The Critical Success Factors of Distributed Computing Are Organizational, Not Technological

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ABSTRACT

For more than two decades distributed data processing (DDP) has been predicted to be a major factor in information management. However, in spite of all the interest and activity, firms have not realized the full potential of the distributed style of computing. A three-step approach is utilized to address this problem. First, the full potential of DDP is clarified, second, the major reasons why the full potential of DDP has not been realized are discussed, and third, the critical success factors required to realize the benefits of DDP are elucidated.

INTRODUCTION

Since the late 1970s, distributed data processing (DDP) was predicted to be a major factor in information management [2, 3, 7]. Now, more than a decade later, this prediction is still valid if the proliferation of buzzwords in the literature is any indication, e.g., open enterprise-wide computing, cooperative processing, and client-server architectures.

However, in spite of all the interest and activity, firms have not realized the full potential of the distributed style of computing. In general, advances in computer technology have far outpaced gains in productivity. Today, a silicon chip has the same capacity as an early computer which filled an entire room and since 1960, its cost has declined by 99.9 percent [4]. While annual spending on computer equipment has increased by a factor of 6.5 during the 15 year period between 1975 and 1990, gross domestic product per labor hour has only increased by 15 percent during that same time period, barely 1 percent per annum [25]. The dismal productivity gains are especially pronounced within white collar professions where individuals may spend up to 80% of their time doing nonproductive work such as gathering, storing and transmitting information [4]. The significant downsizing of many large American corporations are telltale signs of excessive levels of non-productive activities and investments.

A three-step approach is utilized to address this problem. First, the full potential of DDP is illuminated. This paper will show how information technology through the distributed style of computing can improve productivity. Second, the major reasons why the full potential of DDP has not been realized are discussed. This failure is often blamed on technical obstacles, and although some do exist, this paper shows that the major reasons are organizational. Third, the critical success factors required to realize the benefits of DDP are elucidated.

Inglesby's [16] definition of distributed computing is adopted in this paper: "A single centrally defined system comprised of multiple individual systems operating to support various sites, all with a common data structure and communication in a consistent automatic manner." This definition shows that DDP requires complete integration since it is a single centrally defined system. Because of the importance of integration, which is described in detail in the next section, the term "integrated computing" is used in lieu of "distributed computing" throughout this paper.

