Design Considerations for Integrated Hospital Information Systems

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Summary

This article describes the main characteristics of the integrated hospital information system (HIS) environment, discusses design objectives, and analyzes four design issues—system architecture, conceptual data base design, application portfolio, and plans for development and implementation. The main objective is to provide managers and system designers with a guiding blueprint for HIS design based on state-of-the-practice technological capabilities and current experience with integrated HIS. Clearly, the capabilities of present information technology provide more feasible ways to implement integrated HIS in a distributed environment. This approach answers hospital information needs by shifting some of the processing and data to the end-user level, yet allows management to retain control of the central portion of the data base while facilitating data sharing among various organizational units.

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The introduction of information technology in the hospital environment has paralleled an increased need for timely and accurate data from various sources, technological innovation, and a growing awareness of the need to integrate all information systems under a uniform umbrella of an integrated hospital information system (HIS) (Bakker et al. 1988). The sheer amount of data in hospital operations represents an opportunity to implement an information system that can gather, organize, and process administrative and patient-related data; retain data for retrieval and analysis; summarize data into reports; and assist in administrative and medical audits and utilization reviews. The ability to store and retrieve accurate, timely, and consistent data, effectively report those data, and allow transferability of data to other applications within a hospital environment is valuable for effective management of hospitals and treatment of patients. Moreover, getting timely information out of a system assists physicians and other hospital personnel to do their jobs and improves work gratification and patient satisfaction (Vahl 1978; Bartone 1983; Covvey, Craven, and McAlister 1985).

New opportunities in information technology—availability of mini- and microcomputers, decreasing hardware costs, increased availability of quality software packages, and improved ability to integrate information systems within and among organizations—are shifting the way information systems are used to support organization activities. These developments may enhance the utility of distributed information systems in hospitals and improve the effectiveness and efficiency of their functioning. Yet, while enhanced information systems have much to offer hospitals, organizational risks—such as loss of control, creations of islands of information, and redundancy and inconsistency of data among applications—may increase unless attention is given to system design (Minard 1987).

The Hospital Information System Environment

A hospital conducts a wide variety of activities in which an application of information technology may be of great use. Computer-based information systems can be implemented in such functional areas as administrative management, patient care, and facilities management. By accumulating and organizing information in a form that is immediately accessible, administrators and medical professional are free to concentrate on their work rather than on clerical tasks. Information technology can improve productivity by reducing paper flow and redundant retranscription of information; it can improve the use of hospital facilities and the allocation of scarce resources; it can improve

patient care by assessing data and making recommendations for care, as in indicating whether a given treatment is required, recommended, or contraindicated; and it can enable a hospital to move from a retrospective to concurrent review of quality and appropriateness of care (Martin 1988).

As the need for information systems in hospitals grows, several approaches to their development exist, with the stand-alone approach and integrated HIS approach at opposite ends of the spectrum (Ball and Boyle 1980). Stand-alone systems consist of individual applications that are developed and implemented independently, and they address specific requirements of single departments or specialties. Due to their nature, they usually do not communicate with one another nor do they share common data. In contrast, with an integrated HIS approach, a comprehensive information system that crosses departmental and specialty boundaries is implemented. Such systems are institutionally based, patient care– and administrative-oriented, and have communication networks superimposed upon them.

The objective of an integrated HIS is to aid a hospital in achieving greater operational efficiency and control of information-oriented tasks in administrative and patient care areas. Because the hospital industry is becoming aware that an integration of patient care and administrative data is both desirable and necessary to the well functioning of these institutions (Ball and Boyle 1980; Minard 1987), design considerations of integrated HISs demand serious attention. Employing proven information processing technologies in a hospital environment, the following sections discuss design objectives and considerations for a distributed, integrated HIS—a system that can provide hospitals with a fast and accurate mechanism for internal communication and data sharing among the various service locations within the hospital environment.

Design Objectives

Design objectives that should serve as guidelines when considering alternatives to an integrated HIS include

- *Functionality*—a full range of features and functions within each application to assist the processing of information and support decision making in operational, management, and strategic echelons
- *Responsiveness*—quick and accurate response to transactions critical to a hospital's functioning
- *Reliability*—maintaining and providing accurate and updated data to support patient care

- *Availability*—supporting administrative functions, facilities management, and delivery of patient care when users need it
- *Flexibility*—ability to deal with various information needs and adapt to changes in information requirements
- *Deployability*—ability to modify the configuration of a system to handle a different or expanded set of problems
- *Modularity*—ability to develop and implement a system designed so that applications can, to some degree, operate independently where the order of development and implementation is dictated mainly by the logical interrelationship of the applications
- *Efficiency*—improving the use of hospital facilities and resources
- *Security*—limiting access of sensitive and confidential data to only authorized personnel
- *Ease of use*—producing output that can be trusted and easy to learn and operate
- *Evolutionary growth*—the ability to grow from an existing state to a desired state
- *Cost control*—handling pressure to cut costs as key to the evaluation of design alternatives.

Hospital Information System Design Considerations

In plotting the course for an integrated HIS design, we can focus only on the general considerations for a system's organization and technical capabilities rather than on any detailed design specifications for a particular HIS. It is clearly impossible to prescribe detailed specifications that will fit an individual hospital since such specifications depend on the particular characteristics of each institution and should be determined by that institution. It is possible, however, to harness technological innovations to the HIS environment and propose guidelines for general design of any integrated HIS.

