Distributed Computing Systems, Structure And Strategy

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Abstract

Disparate studies have provided inconsistent results of the effect of information technology (IT) on organizational structure and strategy. Additionally, some other studies indicate contradictory outcomes from the implementation and use of identical technologies. This study examined the effects of distributed application systems on organizational structure and strategy. Using distributed application system (DAS) components as measures of distributivity, the study examined the impact of distributivity of data, program and user-interface on the dimensions of organizational structure and business level strategies.

The research findings indicate that there is a synergic relationship among the components of DAS, and that the DAS components are highly intercorrelated. Further, the study has demonstrated that user-interface replication in DAS is strongly associated with data replication and program partitioning has a strong impact on user-interface partitioning.

Introduction

The impact of computerization on decentralization (multiple autonomous sites) and centralization (single site) has been debated over 3 decades. The advent of distributed computing systems (DCS) has added a new dimension to this debate. At issue is the effect of DCS on organizational structure and strategy. Disparate studies have produced contradictory outcomes from the implementation and use of different technologies and others have not yielded anything substantial. It seems logical then to conclude that there might be a relationship between information technology, structure and strategy. This study adds another dimension of IT, namely, the extent of distribution of IT within an organization. The study targets the technology dimension by considering the level of distributivity of IT within an organization as a measure of technology and its implications on structural properties and business level strategies (BLS). The study addresses a critical gap in the literature pertaining to structure, strategy and DCS by integrating the three factors and examining how these factors influence each other.

Research Questions

This study will address the following research questions: Do organizational structure and strategy factors have any relationships with distributed computing systems? To answer this, the study will investigate the following sub-questions: Is there any relationship between DCS and the dimensions of organizational structure? Do competitive strategies (AKS, BLS) have any relationship to DCS?

The study examined the widely accepted structural properties: complexity, formalization and centralization and their relationship to business level strategies: product differentiation and cost leadership and DCS as the enabler.

Distributed Application Systems

A distributed application system (DAS) may be identified by a set of two distributivity components, replication and partitioning along which distributed computing systems (DCS) differ. In combination, there are data

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replication, program replication, user interface replication, data partition, program partition, and user interface partition. The distributivity attributes distinguish DAS from non-DAS and other types of DAS.

The application system (AS) is believed to be the foundation of the DCS and is recognized as "the most critical aspect of distributed computing." (Umar 1992). It is further believed that the level of distributivity in the DAS determines the level of distributivity in the DCS (Fletcher 1997). Some researchers, for example Singh (1994), have argued that DCS can be measured along the following dimensions: distribution of sites (data), degree of node autonomy, network variety, degree of distribution in processing, degree of site administration autonomy, degree of heterogeneity and hardware platform.

The variables mentioned above (the DAS components) will be used as the dimensions of DCS because they may be the driving force that could have an impact on the structure and strategy of an organization. Before presenting our model, it is worthwhile to present some of the key terms associated with DCS. These include data integration, cooperative processing and client server.

Data Integration generally means the standardization of data definitions and structures through the use of a common conceptual schema across collection of data sources (Goodhue et al. 1992). Without data integration, there will be increased processing costs and ambiguity of meaning (Huber 1984). It is further asserted that, if interdependence among business units is high, data integration may facilitate communication among business tasks and units. Data integration is not distributed computing but could be considered as an important enabler.

Cooperative Processing has been defined (Atre 1992) as "one in which portions of an application run on different computers, and data may be at various installations." Khanna (1994) notes that cooperative processing assumes the presence of DCS that allows transparent access to data. Intuitively, it seems DCS could meet many requirements of cooperative processing.

Client Server Computing allocates application processing between the client and server process and contains the following: presentation logic (user interface), application logic (processing), and data management logic. These three basic components of the client server system can be distributed over several machines.

A Model For The Impact Of DCS

In an organization, the technology employed, the structure, the strategy, individual roles and management process are interdependent (Leavitt, 1965; Rockart and Morton 1984). The advent of new technologies are accelerating the pace of change at corporations by establishing new organizational forms and performance standards (Teng et al. 1993). If one attribute is changed, there will be an impact on other attributes. A change in technology may have powerful interactions with other organizational attributes. For example, technology may be a necessary prerequisite for a shift in strategy or structure, because it has a potential for changes in information flow affecting individual roles and organizational structure (Goodhue 1992).