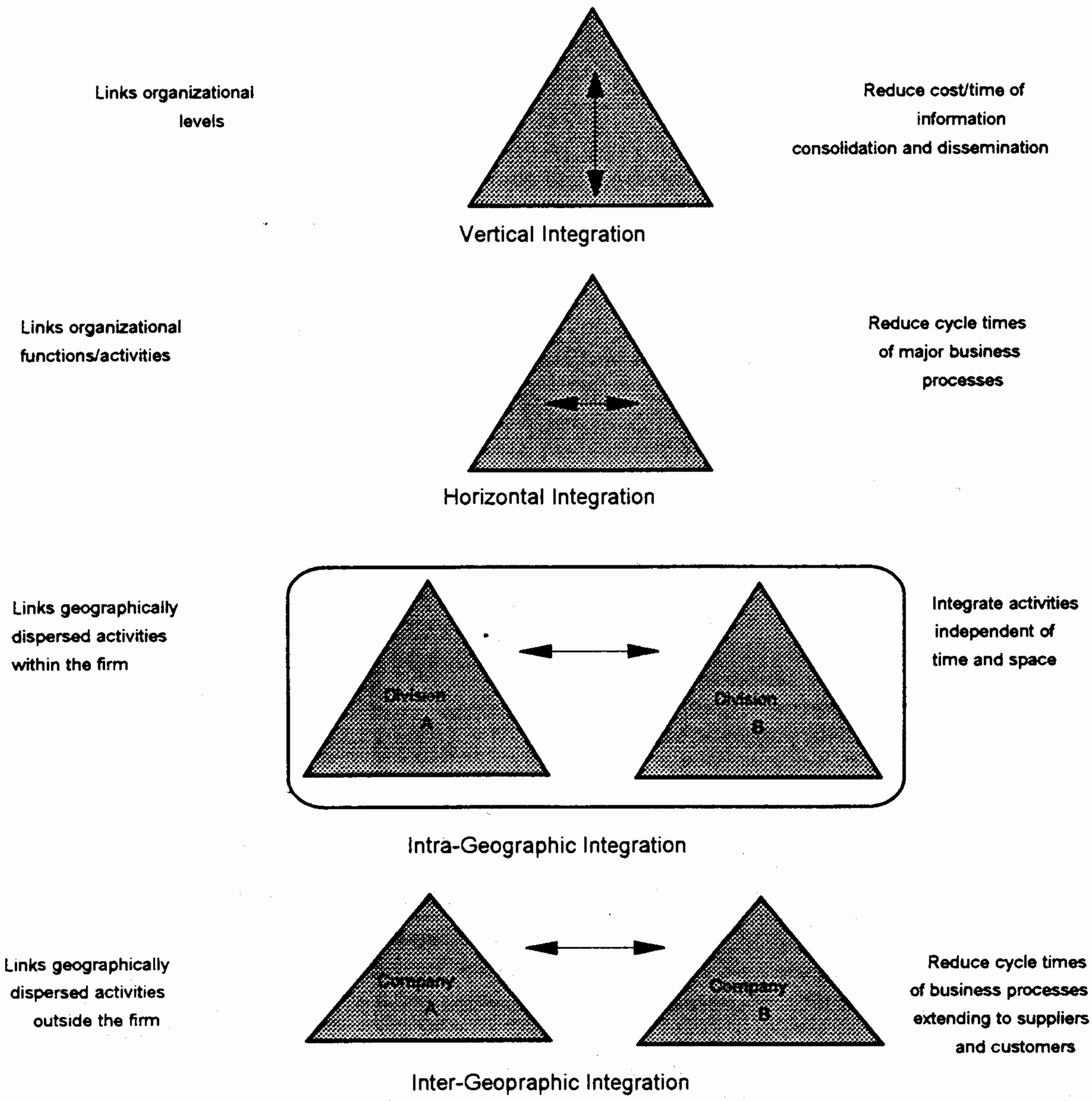
BENEFITS OF INTEGRATED COMPUTING

Information technology is the most powerful tool available to industry to integrate activities and effect strategies. This section describes how information technology maximizes profits by integrating the organization. This integration occurs in four dimensions (see Figure 1): vertical, horizontal, intra-geographic and inter-geographic [17,p.73].

Horizontal Integration

Horizontal integration links activities within a business process typically occurring across organizational functions. Business process integration eliminates nonvalue-added activities and idle waiting periods resulting from repeated and often manual efforts collecting and reconciling incomplete and inconsistent data as it flows from one step to the next. Costs are reduced and customer satisfaction is improved by reducing the cycle times of major business processes such as

Figure 1
Dimensions of Integrated Computing



order fulfillment, acquisition of raw materials and cash collection. For example, when an order processing system is linked to the inventory and shipping systems, orders are fulfilled sooner; inventory management is improved and customers can be immediately informed of any inventory shortages.

Vertical Integration

Vertical integration links activities which span organizational levels. From lower to higher organizational levels, information is integrated from the following types of systems: transaction systems (accounting and order processing), operational systems (inventory management and cash budgeting) and executive information systems (market research and competitive analysis systems). Vertical integration reduces the costs of both the consolidation and the dissemination of information by eliminating nonvalue-added work as information traverses organizational levels in upward and downward directions respectively.

The integration of information as it traverses organizational levels in an upward direction improves management decision-making and economies of scale since information is more accurate, timely, complete and consistent. Similarly, organizational plans and strategies can be effected more quickly and completely by integrating information as it traverses the organizational levels in a downward direction. For example, a purchasing function can readily assess material requirements across the company (upward traversal) and take advantage of volume discounts not possible if handled by local operations. The contracted prices and associated purchase orders can be immediately reflected in divisional manufacturing systems (downward traversal).

Intra-geographic Integration

Intra-geographic integration links physically distant activities within a firm. Intra-geographic systems expand the capabilities of horizontal and vertical integration by transcending time and space. By integrating worldwide information, larger pools of resources can be tapped including inventories, currencies, vendor expertise and employees. Economies of scale can be achieved by offsetting resource shortages with surpluses from around the world. Conversely, differences in resources can be exploited. With the integration of cross-geographic information, the physical centralization of a particular function is no longer necessary to achieve economies of scale and therefore responsiveness to local needs can be maintained. For example, by integrating specialized product with local market information, an advertising campaign can be developed which achieves both economies of scale through specialization and responsiveness to local needs. Similarly, with integrated project management and product engineering systems, people with different skills from around the world can be mobilized to solve a particular business problem.

