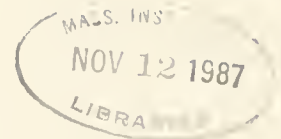


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A FRAMEWORK OF COMPOSITE INFORMATION SYSTEMS
FOR STRATEGIC ADVANTAGE

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September 1987

#WP 1937-87

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A Framework of Composite Information Systems for Strategic Advantage

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ABSTRACT One important category of strategic applications involves inter-corporate linkage or intra-corporate integration. Applications in this category require multiple systems to work together. We refer to this category of Information systems as *Composite Information Systems* (CIS). This paper presents the research issues and directions we have identified to date that may lead to a comprehensive foundation of CIS. With the systems environment in context, we investigate the strategic, technical, and organizational issues involved in CIS and the corresponding research directions. We are actively building a theory of CIS based on the research directions we have identified.

KEY WORDS: database management systems, organizational information systems, strategic computing, systems development.

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A Framework of Composite Information Systems for Strategic Advantage

1. Introduction

Significant advances in computer and telecommunication technologies have created a wide range of opportunities to meet information needs and to gain strategic advantage. It has become increasingly clear that the identification of strategic applications alone do not result in success for an organization. In fact, a careful and delicate interplay between choice of strategic applications, appropriate technology, and appropriate organizational responses must be made to attain success, as depicted in Figure 1.

The challenge is how to develop an integrated strategic-applications, technology, and organization research initiative to clearly define, articulate, and resolve the issues involved in deploying information technology within and/or across organizational boundaries. This need has been noted by McFarlan [1984] in addressing the challenge in information systems (IS) research:

The IS field requires applied multidisciplinary research. On the one hand, deep understanding of changing hardware and software issues and data base structures (the specialty of IS researchers) is needed. Another approach to the field considers how technology can influence an organization; it includes research on change management and relies heavily on the efforts of organization theorists. ... Finally, the use of IS technology to affect channels of distribution, product cost structures, and the nature of products offered has driven this field close to corporate strategy and marketing and brought it face to face with the ideas of competitive strategy and value added. The problem of effectively combining these disciplines is knotty.

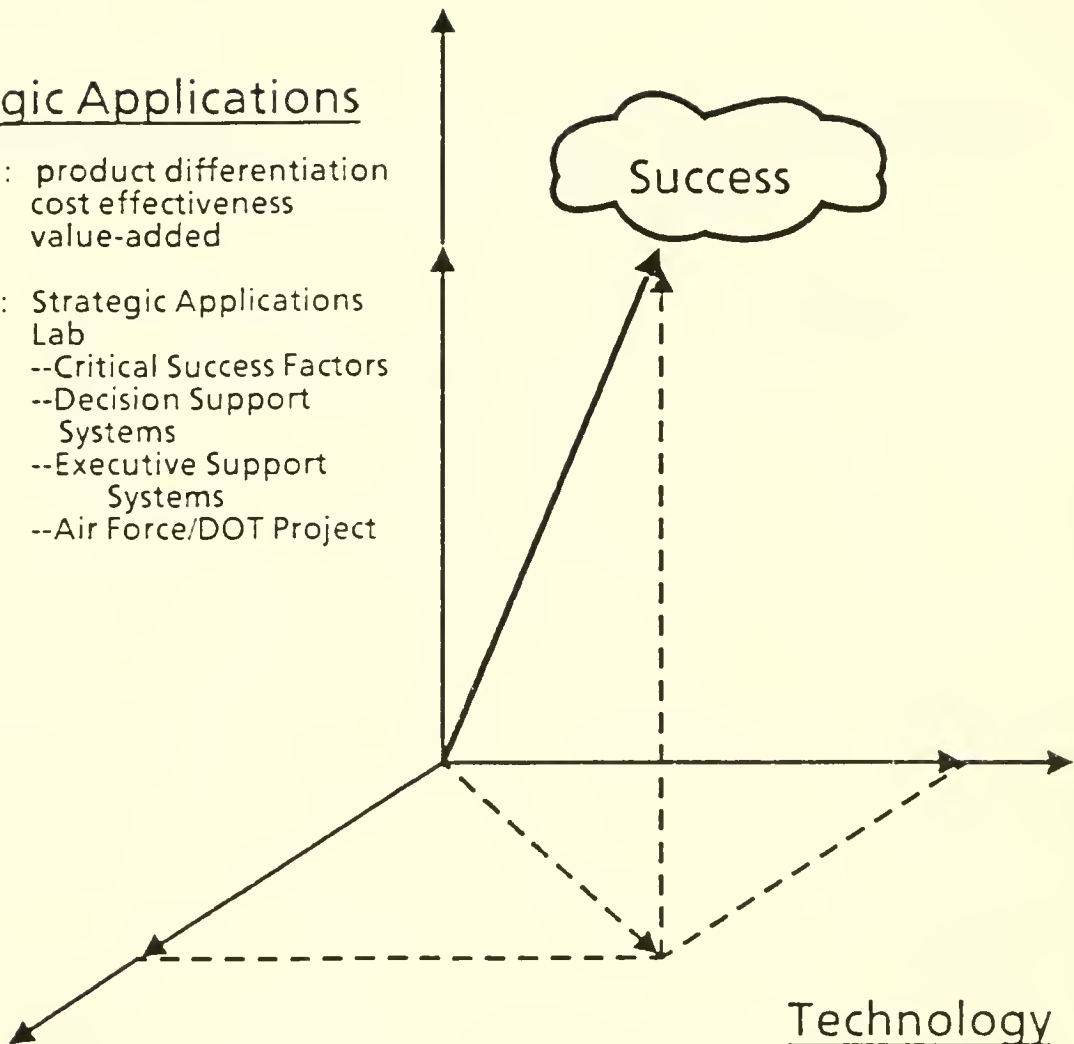
Consider the electronic banking system, shown in Figure 2, where three separate subsystems are being used for cash management, loan management, and letters-of-credit processing by a U.S. bank. Suppose a client requests that \$100,000 be transferred to another account. If that client's cash balances in the funds transfer system can not cover that transaction, it will be rejected -- even though that client may have a \$1,000,000 active letter-of-credit! This rejection, besides being annoying and possibly embarrassing to the client, will require significant effort to correct by manually drawing on the letter-of-credit to cover the funds transfer.