To examine the relationship between the level of distributivity of data, program, and user-interface, and structural properties and business level strategies, we have to make some assumptions. Our basic assumption is that the distribution level of DCS is one of the fundamental tools by which organizations can alter the way work is done. For example, if management wants uncertainty resolution and/or decision-making to occur as close as possible to the action, and does not want extensive communication from a central location, a high level of DCS may be necessary. Valduriez (1996) notes that: "Fragmentation of data is desired because it makes possible the placement of data in close proximity to its place of use, thus potentially reducing transmission costs." The fragments of data may also be replicated, thus the potentiality of cost effectiveness may be realized because it may be more effective to duplicate data as it changes rather than move it between sites every time it is needed. Distributivity may not be any better at supporting tasks than centralized systems, but they may be cheaper and/or more efficient. It can generally be said that decision-makers are boundedly rational due to limits of human information processing and communication. The use of DCS could expand these limits by improving the local quantity, quality, and efficiency of data collection and storage, processing and communication. If it is true that the use of IT has a positive impact on the strategic

decision-making process, as argued by Huber (1960), then it is reasonable to believe that the extensive use of IT may have a greater impact than limited use. A high level of distributivity may accompany the extensive use of IT. Therefore, we can explicitly or implicitly say that the level of DCS is one of the fundamental tools by which organizations can partly transcend bounded rationality, which involves the reduction and/or management of complexity (eliminating uncertainty).

The other basic assumption is that a high degree of distributivity of IT may encourage the creation of new ideas and hence product differentiation. This assumption is related to what Simon (1973) called "discovering the path of virtue." Simon argued that if magic was to be performed, it was not through the creation of new organizations and enforcing virtue, but discovering the path of the virtue. It may be said that a higher level of distributivity may bring in new decision-making processes through comprehensiveness, technical sophistication and pluralism. This has been supported by Thompson (1967) who argued that "the innovative organization will be characterized by structural looseness with less emphasis on narrow, non-duplicating, non-overlapping definitions of duties and responsibility." Job description will be the professional type rather than the duty type. Communication will be free and legitimate in all directions. Assignment and resources decisions will be much more decentralized than customary.

We can also assume that a high level of distributivity of DAS components can improve operational coordination among business units. For example, most organizations do not operate from a single room, some not from a single building or even a single continent. They have employees generating and demanding access to data and programs from different regions of the world. Linking these operations together requires a DCS that allows data and programs to be shared in many different ways. The advent of DCS has contributed to the improvement of internal and external coordination and has made all types of enterprise-wide data accessible to their employees (Valduriez 1996).

The strategic alignment model initiated by Henderson and Venkataraman (1989) and later by Luftman et al. (1993) consider both the strategic fit between strategy and infrastructure as well as a functional integration between business and IT. Two types of integration are noted, viz: strategic and operational. Strategic integration deals with the links between business strategy and IT strategy reflecting the external components. Operational integration deals with the internal domain, the link between organizational infrastructure and processes and information system infrastructure and processes. There is need to align the external domain and internal domain of IT because the dynamic environment requires an internal domain, which is flexible and can react swiftly to external changes.

The overall model of the impact of DCS on structure and BLS is shown in Figure 1 below. The importance of each of these impacts is defended by theoretical arguments initiated above and illustrated by business process reengineering (Teng et al. 1993). Thus, in this research we focused on DCS and how the organization of its components affect the structural properties of an organization and BLS.

Concepts Of The Proposed Elements

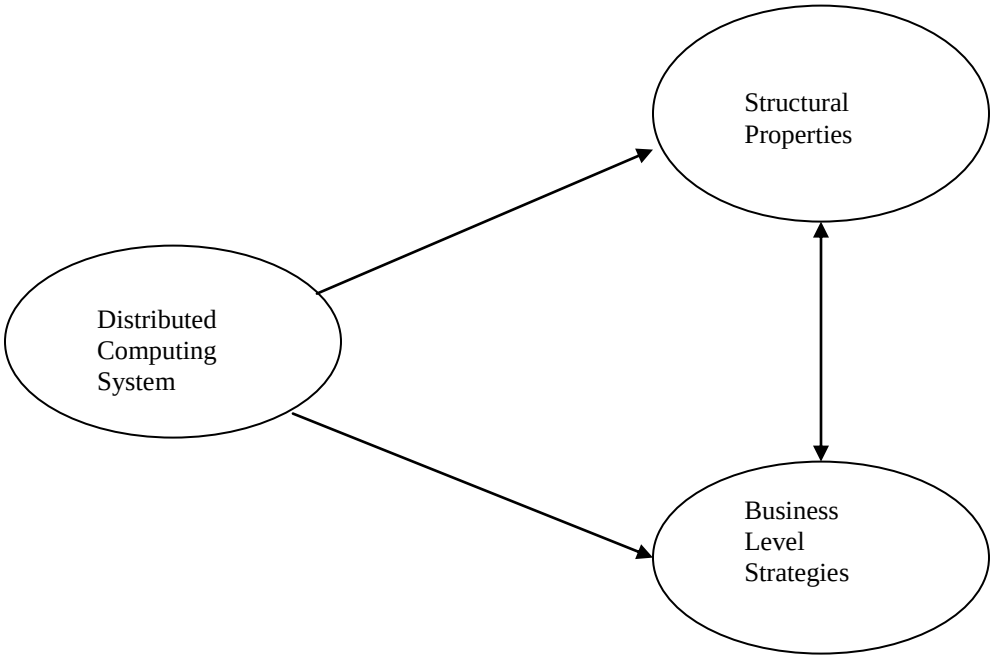
In this section, we discuss some of the issues related to our model in Figure 1.