Inter-geographic Integration

Inter-geographic integration links physically distant systems outside the company. It expands the spectrum of horizontal integration from suppliers to customers further reducing cycle times of major business processes. Examples of inter-geographic integration are well known. By linking the order processing and accounts payable's systems of suppliers and customers, electronic data interchange (EDI) eliminates purchase order and invoice processing. The cycle times of order fulfillment and payments are shortened. By linking retail transaction processing systems to customers, automatic teller machines improve customer service by allowing customers to transact business anywhere at any time. Universal product codes (UPC) integrate the entire retail industry's supplier base to inventory tracking systems tremendously increasing inventory management capabilities. UPC is the essence of integrated computing as defined in this paper: a singly defined mechanism to communicate in a consistent and automatic manner.

Although this genre of discussion would more likely be found in a textbook on organizational theory and design than on computer technology, these are the greatest opportunities afforded by information technology today. Information technology brings organizational theory and design into a new realm of study. By eliminating organizational barriers to the total flow of information, integrated computing can combine the advantages without the disadvantages of two diametrically opposing organizational strategies: centralism and decentralism [24,p.313]. By pursuing an integrated computing style, overall coordination, control and economies of scale can be achieved at a reduced cost and without the loss of local responsiveness and flexibility.

CHALLENGES IN ACHIEVING THE BENEFITS OF INTEGRATED COMPUTING

Just as the benefits of integrated computing are organizational, alas so are the challenges. These challenges are outlined using examples mostly from one large American corporation which will be called Stetson Enterprise in this paper. Although this perspective is primarily based on one company's experience, the insights can be applied to American industry in general. Virtually all large American corporations are undergoing downsizing efforts, forced by competitive pressures to shed nonvalue-added activity and investment. The research presented in this paper and conversations with information systems executives and consultants indicate that all large American companies are grappling with the same basic issues. The severity of these challenges is likely to vary directly with size, age and investment in existing information system infrastructure.

Before discussing the specific challenges, it is necessary to dismiss technology itself as the major culprit. While computing literature is replete with technical obstacles of integrated computing, these obstacles will quickly be surmounted. Technological advance is rapid. Today, multi-vendor, heterogeneous integrated systems are a technological reality. For example, Arthur Anderson's "Hospital of the Future" integrates the clinical and administrative systems of twenty different vendors [5]. It is based on HL7, an application level standard, developed by an industry consortium.