If the bank can tie the three separate subsystems together to access information in concert, so that funds can be automatically drawn on the letter-of-credit, then

Strategic Applications

Concerns: product differentiation
cost effectiveness
value-added

Research: Strategic Applications
Lab
--Critical Success Factors
--Decision Support
Systems
--Executive Support
Systems
--Air Force/DOT Project



Technology

Concerns: database
communications
expert systems
connectivity
interfaces

Research: Knowledge and
Information
Delivery Systems
(KIDS) Lab
--INFOPLEX
database machine
--multiprocessor
architectures
--expert systems

Organizational

Concerns: organizational structure
role
leverage individual
group activities
coordination

Research: Organizational Sciences Lab
--management in the 90's
--group decision making
--dynamics of software
project management

Figure 1 A Strategic Applications, Technology,
and Organizational Research Initiative (SATORI)

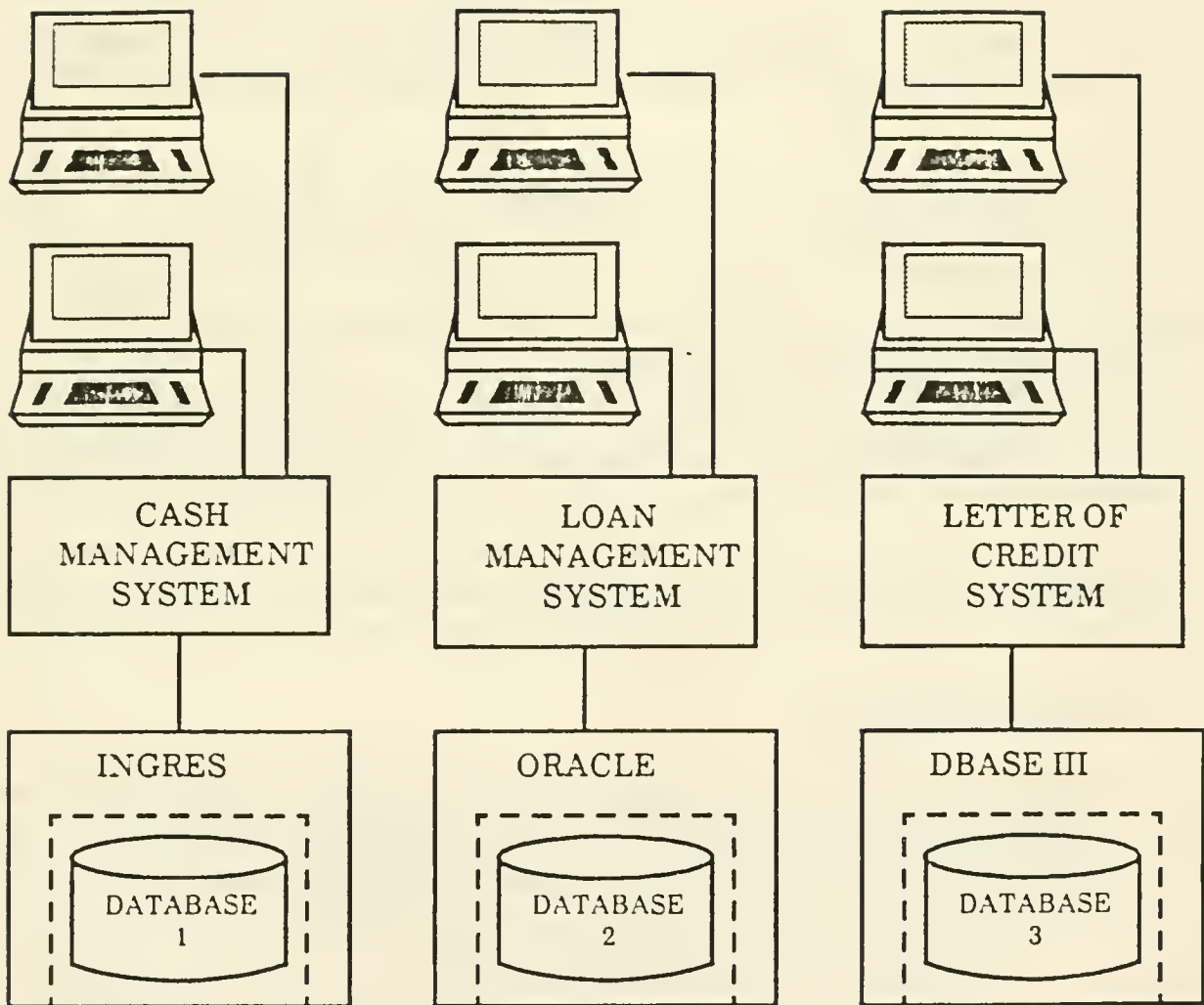


Figure 2 An Electronic Banking System
Without Integration

product-differentiation will be achieved via the enhanced quality of service and reprocessing costs can be reduced since special manual intervention can be avoided.

1.1 Diversity of Situations

It should be emphasized here that in both of the examples described above, the problem is not one involving data alone. Instead, process- or program-related information also must be selectively retrieved to generate meaningful results. Present-day systems are generally inadequate to handle either of the scenarios described above. Newer techniques need to be developed to allow easy, efficient, and intelligent access to information hosted on heterogeneous systems. Four categories of situations requiring such integration have been identified [Madnick and Wang, 1987b]:

1. Inter-organizational - which involve two or more separate organizations (e.g., direct connection between production planning system in one company and order entry system in another company).
2. Inter-divisional - which involves two or more divisions within a firm (e.g., corporate-wide coordinated purchasing).
3. Inter-product - which involves the development of sophisticated information services by combining simpler services (e.g., a cash management account that combines brokerage services, checks, credit card, and savings account features).
4. Inter-model - which involves combining separate models to make more comprehensive models (e.g., combine economic forecasting model with optimal distribution model to analyze the impact of economic conditions on distribution).

1.2 Research Purpose

Porter [1985] found that information technology is changing the rules of competition by: (1) changing industry structure; (2) creating competitive advantage; and (3) spawning completely new businesses. These strategic goals can be achieved only if the underlying technical and organizational infrastructure can support the required deployment. However, as depicted in Figure 3, no established process or methodology is available for linking strategic applications to appropriate information technology and organizational context.

An effective corporation is one that successfully reconciles the problems and opportunities across these three domains. It is important to recognize that no single pattern of interconnection among these three domains is likely to be consistently