Structural Properties

What are the dimensions of organizational structure? Traditional responses to the question include such variables as hierarchical and lateral levels, span of control, complexity, formalization and centralization (Blackburn 1982). The number of variables differs from study to study. According to Ford and Slocum (1977), there is some disagreement as to whether control strategies, vis-à-vis centralization and formalization, are part of one structural type or are autonomous dimensions. Earlier research of Pugh, Turner, Hickson, Hinings (1968) suggest a few dimensions of organizational structure. James and Jones (1976) and Champion (1975) suggest seven and eight dimensions respectively. Montanari (1978) proposes 16 possible dimensions of organizational structure. All these dimensions are part of complexity, formalization and centralization. Because of the tradition and the frequency use, this research used complexity, formalization and centralization as the dimensions of structure. This composition is

not universally accepted, but for the purposes of this research, the three characteristics are accepted as the core components of organizational structure.

Figure 1: The Model of DCS, BLS, and Structure



Complexity

According to Slocum and Ford (1977), complexity refers to the degree of differentiation within the organization. Differentiation may be horizontal, vertical, spatial or personal in nature. It includes the number of hierarchical levels (vertical), the number of functions (horizontal), and the number of operating sites (spatial). As defined by Robbins (1990), vertical differentiation is the number of levels, i.e., the number of persons in the longest chain of the process hierarchy. Horizontal differentiation is the number of different occupational specialties representing distinct blocks of knowledge. This is not the same as job titles.

Formalization

Formalization refers to the use of rules which, in most cases, are called "red tape of bureaucracy" (Hage and Aiken, 1967). If a function to be performed is highly formalized, the performer has little to say over what is to be done, and how it should be done. There are explicit job descriptions, lots of organizational rules and clearly defined procedures to be followed. When there is low formalization, employees are relatively non-programmed. In most cases, they have freedom in performing their work (Robbins 1990).

Evaristo et. al. (1995) defines formalization as "…the level of specification and structure afforded by the task." Hence, each task has its own characteristics defined in terms of time pressure, task formalization and task complexity. If tasks are structured, an automatic response is developed requiring minimal cognitive effort (Evaristo et. al. 1995).

Centralization

Centralization refers to the degree to which all decisions are concentrated at a central point. The basic thesis is that concentration of decision making at the top of the management pillar can also be distributed to sub-unit levels. This dispersion of decision making is called decentralization.

Business Level Strategies

Defined formally, strategy is an integrated and coordinated set of actions taken to exploit the core competencies and gain competitive advantage over rivals (Hitt et. al. 1995). Core competencies are resources and capabilities that serve as the foundation of competitive advantage over the firm's rival in the business. They are the primary determinants of a firm's value crated strategy. BLS may be defined as detailed action taken to provide value added to customers, and gain the competitive advantage by utilizing core competencies in a particular segment of the market. BLS is concerned with the firm's position within an industry relative to the competitors in the market. According to Porter (1980), there are four generic BLS: cost leadership, differentiation, focused low cost, and focused differentiation.

Cost Leadership Strategy

In the implementation of a cost leadership strategy, firms offer products with acceptable features to their customers at a lower price compared to the competitors. Having the low cost position serves as a valuable defense and offense against the rivals (Wheelen & Hunger 1992; Hitt et. al. 1995). Albeit, product quality cannot be totally ignored here (i.e., basic product performance is still required), cost minimization is the single competitive criterion and an overriding priority (Parthasarthy and Sethi 1992). The competition is at the lower end of the market where product differentiation is minimal and the market highly price sensitive. Low cost relative to rivals becomes the running theme through the entire strategy (Govindarajan 1988).