Figure 2
Challenges of Integrated Computing

Organizational Structure and Strategy

Business strategies stymied by IS application portfolio

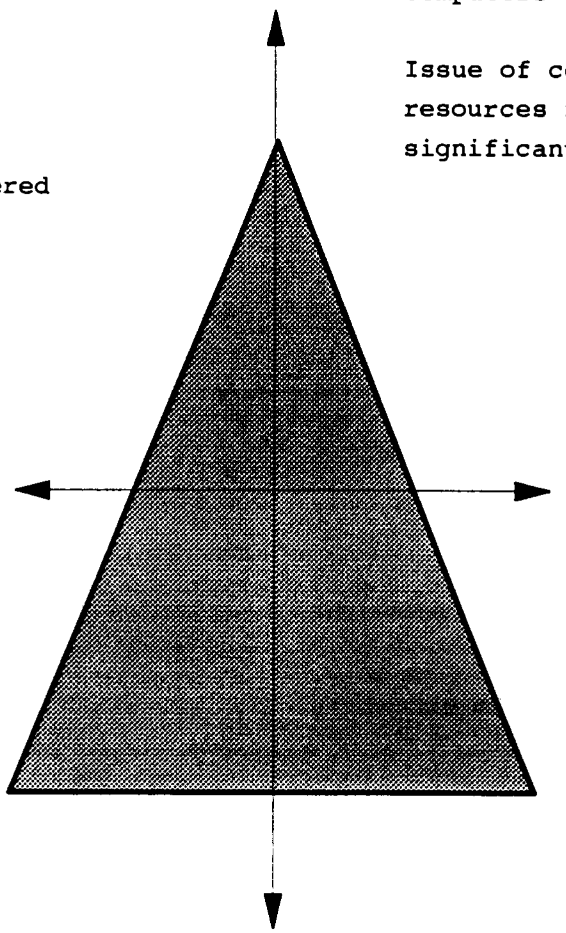
Low top management involvement

IS function not empowered

Control

Rapid proliferation of micro computers

Issue of control over IS resources not recognized as significant factor



Planning

Expensive and complex

Short-term incentives prevail

A purely centralized or decentralized process is ineffective

Management Approach

Systems managed along de partmental boundaries

Systems support manual processes

Inherently difficult to and adapt

However, one thing that cannot be demonstrated is the transition from the "Hospital of Today" to the '"Hospital of the Future." As a laboratory experiment, the "Hospital of the Future" is completely devoid of organizational dynamics.

Rather than the technical obstacles, the major challenge of integrated computing is to change the organizational paradigms and disciplines necessary to deploy integrated computing systems in a manner which can harness its greatest capability — organizational integration. For example, CASE technology promises to integrate the software engineering process, yet remains underutilized. Among other paradigmatic and disciplinary changes, the effective use of this technology requires: that the software engineering become a science subject to rigid methods, rules and criteria; that the programming function itself (e.g. actual scribing of code) become obsolete; and that fewer not more new lines of code become the incentive.

The organizational challenges of integrated computing can be broadly categorized into 4 key areas (see Figure 2): control, management approach, planning and organizational structure and strategy.

Control

During the period of the 1970s and early 1980s, control of information management was decentralized. Smaller computer systems proliferated. In 1970, the percentage of mainframe, minicomputer and microcomputer sales was 94 percent, 6 percent and 0 percent. By 1987, the comparative breakdown was 40 percent, 40 percent and 20 percent respectively [15]. Smaller computer systems were easy to justify. The cost per performance unit of smaller computers continued to decline relative to larger computers. According to one study, the cost per MIP (millions of instructions per second) of a microcomputer was less than five percent of the cost per MIP of a mainframe computer [20]. Smaller computers could not only be purchased at a low introductory price but also could grow in small increments.

In addition to the favorable economics, smaller computers satisfied unmet business needs. Large central systems had reached a point of diminishing returns. The backlog of information system requests grew to tremendous proportions and the incremental cost of adding new applications rose substantially [9].

Given these trends, it is unlikely that any large firms have avoided the proliferation of microcomputers. During this period, Stetson counted dozens of different general ledger, vendor payable, budgeting, and labor tracking systems throughout the company. Similar examples could be found in virtually all application areas.

Unfortunately, the decentralization of computing location, had the practical effect of decentralizing control [19]. In the words of one manager his new microcomputer "permitted him to do few small applications unencumbered by the red tape and priority system of the data center where such applications should officially be done [6]." Even in situations where the initial decentralization effort is carefully planned and controlled, the newly decentralized systems quickly grew in size and purpose as users gained experience and identified new functions to automate. At one university, computing capability was decentralized to an administrative department, initially involving one minicomputer and an IS staff of ten. Within three years the department was purchasing its third computer and had an IS staff of forty [19].

Once control of information resources is decentralized, it is difficult to standardize systems of different organizational units. Usually, standardization means eliminating a multitude of different systems which have evolved over the years to meet the nuances of respective constituencies yet which perform the same essential function. Substantial investment in terms of person career years exist in each of these systems and since information vests the power to make decisions, the control of these systems is tantamount to career longevity and mobility. Consequently, organizational politics becomes the major factor governing information system decisions.

During the last decade, Stetson has made significant progress reducing the numbers of different systems and standardizing data across systems. Managers credited with this progress, agree that the major challenge was managing the organizational politics surrounding the control over information resources.

Management Approach

When control of computing resources was decentralized, information systems were developed along departmental or divisional boundaries with little regard for overall organizational use of the information or whether or not the system supports the strategy of the firm [4]. At least a couple of explanations exist for this evolution. First, behavioral research shows that individuals and departments will value their personal and departmental interests more highly than those of the organization [19]. As a result, information systems are suboptimal for the organization as a whole. Second, departmental systems are by definition limited in scope. As a result they are easy to understand, deliver relatively short-term results and are politically simple, e.g. they obey turf boundaries [2].