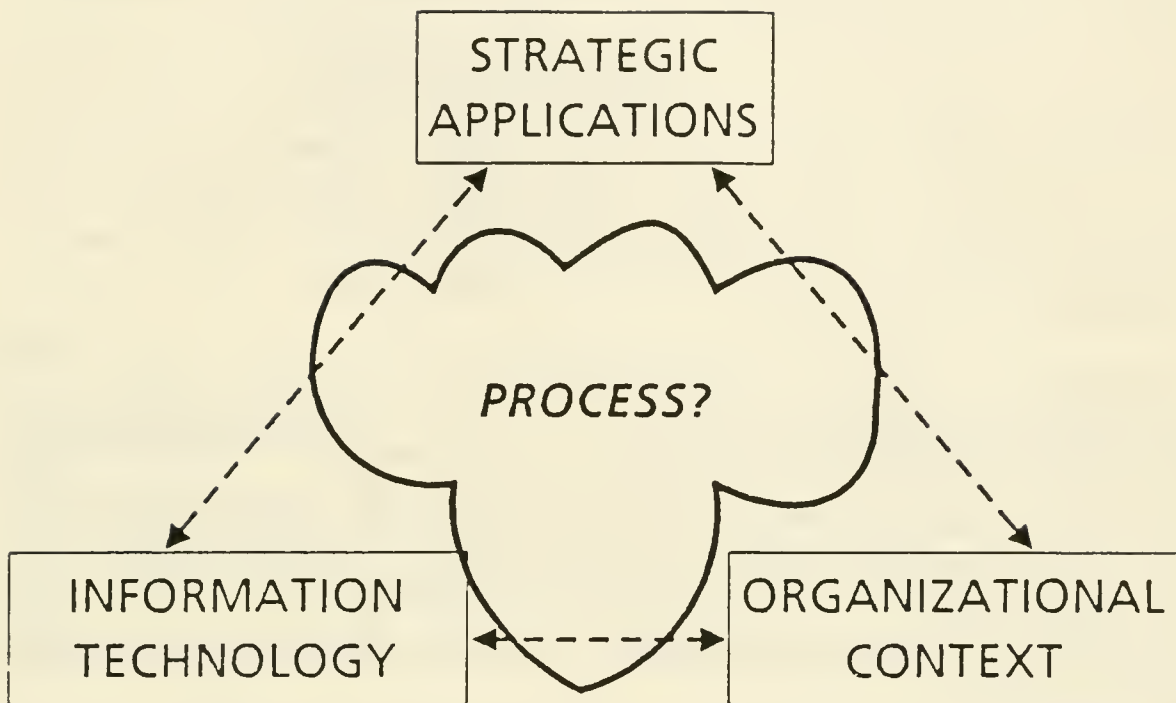


Figure 3 Need for A Process to Link Strategic Applications, Information Technology, and Organizational Context

successful. Thus, one corporation may wish to lead from its technological domain and reconcile the other two domains accordingly. In contrast, another corporation may wish to develop its strategic applications from its product/market choice and develop its technological and organizational capabilities accordingly. It is how the corporation successfully matches its internal capabilities with the external requirements that determines its level of success in the marketplace.

One important category of strategic applications involves inter-corporate linkage (e.g., tying into supplier and/or buyer systems) or intra-corporate integration (e.g., tying together disparate functional areas within the firm). The authors refer to such a system that consists of a number of loosely-coupled and/or federated systems as a Composite Information System (CIS).

For the purpose of illustration, the process of linking strategic applications, technological innovations, and organizational contexts is depicted in Figure 4. In this CIS process model, strategic goals are specified based on visions, experiences, and/or theories. Using this specification, appropriate characteristics of a CIS that meets the strategic goals can be identified. A set of technological and organizational problems associated with each type of CIS is identified and matched with appropriate solutions. In order to perform the matching task more methodologically, it is necessary that

- The critical strategic goals of an organization be clearly articulated;
- The major characteristics of CIS be identified;
- Technological problems and solutions be investigated;
- Organizational problems and solutions be examined; and
- Inter-relationships among strategy, technology, and organization be studied.

The focus of this paper is to identify research issues involved in CIS and research directions that may lead to a theoretical foundation. This foundation will provide an important setting for the design and use of CIS. Using the CIS process model illustrated in Figure 4, the CIS environment is examined to surface assumptions that organizations may have in developing and/or deploying their information systems. With the systems environment in context, we investigate the strategic component, the technical component, and the organizational component of CIS.

Section 2 discusses systems environment. Section 3 examines the strategic-management context. Technological obstacles and solutions are detailed in section 4.

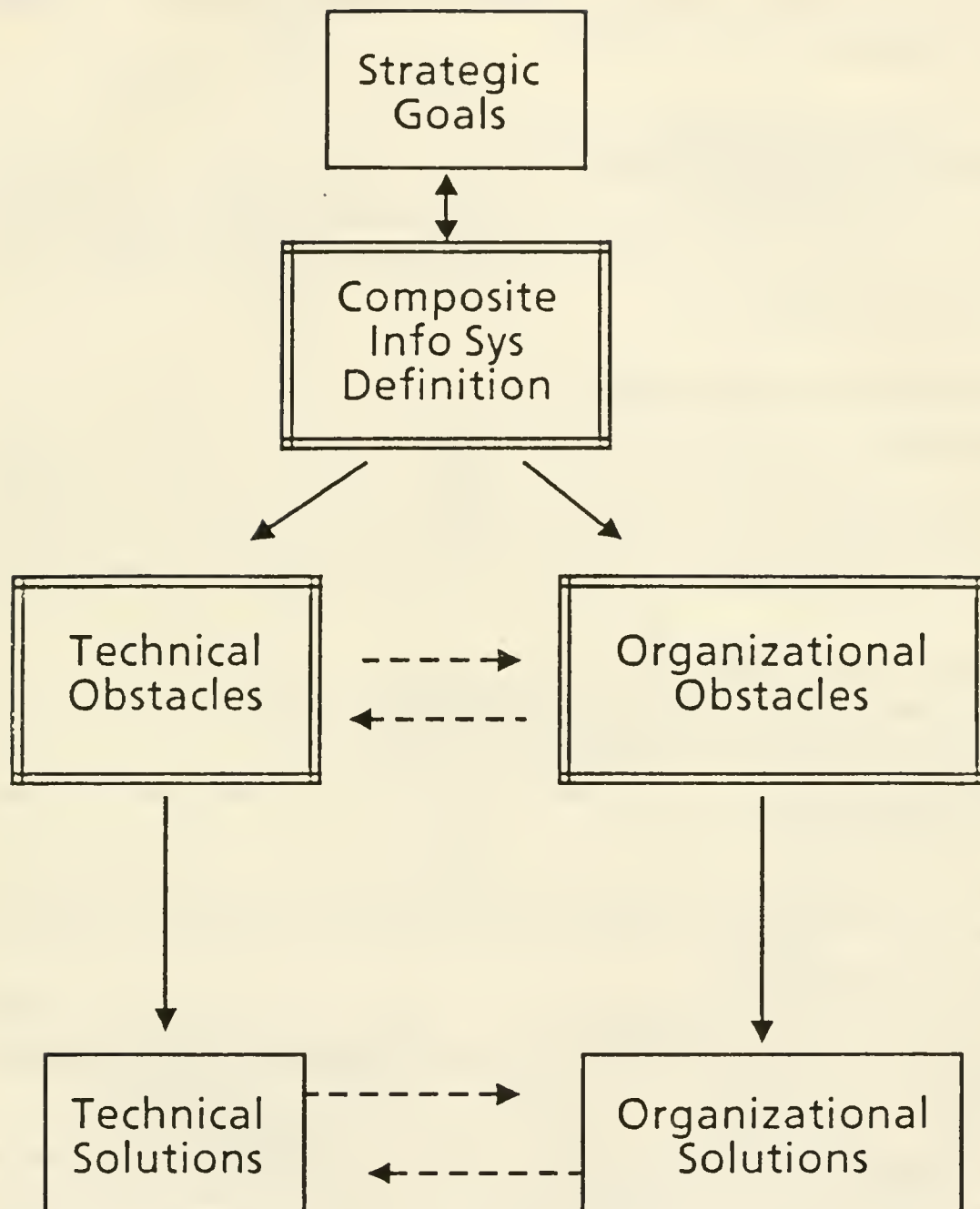


Figure 4 A Composite Information Systems Model

In section 5, organizational obstacles and solutions are investigated. Finally, concluding remarks are made in section 6.