Differentiation Strategy

The differentiation strategy calls for organizations to provide customers with different kinds of products that have unique attributes. Because these products are unique, they are sold at premium prices. This strategy calls for subjective measurements (Porter 1980; Wheelen & Hunger 1992; Hitt et. al. 1995) and incentives instead of quantitative measures. Unlike the cost leadership strategy that emphasizes low cost, differentiation emphasizes high quality. The following elements can be used to measure this strategy: unique product design, product features, brand identification and product quality (adding value).

Cost Focus And Focused Differentiation

A focus strategy is one whereby an industry or firm wants to use its core competencies to serve the needs of a segmented group in the industry. The success of the industry depends on its ability to find the segments of the market, which are poorly served by the competitors (Wheelen & Hunger 1992). When the lower cost and differentiation strategies are focused on a market niche (Porter 1980; Wheelen & Hunger 1992), they are referred to as cost focus and focused differentiation. Competing in a single market based on the product mix is called flexibility (Parthsarthy and Sethi 1992). Gerwin (1989) and Meredith (1987) call them speedy flexibility. As our point of reference, we use an adaptation of Porter's generic competitive model. As shown in Table 1, Porter's four generic strategies have been referred to collectively as "competitive strategy" (Hitt et. al. 1992), from which firms choose to establish and maximize competitive advantage within any given industry.

Table 1: Porter's Competitive Strategy

Cost	Uniqueness
Cost Leadership	Differentiation
Focus Low Cost	Focused Differentiation

Porter argues that competitive advantage is achieved when the state of the organization is focused on one of the above competitive strategies. According to the recent research (Miller & Friesen 1986), Porter's generic strategies are not mutually exclusive. This means that a firm can pursue several strategies simultaneously.

Measures Of Proposed Elements

In this section, the conceptualization and measurement of each of the variables used will be discussed briefly. We have introduced a number of items for each of the concepts: formalization, complexity, centralization and business level strategies. We shall now set forward the procedures used for measuring them.

Formalization – (Standardization Of Tasks)

The measurement of formalization is based on the Aston Group Formalization Scale which measures the extent to which rules, procedures, instructions and communication are written down. The scale will be used to express values of this variable. Formalization is indicated by the following measures: job codification and rule observation. The higher the score on this scale, the more the organization is formalized vis-à-vis the definition.

Complexity

As defined by Robbins (1990), two variables are used to define complexity, viz: vertical differentiation (VD), which is the number of levels, i.e., the number of persons in the longest chain of decision-making hierarchy and horizontal differentiation (HD), which is the number of different occupational specialties representing distinct blocks of knowledge (this is not the same as job titles). The operationalization of VD is similar to that given by Dewar and Hage (1978). They also define HD as the number of departments.

Centralization

To measure centralization, a modified version of the Aston Group Scale will be used. The scale represents the level in the organization at which the number of decisions covering a range of activities can be authoritatively taken, e.g., 5 represents decisions taken at the highest level in the hierarchy, whereas 0 represents the lowest level in the hierarchy.

Business Level Strategies

The competitive position of an enterprise system can range from a superior position to an inferior position relative to the position of its competitors (Oliva et. al. 1988). BLS answers the following question: How will an enterprise compete in one business or in a particular product? Porter's (1980) typology will be adopted because of its wide spread acceptance, viz: differentiation and low cost. Characterizing the scale can be attained or accomplished by different methods, vis-à-vis, brand image, new product development and product innovation in differentiation strategy. Cost leadership will be gauged by using efficiency of operation and relative selling price. A 5-point Likert Scale will be used with values ranging from "not important" to "very important". The score of the items will be summed for a combined single scale.

Dimensions Of Distributed Computing Systems

The components of the application system (AS), application data, application program and application user interface are the foundation of DCS and the focal point of this research. In this section, we pursue some issues pertaining to our research. The principles of database design are the same either in distributed or non-distributed database design.

A distributed database design can be measured along various dimensions. For example, consider a relation r that is to be stored in the database. There are many factors involved in storing this relation in a distributed database; we will be concerned with replication and partitioning.

Replication – The system maintains many similar copies of a relation. Each replica is stored in a different mode. If relation r is replicated, a copy of a relation r is stored in multiple sites. If there is failure in one site which contains r, then the relation may be located in a different site. The system can still process queries despite the failure of one site.