Unfortunately, most of these departmentally developed systems simply replaced existing manual systems which are inherently not integrated [27,p.298]. Today the costs of integrating these systems are monumental. It is estimated that a major systems rearchitecture for a one billion dollar company would cost tens to hundreds of millions of dollars [13].

The following analysis of Stetson's fixed asset management process illustrates this departmental or project management approach. An inventory of asset-related systems revealed: a system used for fiscal asset accounting, a system which tracked assets on consignment, a system which tracked assets prior to being placed in service, a system which tracked idle assets used as a clearinghouse to share assets within the company, a system used by facilities and data center groups throughout the company to manage their assets, and many physical asset inventory systems. All of these systems interfaced with one another through batch file transfers and manual transactions creating a labyrinth of convoluted data flows.

Each of these systems was supported by a team of developers, operators and users. Several of the teams were engaged in independent efforts to replace the existing system with either a newly developed or an externally purchased system. Despite evidence showing that their similarities significantly outweighed their differences, independent project efforts were continued.

The system used to track assets prior to being placed in service was built nearly twenty years earlier in order to accumulate spending for large assets such as buildings which took years to construct. Even though this type of asset was now the exception, all assets were processed through the system, as a rule. Analysis showed that by capturing more data at the beginning of the procurement process, the system and all associated work could be eliminated. However, it appeared unlikely this opportunity would be pursued in the near future since the system which required modifications was "owned" by an external department who would not directly benefit from the change.

The plethora of asset tracking systems and physical inventory systems existed since many different groups had responsibility for the management of their own assets and each group automated their own process. Most of the functionality in these systems duplicated the functionality of the other systems. However, it was significantly easier to build departmental systems since individual groups did not share functionality, data, or development resources.

This example illustrates a flawed management approach. Systems within a process are not managed as a whole where activities can be synergized and leveraged. Rather than integrating activities within a process, existing systems which are often based on disjointed manual processes, are simply replaced. Significant opportunities to improve the efficiency and effectiveness of the overall process are forgone.

Several factors may explain this management approach. First, the existing process is well understood by all involved individuals and is therefore more easily pursued through natural habit. Second, management fears missing promised schedules and deliverables in an environment where short-term results are rewarded. Third, process integration is a more difficult alternative and is necessarily longer-term. With the introduction of external dependencies, organizational politics will inevitably interfere with plans and short-term objectives.

Planning

A more coordinated management approach could be facilitated by a company-wide planning process. Unfortunately, studies show that firms do not successfully use widely accepted planning processes [22]. Where formal planning processes do exist, it is unlikely they involve information systems. At Stetson, a formal long-range planning process exists to establish budgets for business units within the company but it does not include information system objectives.

Instead, both a centralized and a decentralized IS planning process have been attempted without success. At one point, a central IS organization developed a high-level information systems architecture for the company. This architecture was published and widely distributed to IS employees. However, the architecture is not used for any substantive purposes as the central group had no control over necessary resources to even translate the architecture into specific plans.

The IS planning function is also performed in different operational groups. However, within the operational groups, daily responsibilities take precedence over planning. As research studies have found, organizational incentives do not reward widely accepted planning principles [21]. While plans that are created within these operational groups do get executed, they are short-term focused and not integrated into corporate-wide business plans.

As this case illustrates, neither a purely centralized or decentralized planning process is effective. Planning within individual operations, where the modus operandi is short-term, cannot achieve overall integration. On the other hand, the central IS group has neither the authority nor the resources to handle the difficult task of coordinating integrated systems planning across the company. Integrated computer planning is expensive and complex as it provides a very large number of choices [18] involving wide ranging activities and having substantial organizational impact [7].

Structure & Strategy

Information systems that do not fit the organization they were designed to serve are not uncommon [7]. Given the decentralized control of IS resources, a project-oriented management approach and poorly coordinated planning processes, this disappointing result is inevitable. The failure to integrate business activities is a major reason why companies cannot achieve strategic goals with IS technology [3].