2 Systems Environment

In order to characterize different types of Composite Information Systems, it is necessary to investigate directionality of constraints, environmental factors, and systems development approaches.

2.1 Directionality of Constraints

The problems encountered in attempting to integrate separate systems are often expressed in terms of incompatibility among different computer systems, operating systems, programming languages, database systems, data formats, and subsystem protocols. Presumably, these problems may not exist under ideal conditions in which one:

- Could forecast future needs perfectly.
- Had a high degree of communication with all related groups.
- Agreed upon standardization of almost everything.
- Did not keep developing new systems (e.g., product areas, modeling techniques, database systems, etc.)

The identification of these conditions has elicited three types of constraints on the development of CIS (historical, future imperfect, and future perfect), as shown in Figure 5 and discussed below.

Historical (A): In this category the individual systems to be integrated already exist and are not expected or able to be changed in the near future; thus constraints are imposed by the past on CIS.

Future Perfect (C): In this category, the individual systems to be integrated do not yet exist or are assumed to be replaceable; thus no prior constraints are imposed on this type of CIS. In particular, designers are free to define constraints to impose upon future systems to facilitate integration. This type of process is feasible when we start all systems from scratch and observe the four conditions described above.

Future Imperfect (B): Situations A and C represent extremes. In most cases, some systems already exist while others will be developed in the future. As a result, some historical constraints are imposed. Yet compatible standards for the future are

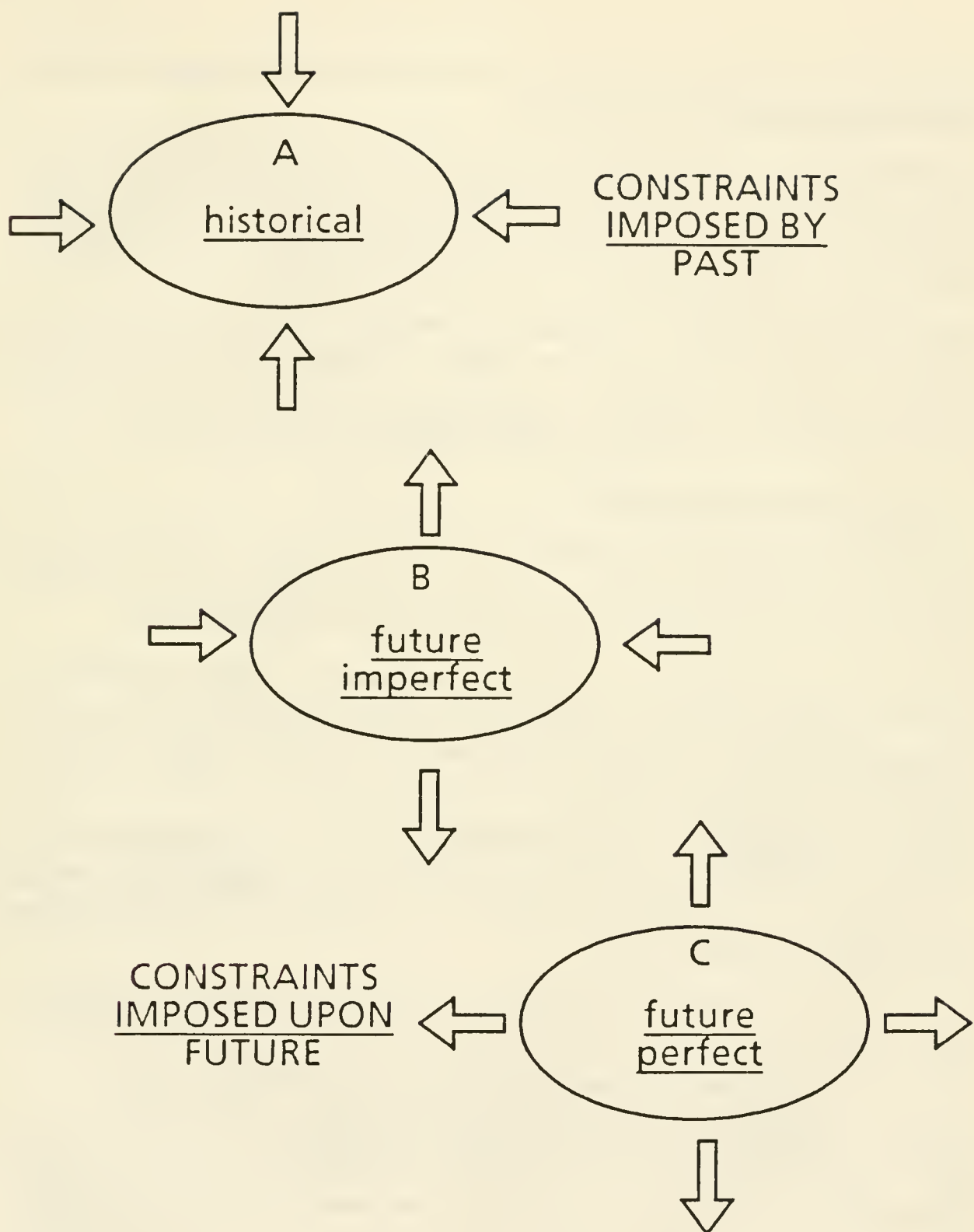


Figure 5 Directionality of Constraints in Composite Information Systems

desirable, since when new systems are developed, they will, in turn, impose new constraints on subsequent future systems.

The directionality of constraints indicates the degree of flexibility of a CIS to be designed. Presumably, a system can be designed as a future-perfect system, which becomes future-imperfect when implemented, and finally settles in as part of an organization's "historical" infrastructure, as shown in Figure 6.

Further research is needed to estimate the rate-of-change of a system, given its directionality of constraints and other characteristics such as systems development approaches. The rate-of-change of a system is a measure of its volatility. The ability to estimate the volatility will help organizations to plan for change.

2.2 Environmental Factors

Three key conflicting organizational forces were found to have significant impact on the overall environment for CIS: autonomy, evolution, and integration [Frank, Madnick, and Wang, 1987]. Tradeoffs need to be made among these factors.

Autonomy may be driven by technical requirements, such as distribution of function or parallel development; organizational requirements, such as the need to delegate responsibility or to tailor system closely to functional needs of each group; or strategic requirements, such as security or reliability.