Partitioned – Data in a relation can be partitioned into fragments which are& located at different sites. A composite object will be fully partitioned if there is at least one constituent object in each site or node of DAS. There are two different schemes for partitioning a relation: horizontal partitioning and vertical partitioning.

Horizontal Partitioning – This is the movement of application data, application program and application user interface across different modes.

Vertical Partitioning is the same as "decomposition". Columns are attributes. The columns in a table are split into different fragments and each attribute is mapped to at least one fragment. Replication and partition can also be partially replicated or partially partitioned.

Partial Replication – A composite object can also be partially duplicated if at least one of its decomposed objects is replicated or if one or more of its decomposed objects is duplicated.

Partial Partition – A composite object is partially partitioned if at least more than two of its decomposed objects are placed on different nodes.

Partial partition and partial replication can co-exist. In an ideal situation, data, programs and user interface can be mapped to the above states. The combination of AS components to the distributivity dimension results in six variables: (1) data replication; (2) data partitioning; (3) program replication; (4) program partitioning; (5) user interface replication; and (6) user interface partitioning.

In summary, distributivity of database may be the result of business practices; according to Khanna (1994), more distributivity is inevitable. As indicated, different levels of distributivity may exist for each of the variables mentioned above.

Development Of Sample Population

This section describes how the sample population of this study was developed. Four procedures were adapted as personal references to collect the data. The first procedure was to contact management consultants who provided the researcher with the names of potential contributors from management environments. The second procedure was to contact MIS consultants who provided the researcher with names of potential contributors from MIS environments. The third procedure was to request CEOs and MIS administrators to contact their supporting staff to participate in the study. The fourth procedure was to make direct telephone calls to organizations located in New York and New Jersey. The purpose of telephone calls was to facilitate the response. Questionnaires were mailed to the four personal references via self-addressed envelopes asking CEOs to answer strategy questionnaires, MIS administrators to answer DAS questionnaires, and supporting staff to answer structure questionnaires.

Data Collection

Three sets of questionnaires were mailed to chief executive officers (CEOs) of participating organizations. The CEOs were requested to answer questionnaire set "A", and distribute questionnaire sets "B" and "C" to departmental heads and information system managers respectively. Each participant was asked to mail the response directly to the researcher. Sixty-two questionnaires were returned in a usable form.

Data Analysis

Data was analyzed using inferential statistics in the SPSS environment. Inferential statistics focused on correlations and regressions. This study used factor analysis to identify a set of underlying dimensions. Factor scores were then used for cluster analysis to develop taxonomies for strategy and structure. It has been argued (Kim et al, 1988) that cluster analysis is more useful than multivariate technique in the development of empirical taxonomies because only a few factors are extracted. Additionally, cluster analysis does the task of partitioning a set of objects into homogenous subsets based on the inter-object similarities.

Results

Items from the strategy questionnaire were factor analyzed using the principle component method with varimax rotation and those items with insignificant loadings were eliminated. Table 2 below shows the result of 10 strategy variables. The 10 variables were reduced to four factors that accounted for 76.79 percent of the total variance. The four factors reflect Porter's (1980) business level strategies – differentiation, cost leadership, product differentiation and market differentiation. The first factor, differentiation, is highly correlated in terms of factor loading with the first three variables – high price products, market differentiation, and emphasis on special markets; all of which indicate the importance of differentiation in the market environment. The second factor, cost leadership, has two variables with factor loading above 74 percent – pursuing high product efficiency and pursing operating efficiency, which reflect the organization's determination to be a leader in cost reduction in terms of efficiency. The third factor has two variables with factor loading above 69 percent. These factors are highly correlated in terms of factor loading with emphasis on special markets and image building of the firm and products. One factor cross-loads with another factor. The fourth factor, product differentiation, has two variables with factor loading above 82 percent – new product development and product differentiation. This factor puts emphasis on new product development and the differentiation of these products; a reflection of the organization's willingness to be different in terms of innovation. The factor scores of these four factors – differentiation, cost leadership, marketing differentiation and product differentiation – were used rather than the 10 strategy variables to develop a taxonomy of strategic variables.