At Stetson, strategies to organize around customers and to provide a single contact point within the company for its multinational customers were stymied by its information systems portfolio. Each geographic region of the world had its own stovepiped systems handling different aspects of their customers' business. This situation existed since at one time, business units had been aligned by product segment and at another time by geographic segment. The life span of the system was greater than the life span of the strategy and structure it supported. Because the systems were designed to service the needs of one specific structure, they could not be easily adapted to structural and strategic organizational changes.

With strong divided IS functions and an impotent central IS function, systems could not be integrated in order to achieve organizational strategies. The structure of the IS organization did not mirror the organizational structure and therefore its systems did not reflect the interdependencies. Specifically, there was no pinnacle within the company where control and coordination extending to all organizational units — was maintained. Within the IS profession in general, the Data Processing Manager has only recently ascended to a more prominent Chief Information Officer and at Stetson, a feeble IS function continues to report into administrative and financial functions.

CRITICAL SUCCESS FACTORS

Based on the preceding discussion of the evolution and challenges of integrated computing, critical success factors are identified for each of the four key areas (see Figure 3): control, management approach, planning and organizational structure and strategy. These critical success factors are interdependent and in order to achieve the benefits of integrated computing, all must be attained. Each of these success factors require the intimate and active involvement of the Chief Executive Officer since they exert considerable impact on the organization by changing work flows and responsibilities and by shifting the balance of power and influence within the company [8]. The key areas are addressed in reverse order from which the problems began.

Strategy and Structure

Information systems must match an organization's strategy and structure to facilitate the achievement of business objectives. At the lowest level, this objective requires that the responsibility for information processing activity be given to the business unit most closely associated with it [28]. When systems fit an organization, information processing is necessarily distributed since organizational activities are distributed [6]. At the highest level, control over information processing activity must be elevated to an organizational position which can ensure systems mirror organizational interrelationships and provide optimal results for the company as a whole.

Planning

Control of the planning process should be centralized [24, p-.323] while execution of the planning process should be decentralized to business users and technicians. The IS planning process should be tightly integrated with the overall business planning process. In this manner, planning is orchestrated to achieve overall integration and responsiveness to both business requirements and technological capabilities.

Management Approach

A process-oriented function approach rather than an project-oriented application approach is required [2]. A process-oriented approach ensures that systems are adaptive to structural and strategic change since they are solidly founded on the least common denominator of data entities and process activities which integrate the company. Integrated computer systems are resilient to organizational change since the business entities and activities upon which they are based remain stable.