Integration may be driven by needs to address broader issues that encompass all the individual systems, such as standardization; or interdependencies among systems, such as receiving design output from one system to prepare maintenance documentation in another system.

The third factor, evolution, recognizes that the needs of each system as well as the needs for sharing among systems will change over time. The rate and form of this evolution may tip the balance between autonomy and integration.

Although autonomy and integration are conflicting factors, with evolution as a further complicating factor, it may be possible to define system architectures with sufficient flexibility in order to accommodate these diverse requirements. Examples of such approaches have been investigated [Frank, Madnick and Wang, 1987; Madnick and Wang, 1987b]. Further research is needed to identify the characteristics of CIS, which in turn can be used to link strategic goals with technological and organizational solutions.

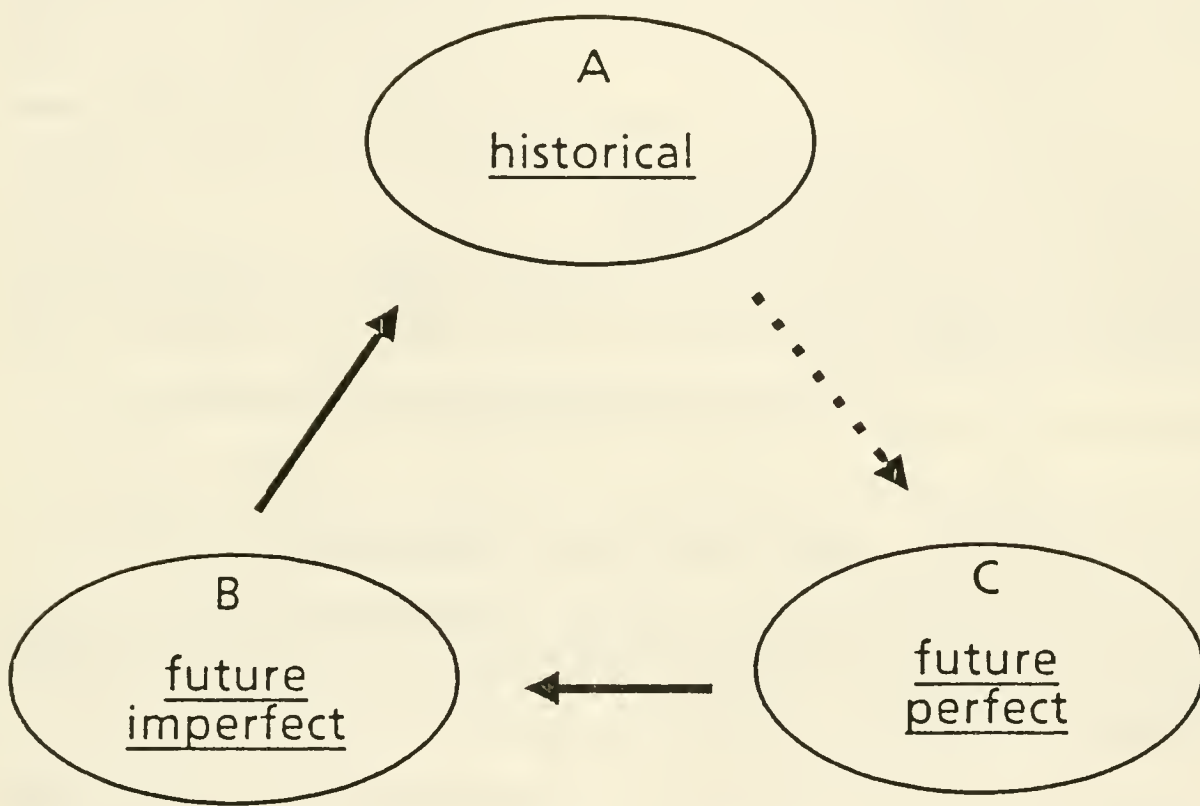


Figure 6 The Path from Future-Perfect,
Future-Imperfect, to Historical

3 Strategic Management

The role of information systems in many corporations is changing from the traditional "support role" towards a "strategic role," which is integral to the formulation and implementation of business strategies. It is well accepted that a failure to link information systems to the strategic context is likely to result in organizational ineffectiveness. The question is how to motivate organizations to develop and deploy CIS.

Consider the following case study of a large Midwest hospital [Osborn, 1987]. Using the Critical Success Factors (CSF) approach [Rockart, 1979], two key strategic concerns for the hospital have been identified:

- (1) Volume and occupancy levels are critical due to compression of margins; and
- (2) Physician affiliation is critical since over 60% of patients are guided to the hospital by physician referral.

In parallel, two critical strategic issues affecting physicians have been noted:

- (1) Office-overhead costs have been rising, estimated to be over 60% of revenues by the end of 1987; and
- (2) Referrals by other physicians and hospitals are crucial sources of patients.

Three internal motivations have been exploited, in the Mid-west hospital case, that contribute to the development and deployment of CIS besides external forces such as organizational authority:

(1) **Bi-directional benefits.** "Bi-directional" means that there are benefits received by both parties. For example, electronic-referrals by hospital to doctor increase doctor revenue and simplify office procedures while referrals by doctor to hospital increase hospital volume and help to even out scheduling loads.

(2) **Symbiotic payoffs.** "Symbiotic" means payoffs to all participants works only when they cooperate. For example, electronic transmission of laboratory test requests and results benefits both the lab and the physician, saving considerable staff time and minimizing delay for both.

(3) **Asymmetrical control.** By agreement, participants have different level of control over the CIS. For example, since the physicians have neither the time nor interest to set up the network (but do reap the benefits noted above), they are willing

to allow the hospital to control it as long as it does not constrain their usage. The hospital, on the other hand, is willing to take on this task since it provides an evolutionary basis for extracting information that will be needed in the future.

A composite information system was developed by the Midwest hospital to provide a convenient interface between physicians and the hospital. The use of flexible low-cost prototyping technology was found to be very valuable since it allowed the hospital to start small, yet grow and evolve from experience and respond to needs rapidly. Although the issues listed above are revealed from this specific case, they are representative of most CIS situations.

Research into the linkage between the strategic goals and the role of CIS is still in a formative stage. It is imperative to articulate the linkage between the strategic goals and the CIS role for different system environments in order to attain success. With the recognition that strategic management provides an important setting for the design and use of CIS, we now discuss the technical details.

4 Technical Obstacles and Solutions

There are many technical obstacles that hinder the development of CIS. These problems can be divided into four categories, as depicted in Figure 7: information, knowledge, connectivity, and interface. For brevity, a system that incorporates these categories collectively is referred to as a Knowledge and Information Delivery System (KIDS).

Many future KIDS will consist of components for intelligent problem-solving (e.g., knowledge-intensive applications), components for front-end processing (e.g., virtual-terminal drivers, STAR-like workstations), components for specialized functional engines (e.g., image enhancers and speech processors), and components for shared information management (e.g., database machines). This section summarizes research issues and directions involved in KIDS in the context of these components.

