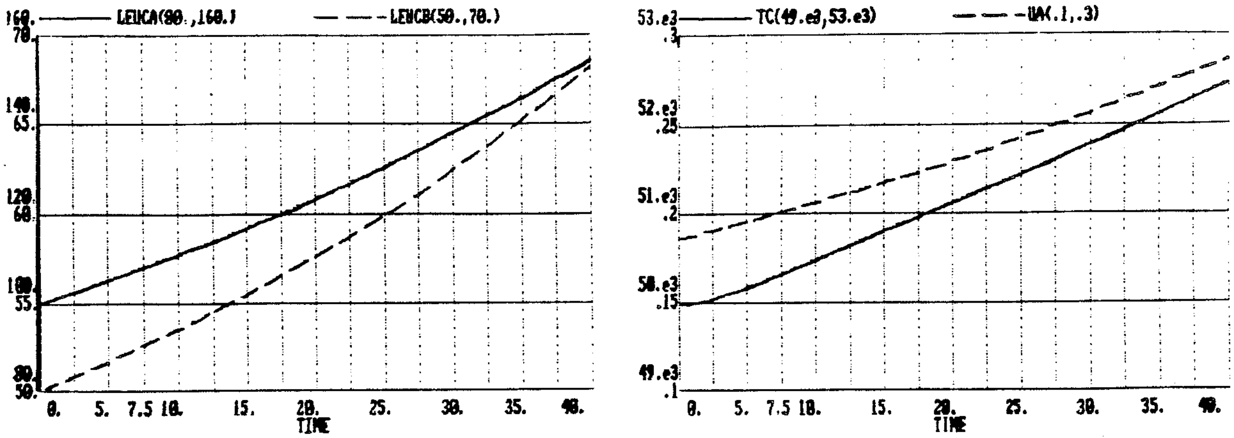
The benefits derived from end-user computing, shown in Figure 3, increase as user's develop more applications, provided a steady infusion of management support. The total costs associated with end-user computing increase proportionately to benefits. This relationship is reflected in the steady rise in user abilities, where the monetary investment is converted into a value added resource.

The next step in the research is to calibrate the model to a specific organization to examine the following decision and policy issues:

1. What level of investment yields an acceptable level of benefits?
2. What level of management control is optimal to insure quality assurance yet allow for system flexibility?
3. How sensitive is user involvement (and their perception of management support) in the application development process?
4. Which factor (number of users, frequency of use, complexity, or criticality) contributes most to application usefulness, and does this vary by organization?

The model also will be extended to consider variations in employment of different levels of technology to user computing experience.

**Figure 3. Output Examples**




## CONCLUSION

Potential benefits of end-user computing include increased individual performance, increased learning about the job and new approaches to tasks, improved competitive advantage from the definition of new product/market opportunities, and the improvement of internal organizational effectiveness by providing important information to management (Gerrity and Rockart, 1986). Factors contributing to end user computing present a complex model, however, the potential advantages to be gained warrant their examination in order to gain insight into how to reap the benefits of end-user computing while minimizing potential risks and disadvantages. In this article we have presented a theory of end-user computing growth and management in organizations which is based on an extensive review of the empirical and conceptual literature available.

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