Control

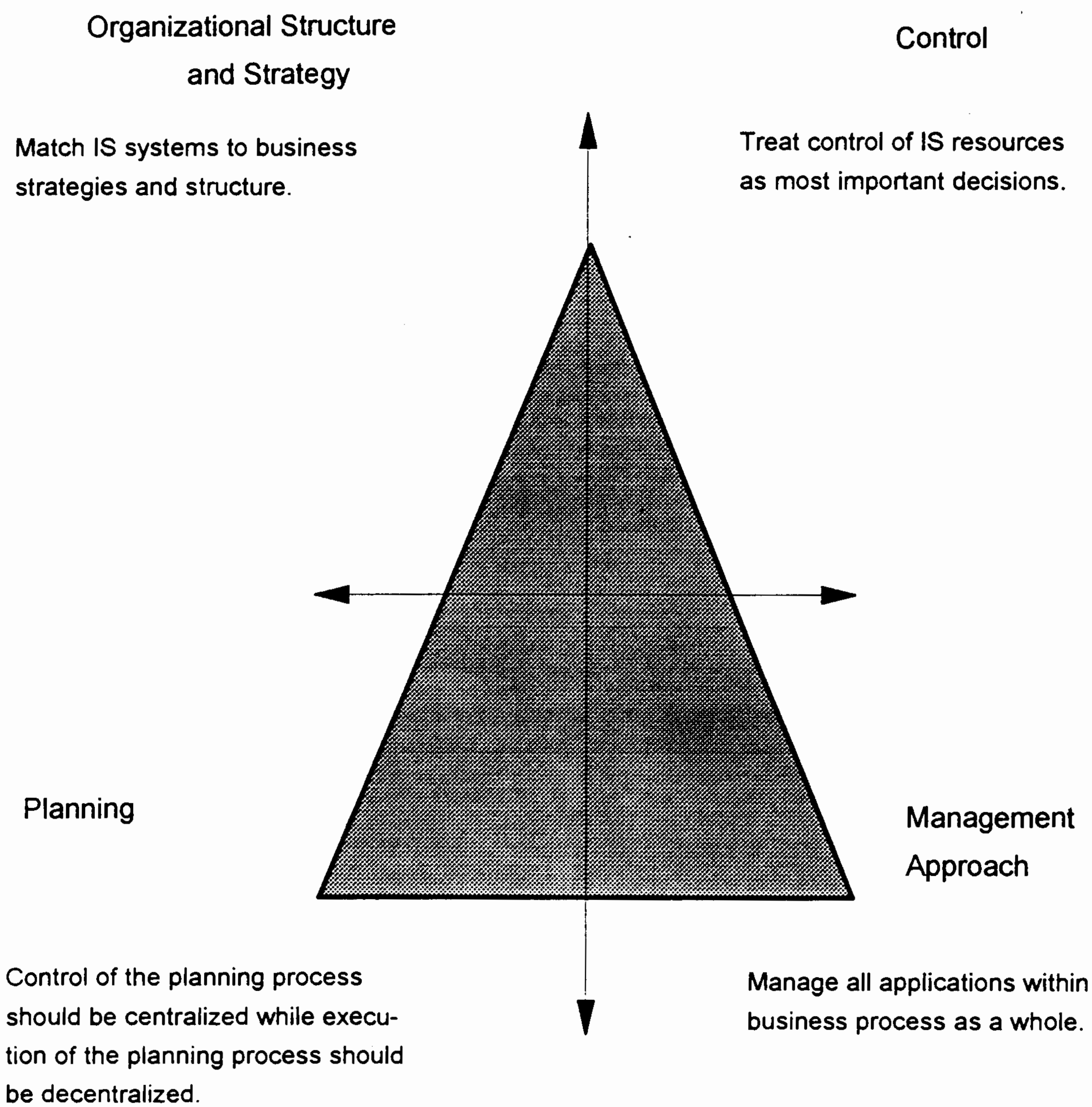
The decisions governing control over IS resources must be treated as the most significant management task in constructing an integrated computer system [19]. Organizational politics play a significant role in making these decisions since power tends to rest at the level where the necessary information is accumulated [6]. Consistent with the first critical success factor, decisions about control over IS resources should parallel the organizational arrangements to which they are applied at all levels within the company [19].

CONCLUSION

The rate of technological advance has far outpaced productivity gains within the United States. This fact alone makes it painfully clear that the benefits of information technology, in general, have not been achieved. Specifically, firms have failed to harness information technology's most powerful capability — organizational integration. This paper has shown that this capability can be achieved through integrated computing. Integrated computing has the potential to eliminate nonvalue-added activities, flattening the organizational pyramid and improving economies of scale. At the same time, integrated computing can create an environment which is more responsive to changing business conditions by providing meaningful information to the appropriate people at the appropriate time.

The realization of these benefits requires a fundamental rethinking of business processes [11]. Technology is not the obstacle in integrating diverse systems nor is it the solution of the future. However, information technology must be considered of paramount importance in rethinking these pro-

Figure 3
Critical Success Factors of Integrated Computing



cesses since it is the most powerful tool available to achieve the required level of integration.

The evidence presented in this paper and more ominously, the recent downsizing of many large American companies suggests that firms have been largely unaware of the monumental yet extremely latent costs of poorly integrated systems. Top management has not orchestrated organization-wide planning which includes information technology strategies. Systems function as stand-alone units optimizing the goals of the department and not the organization. Most of these systems support business processes which were developed before computers and communications ever existed

[11]. As a result, business processes contain significant nonvalue-added activities and can no longer respond to changing business conditions. Consequently, information systems do not reflect organizational interdependencies and have become an encumbrance to improving productivity and achieving business strategies.

The consolidation of organizational units as a result of downsizing will achieve a certain level of integration by default. However, this method alone will not achieve the benefits of integrated computing since it does not address the fundamental issue of how to distribute work within a large company without the loss of control and coordination.

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