4.1 Information

The trend towards distributed databases began almost ten years ago. For example, the INFOPLEX project was initiated in the late seventies at MIT and has been directed towards developing next generation distributed database architectures that

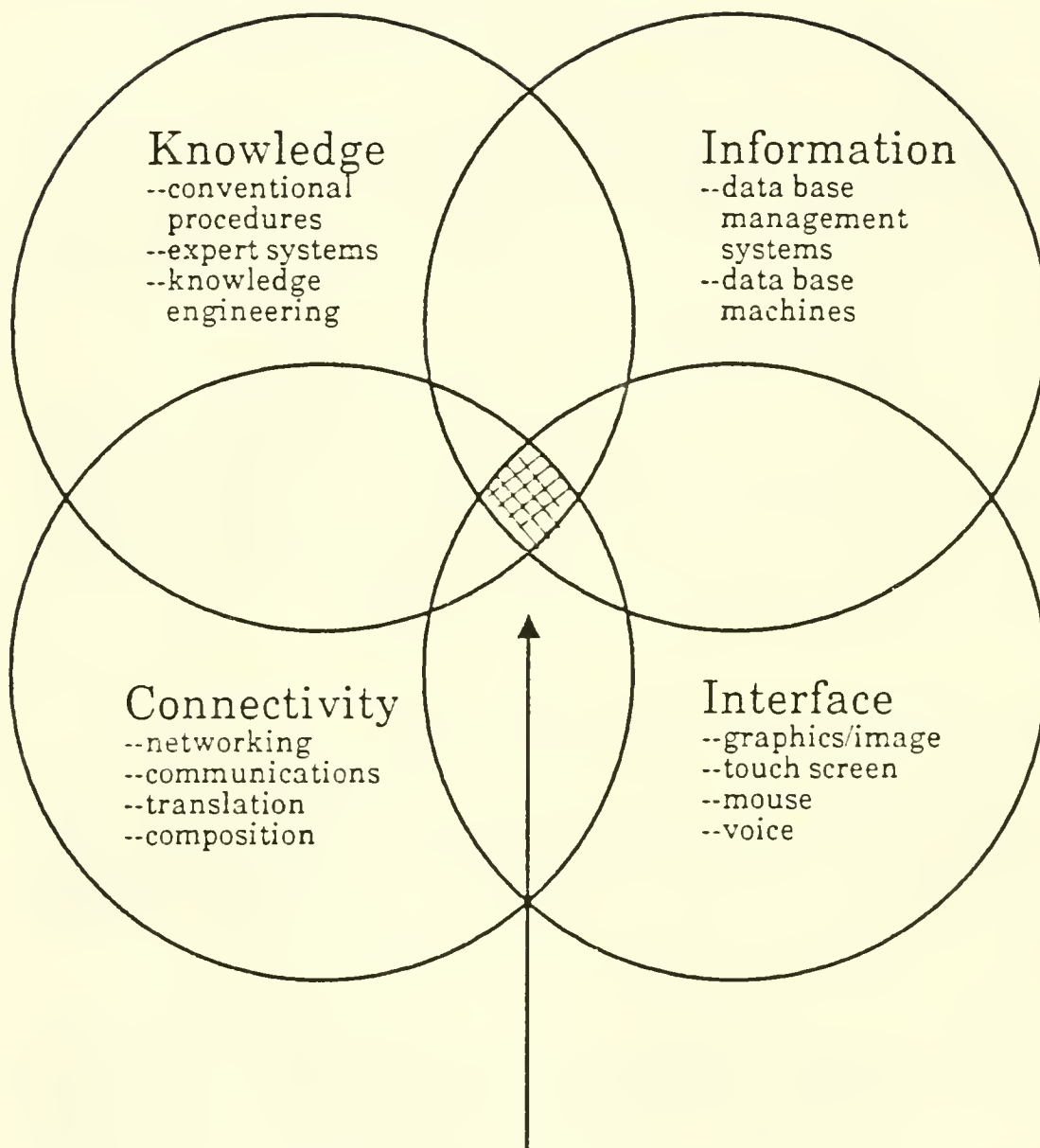


Figure 7 Knowledge and Information
Delivery Systems [KIDS]

can offer improvements in terms of retrieval speeds and storage capacities [Madnick, 1979; Madnick and Hsu, 1986]. Based on the insights gained while designing and developing the INFOPLEX architecture, and a careful review of other architectures, a number of observations are made regarding *homogeneous* and *heterogeneous* DBMS strategies for retrieval and update.

In a retrieval-only homogeneous DBMS, the update operation is intended to be carried out on a "local basis" only. In such an environment, the active areas of research include:

- Coordination of Locking Operations: A local store operation should *not* cause an erroneous result to be generated in response to a concurrent global retrieve request;
- Pipelining and Parallelism: This area involves careful design of retrieval routines and possible segmentation of the memory space;
- Communication Protocols: Data should not be transferred at the lowest level. Instead, high level data, models, and queries should be transmitted and deciphered by the receiving computing element; and
- Distributed Control: No files or critical information should be maintained on a centralized basis. Also, all control and arbitration operations should be decentralized to the maximum extent possible.

When update is permitted in a homogeneous DMBS, the following issues gain increased significance in addition to the issues outlined above:

- Multiple Copy Problem: Because of updates taking place in an asynchronous mode across different computing units, the copy of the database on one computer may be different from the database on another computer. This anomaly can lead to erroneous results;
- Disaggregation Problem: It becomes difficult to decide how to split up a single update transaction in order to update related databases in a structured manner. For example, if a person holds five accounts in a bank, and each account is maintained on a different computer, it is difficult to select the optimal method for handling an incoming remittance. Should it be split equally over the five accounts, or not?

- Concurrency Issues: Concurrent store and retrieval operations can potentially lead to incorrect results, unless effective locking schemes are implemented; and
- System Coordination Issues: If a computer generates and transmits update instructions to all other computers, what is the responsibility of the receiving station? What happens if no acknowledge message is received? Such questions gain importance in situations where each computer belongs to different functional units which enjoy relative autonomy.

In the context of heterogeneous DBMS the problem acquires added complexity since systems operate in an independent manner, thereby making it difficult to define common standards and protocols for update.

Prototype systems that have been developed and refined to date, such as Multibase, have avoided the problem of *global-update* by not allowing such updates to take place. Some new systems are coming up with partial answers, and their salient characteristics are described in [Bhalla, et al., 1987].

We now turn our attention to the more challenging task of integrating knowledge and information.