Table 2: Varimax-Roted Matrix of Strategy Variables

	Differentiation	**Cost Leadership**	**Market Differentiation**	**Product Differentiation**
High price products	**.903**	.145	.019	.0243
Market differentiation	**.859**	-.201	.201	.112
Emphasis on special markets	**.581**	-.164	**.698**	.252
Image building of the firm and products	.052	.004	**.904**	-.032
New product development	.063	.243	-.088	**.829**
Product differentiation	.181	-.027	.059	**.842**
Pursuing high product efficiency	.211	**.868**	.319	.253
Pursuing operating efficiency	-.143	**.749**	-.153	.203
Low price products	.481	.472	-.378	-.094
Pursuing cost advantage in materials	.140	-.527	-.576	.382
Eigenvalue	2.905	2.556	1.139	1.079
Percentage of cumulative variance	29.05	54.61	66.00	76.79

Note: Factors with significant loadings are shown boldface.

Items from the structure questionnaire were factor analyzed using the Principle Component method with varimax rotation. Those items with insignificant loadings were eliminated. Table 3 below shows the result of the factor analysis of 12 structure variables. The 12 variables were reduced to two variables, decentralization and formalization. The first factor, decentralization, has four variables with factor loading above 40 percent – encouraged to speak my mind, encouraged to make decisions, superior often seeks out my advice and check with superior, which is negatively correlated. When work is decentralized, workers do not have to check with superior. The second factor, formalization, has four variables with factor loading above 53 percent – check with superior,

rules and procedures for handling problems, rules and procedures followed in decision making and job is not clearly defined, which is negatively correlated. When work is non-routine, the workers make decisions without further consultation, and when work is routine or structured, rules and procedures are followed. The two dimensions – decentralization and formalization – were used rather than the 12 structure variables to develop a taxonomy of structure variables.

Table 3: Varimax-Roted Matrix of Structure Variables

	Decentralization	**Formalization**
Encouraged to speak my mind	**.839**	-.152
Encouraged to make decisions	**.855**	.049
Superior often seeks out my advice	**.762**	-.216
Check with superior	**-.410**	**.588**
Job is not clearly defined	.153	**-.649**
Rules and procedures for handling problems	-.007	**.754**
Rules and procedures followed in decision making	.092	**.530**
Express my feelings openly	-.281	.167
Do not play active role in decision making	.116	.136
Do not share influence with superior	-.298	.023
Superior makes decisions	-.329	.050
Do not have a voice in decision making	-.312	.022
Eigenvalue	**3.96**	**1.76**

Note: Factors with significant loadings are shown boldface.

The table below presents a summary of correlations as produced from spss printout. Correlations are reported and the level of significance is in parenthesis.

Table 4

Variables	Differre	Proddif	Markdi	Forma	Data Reside	Data Divide	Prog Divide	User Reside	User Divide
Differentiation		.253 (.05)	.517 (.01)						
Decentralization				-.445 (.01)					
Data Reside	-.268 (.05)	-.280 (.05)							
Program Reside			-.252 (.05)		.784 (.01)		.736 (.01)	.866 (.01)	.807 (.01)
Program Divide					.867 (.01)	.254 (.05)			
User Interface Reside		-.321 (.05)			.834 (.01)		.823 (.01)		
User Interface Divide					.843 (.01)		.899 (.01)	.791 (.01)	

Note: Insignificant correlations are not reported.

Table 4 shows that three strategy variables correlate with DAS variables. This is an indication that there is some flow of IT among strategy variables in an organization. Further, the table shows high intercorrelations among the DAS variables.

As indicated in Table 4, there were no significant correlations between strategy and structure. Additionally, there were no significant correlations between distributed application systems and structure. However, there were significant correlations between DAS and strategy or BLS. One example is the correlation between

differentiation and market differentiation in an organization. This was accepted at .01 level of probability. It is also apparent that positive correction of .517 between variable differentiation and market differentiation indicates that 51.7% of the impact of implementing strategy overall supports the market differentiation strategy in the organization. The negative correlation of -.445 resulting from the interaction between variables decentralization and formalization indicates that 44.5% of the impact of implementing the decentralization structure can affect change in an environment characterized by the practice of the formalization structure.

The most interesting finding in this research is the high intercorrelation among DAS variables. Some of the notable examples are: program reside and data reside, program reside and program divided. When DAS variables were combined, there were no correlations to strategy.

Conclusions

For this sample, there were no significant relationships between IT distributivity and organizational structure and strategy. Information Technology is either highly distributed or highly centralized. There are no significant numbers of organizations with a mixture of centralized and distributed technology. When vertically and horizontally distributed application systems were examined independently, we found that vertically distributed application systems were linked to hospital environments rather than service and manufacturing organizations. The assumption is that in hospitals most work is restructured, and therefore, decisions are made independently because hospitals are represented by a number of occupational specialists. 🕮

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