4.2 Knowledge

The challenge involved in integrating different sources of information and knowledge can be illustrated using a space-shuttle mission scenario. Suppose it is necessary to diagnose a hardware problem created by some unanticipated events in the flight of a space shuttle [Davis, 1987]. What procedures and tests should be conducted by the astronauts in time to avoid aborting the mission? Certain data needed for the diagnosis may be found in the shuttle's computer systems, e.g., the expected characteristics of the hardware components and partial operational data. What is unlikely to be available in any on-board system is the knowledge needed to identify the problem and to make the necessary rectification, given the level of incomplete information.

The knowledge to perform this type of processing is probably contained on earth in a DBMS which defines the hardware and a KBS which describes the structure and behavior of the hardware and the accumulated expert knowledge in localizing unanticipated problems. Such processing knowledge must also be accessed to solve the problem. Today, no integrated systems exist which combine product-definition data in DBMS with accumulated expert knowledge in KBS.

With information and knowledge integration in mind, we now turn our attention to connectivity.

4.3 Connectivity

Connectivity needs to be considered at the physical and logical level. *Physical connectivity* refers to the process of actual communication among separate systems. Key issues involved in physical connectivity include problems in terms of bandwidths, security, availability, and reliability. *Logical connectivity* refers to the process of accessing separate systems in concert for composite-answers. A major challenge in logical connectivity is the need to reconcile different assumptions and perspectives due to different mental models embedded in the different systems being integrated.

4.3.1 Physical Connectivity

Based on estimates for the B-1B provided by Rockwell International, it appears that current communication bandwidths are inadequate to even handle textual information and 2-D pictures. Design and manufacturing information is complex, heavily image oriented, and mostly in 3-D. Technical experts at IBM and Rockwell International felt that 3-D images will typically require two to three orders of magnitude larger bandwidth than equivalent 2-D images [Gurfield, 1985]. All this implies that the present communication links appear to be inadequate to handle the communication loads involved in transferring large amounts of information between multiple heterogeneous computers. Installing high bandwidth communication links and incorporating powerful data compression techniques seem promising in enhancing communication bandwidths.

Interconnection of heterogeneous databases makes the overall system more vulnerable to breaches of security. Sophisticated data encryption techniques and user access keys can partially overcome this drawback. However, in most cases, the factors of simplicity and security are at the expense of each other.

Most communication techniques have so far viewed availability in the context of homogeneous resources. For example, non-stop computers such as Tandem contain replicated sets of identical computing resources. In such systems, operational algorithms are straightforward as the choice of the host processor is immaterial. These algorithms must now be expanded based on the heterogeneity of computing and communication resources.

Reliability considerations dictate that the overall system be relatively immune to faults. Again, the concept of reliability has not been researched in the context of heterogeneous, distributed databases. Ideas from fault-tolerant architectures need to be expanded.

We now turn our attention from physical connectivity to logical connectivity.

4.3.2 Logical Connectivity

In order to obtain composite-answers, a Composite Information System must, at the logical level,

- know where all the data are stored, data formats, and the local system query languages;
- decompose the query into subqueries that can be executed by local systems;
- accumulate the results from all the subqueries;
- reconcile differences among the results accumulated; and
- formulate composite answers.

Consider the travel-guides case [Madnick and Wang, 1987c] in which three travel-guides (AAA, FODOR, and the Spirit of Massachusetts) are accessed in concert to obtain a composite answer for "the facilities of Logan Airport Hilton in Boston." The relational database schemata for the three guides are exemplified in Figure 8.

In order to know where all the data are stored and data formats, the schemata and data dictionaries need to be accessed. Assume that a CIS-Executive [Madnick and Wang, 1987b] can decompose the query (i.e., "What are the facilities of Logan Airport Hilton in Boston?") into subqueries that can be executed by local relational databases and the data from all the subqueries can be accumulated, there are still a number of issues to be resolved, as illustrated below.

- **Synonym.** Type-of-lodging such as hotel, motel, and inn in AAA are referred to in MASS as type-of- facilities.
- **Conversion.** the amenity-code 6 in MASS means pool, and 15 means free parking.
- **Format.** In AAA, the data format of facility is in characters, whereas a numeric code is assigned in MASS.
- **Incompleteness.** Each travel-guide provides partial information regarding facility at Logan Airport Hilton in Boston.
- **Granularity.** FODOR simply reports whether TV is available or not, but AAA has three categories for TV (i.e., C/TV for color TV; CATV for cable TV; and

AAA Relations

AAA-Info: (Name*, Address, Rate-Code, Lodging-Type,
Classification, #-of-Units, Phone#, Other)
AAA-Direction: (Address*, Direction)
AAA-Facility: (Name*, Facility*)
AAA-Credit: (Name*, Credit-Card*)
AAA-Rate: (Name*, Season*, 1PL, 1PH, 2P1BL, 2P1BH, 2P2BL,
2P2BH, XP, F-code)

FODOR Relations

FODOR-Info: (ID#*, Name, Address, Comment, Location,
Package, Category)
FODOR-Phone: (ID#*, Phone#*)
FODOR-Facility: (ID#*, Facility*)
FODOR-Service: (ID#*, Service*)

MASS Relations (The Spirit of Massachusetts)

MASS-Info: (Name*, Address, Facility-Type, Rating, #-of-Rooms,
Other)
MASS-Phone: (Name*, Phone#*)
MASS-CC: (Name*, CC*)
MASS-Amenity: (Name*, Amenity-code*)
MASS-Package: (Name*, Package-Name*, Package-Descript)

Note: * indicates the attribute is a primary key.

Figure 8 Relational Schemata for AAA, FODOR, and the
Spirit of Massachusetts Travel-Guides

C/CATV for color cable TV). The level of granularity may lead to contradiction as illustrated below.

- **Contradiction.** AAA indicates that Logan Airport Hilton has color TV without cable, whereas MASS reports that cable TV is available (In reality, it has color TV with paid movies for special stations such as HBO).
- **Ambiguity.** Room-rate in different travel-guides has very different meanings. Example sources of difference include whether tax, breakfast, service charge, and gratuities are included or not.
- **Inconsistency.** The name and address are reported as follows:

AAA: The Logan Airport Hilton; Logan International Airport, East Boston, 02128

FODOR. Hilton Inn at Logan; Logan Int'l Airport

MASS. The Logan Airport Hilton; Logan International Airport, Boston, 02128

To resolve these issues, it is necessary to map synonyms and convert different data formats. View definition and derivation techniques [Date, 1981] can be applied to provide a more comprehensive view from the partial, incomplete information in the local databases. The challenge is to reconcile differences due to the level of granularity, contradiction, inconsistency, and ambiguity.

The problem is complicated by the fact that certain concepts (attributes) may not be defined consistently and completely in separate systems which were independently created and administered. To resolve queries which cannot be handled (or can be handled, but inappropriate) using conventional database techniques, it is necessary to understand the concept that underlies the data. With this concept in mind, reasonable connections may be established based on the content of the database(s). We refer to this type of problem as concept-inferencing.

For example, Brodsky [1986] attempted to determine the cost of the MIT health care program by type-of-illness. The database used by doctors (through Blue Cross) and hospitals (through Blue Shield) were both designed for billing purposes but on a transactional basis (e.g., a doctor service or a hospital stay). To determine the cost of an illness, it is necessary to understand the implicit concept of illness that underlies the data. With the concept in mind, reasonable connections may be established even though it is not possible to determine the cost directly using a sequence of queries to the doctor and hospital databases, due to lack of a unique key. (The key identifier used in both databases is the certificate number, which aggregates on the family

instead of patient basis. As a result, it is not possible to determine the cost by type-of-illness.)

A closer look into the concept inferencing problem suggests that one approach to infer concepts not completely defined in separate databases (e.g., information that cannot be obtained directly using a sequence of database queries) is to reason based on the content of the databases. For example, if a patient is in a hospital during the period when an appendectomy is performed, it is reasonable to assume that the hospital bill, other medical services, and medicines subscribed during that period are due to the appendicitis illness -- even though it is not noted on those particular transactions.

There are many more complexities in this type of applications, such as determining the logical sequence for each family member (the records only indicate the family certificate number, not the specific family member) and eliminating potential confusions (e.g., one family member in hospital for appendicitis, another for a broken leg). To overcome the complexity, it is necessary to develop a theory of processes, events, structure, causality, and constraints in order to derive the required result.

We now turn our attention to user-interface.

4.4 Interface

Information and knowledge systems can be quite challenging, especially for the casual and non-technical user. When attempting to draw upon the power of multiple systems with incompatible idiosyncracies, the challenge can be overwhelming. Friendly user-interfaces shield the user from these technicalities. This aspect acquires added significance in the CIS context.

In most cases, the issue of user interface is examined while designing a new system. However, in the present case, the design of the existing databases cannot be modified. In a sense, the interface layer must be retrofitted to operate on top of previously designed systems. Since the user interface acts as the mediator between the human user and a set of divergent architectures, the task of mediation is more complex than in conventional user interfaces. Usually, a user interface resides on top of a single or homogeneous set of resources. Here, the host environments cover a broad range. As such, the user interface must be consciously designed to be readily portable across dissimilar pieces of hardware and systems software.

Conceptually, it is feasible to use the object-oriented approach [e.g., Dayal et al, 1985] to integrate heterogeneous systems including multiple DBMS, multiple KBS, and multiple TPS (written in COBOL, for instance). Using this approach, one can encapsulate any subsystem as an object with certain attributes, to define mutually agreeable protocols among objects, and to represent hierarchical inheritance properties among objects. The challenge is to realize autonomy, evolution, and integration without sacrificing other criteria such as end-user productivity and system performance - two key ingredients to commercial viability.

We now turn our attention from KIDS to organizational obstacles and solutions.

5 Organizational Obstacles and Solutions

Issues involved in managing inter-organizational systems across corporations are significantly different from the issues of managing inter-organizational systems within a corporation.

In the case of inter-organizational systems within a corporation, corporate strategy directs the role definition and the configuration of the information system that may span multiple organizational units. Thus, although the individual systems may have historically evolved for different purposes, with varying technical specifications, the connectivity is now mandated by the strategic requirements of the corporation. Since the boundaries of the different systems involved fall within a single corporation, the corporate strategy serves as an organizational mechanism for the design and management of this type of inter-organizational systems.

Once a corporation has decided to manage the inter-organizational systems within its own organizational hierarchy, a major issue relates to the necessary reconfiguration of its organizational structure and management processes to achieve its objectives. In the bank example shown in Figure 2, it may call for a shift from the design of organizations based on the traditional "product/service" focus towards one reflecting a more customer focus or even a matrix-type organization. The important issue is that the overall control lies within a single corporation, which can direct the required changes in the structure and process.

While the role of corporate strategy in the redesign and management of inter-organizational systems within corporation may be intuitively appealing, the issue

needs attention now given the recent developments in information technology that enables one to reduce the cost of coordination and integration.

In discussing the management of inter-organizational systems across multiple corporations, three organizational issues emerge as critical: (1) inter-dependent value chains, (2) "competitive" versus "cooperative" roles, and (3) the assignment of the coordinating roles and ownership of data.

Inter-dependent Value Chains. When inter-dependent value chains extend beyond a single corporation, a major difference pertains to the possibility of realizing differential benefits from the system. Current Research is equivocal in relation to the issue of overall efficiency versus firm-level shifts in the sources of comparative advantage. The expectation, however, is that in markets characterized by standardized communication systems among the vertically interconnected firms, the possibility of obtaining firm-level advantage is on the decline. Thus, firms are more open to the issue of inter-organizational systems which span across multiple value chains that are inter-dependent.

"Competitive" Versus "Cooperative" Roles. Consider the case of the B-1B bomber project as discussed in section 1. Rockwell Aerospace is the primary contractor, while there are several secondary contractors, and numerous other smaller contractors. Their roles can be understood in terms of inter-dependent value chains. While the various types of contractors are likely to cooperate for the purpose of sharing the information that leads to improved operational efficiency, there exist serious concerns regarding the "proprietary" nature of the data. Specifically:

- The large set of corporations participating in a project like the B-1B bomber project have to collaborate when their activities are inter-dependent for one project, and have to compete among one another for other projects as well as in the broader marketplace. Thus, each participant is unlikely to view its participation in one project in isolation of the competitive positions in the broader marketplace. Thus, a critical understanding of the relative balance between the cooperative and competitive roles is necessary for the effective design and implementation of any heterogeneous data systems that cut across multiple corporations.
- The possibility that the information necessary to improve operational, transactional efficiency, may also be sources of competitive advantage for some of the players. Thus, different corporations may consider different types of information to be proprietary (reflecting their corporate strategy perspective), thus restricting the overall design of the system. However, since not all

corporations are likely to pursue similar strategies, there is a strong likelihood that some cooperation can be expected. Again, this understanding is necessary for the design of the system.

An assessment of the relative competitive positions and the shared perceptions of the top management teams will be necessary and useful as key inputs for policy actions and responses that may be required to effectively design and implement CIS across a multi-corporation setting.

Assignment of the Coordinating Role and Ownership of Data. The ownership issue is typically approached as a point of negotiation among the concerned participants in the network, while the coordinator is usually the corporation that initiates the design and deployment of the network. It is expected that the perceptions of the different participants regarding the design of an inter-organizational network will be critically dependent on the assignment of responsibility for coordination. However, this issue has not been researched.

6 Concluding Remarks

We have presented the research issues and directions identified to date in the development of a foundation for Composite Information Systems. Using a CIS process model proposed in this paper, the CIS environment is examined to surface key assumptions that organizations may have in developing and/or deploying their information systems. With the systems environment in context, we have investigated the strategic, technical, and organizational components of CIS in terms of key issues outstanding and research directions. We are actively building a theory of CIS based on the research issues as well as the directions we have identified.

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