The first stage in a system development lifecycle is the definition phase, during which functional requirements and constraints are defined to reflect the specific information needs of an organization. Based on these requirements, structured specifications for an integrated HIS are set and demonstrate how the system will be developed.

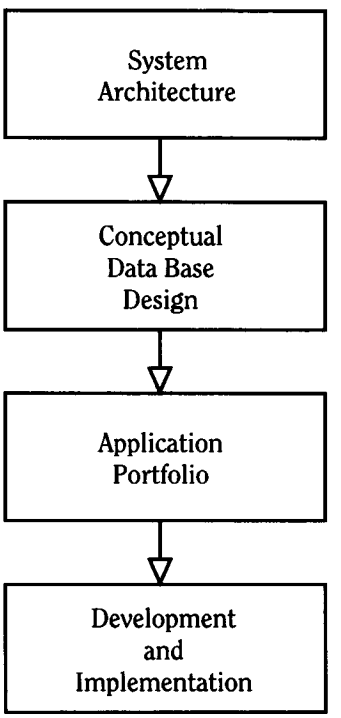
System design is the next step, and Figure 1 outlines the core issues that should be initially considered in a system's design phase. These issues con-

stitute a uniform basis for a general design scheme and can be adopted to any integrated HIS design.

System Architecture

As technology evolves, the primary design issue of an integrated HIS concerns the computerization philosophy and the location of hardware elements. The higher per-computation cost of hardware in the early 1960s required a consolidation of processing power into data centers. Following this trend with technological advances in the 1970s, hospitals tended to have large centralized hubs connected to their various service centers by telecommunications links to remote input/output devices. Advances in information technology in the 1980s, combined with decreasing hardware costs, brought hospital managements to a position where they could select any degree of distribution of information systems, from totally centralized systems to totally decentralized systems.

Figure 1
Core Issues in Hospital Information System Design



The underlying philosophy of decentralized computing (i.e., a system consisting of stand-alone processors and data bases in various sites with no communication links among autonomous computing units) conflicts with desired capabilities such as integration and data sharing that are the basis of an integrated HIS approach. Therefore, a totally decentralized system is excluded from further consideration here.

The two remaining alternatives, centralized and distributed computing, are both capable of supporting an integrated HIS. The main advantages of a centralized HIS lie in economics of scale: large centralized systems reduce the need for multiple hardware, software, space, personnel, and data bases, all the while providing better opportunities for recruiting qualified personnel and maintaining training programs. They also enable management to impose tight control over the information function activities in terms of standardization and security provisions. Coordination of development efforts and budgets is facilitated, and use of system resources can be more efficient. On the other hand, due to many interdependencies, the software is much less flexible and cannot be tailored to any one user or function. Users are therefore less satisfied and poorly motivated because they are less involved and feel less responsible for their application systems. Moreover, a system failure may paralyze the entire organization unless an expensive backup is guaranteed.

The pros and cons of distributed systems mirror those of centralized HISs. Distributed systems are better customized to the specific needs of each department and service center, involving users and increasing system functionality, modularity, and deployability. User motivation and satisfaction is, therefore, increased under a distributed environment. A failure of any particular node has minimum effect on other nodes of the system, increasing the overall availability. Disadvantages of distributed systems include higher costs for all system components (hardware, software, communications, labor, etc.) and more effort in coordination and control (Ahituv and Sadan 1985; Cash, McFarlan, and McKenney 1988; Sewell 1987).[1]

Considering the diversity of needs among hospital departments and facilities on one hand, and the state of the art of information technology on the other, distributed architecture seems to better suit the HIS environment for the following reasons:

- Centralized HIS tend to respond slowly as the number of users grows.
- Any failure of an HIS's centralized computing facility affects all users, whereas in a distributed environment such a failure usually has minimal impact on system availability to a user.

- Compared to distributed systems, centralized HISs are far less flexible to changes, reflecting a major disadvantage in a medical environment where ongoing advances in medical knowledge often require changes in application software.
- Due to their nature, distributed systems are more modular than centralized HISs.

An extensive review of the literature, dealing with the centralization-distribution issue, concurs with this assertion and indicates that distributed systems are more expensive than centralized systems, but better comply with more HIS design objectives (Wang 1987; Sewell 1987; Borovits, Taussig, and Yeheskel 1989).

"Distributed systems" actually comprises a variety of system architectures and characteristics. Since the design for a distributed HIS depends on a hospital's specific attributes, it is again impossible to prescribe an ideal, or even typical, configuration. Figure 2 portrays common, state-of-the-practice modes of distribution that are suited to supporting HIS applications. Each of these modes has its adherents, and each can be termed best for given work environments. To select an appropriate approach, each optional mode should be assessed in light of the following attributes:

- *Functions distributed*. The amount and type of processing available at the distributed node, which can range from simple display functions to full interactive processing.
- *Data distributed*. The portion of the data base that resides at the local node. The location of data govern the type of processing that can be performed at the local node and the type of coupling that exists between the distributed processor and the host.
- *Type of coupling*. The intensity of on-line connection between the central processor and a distributed node. There are essentially three types of coupling: (1) loose—the distributed node is on-line to the host on a scheduled basis to transmit data in a store-and-forward mode. Transactions can be processed to completion at the distributed mode; (2) demand—the distributed node operates in a relatively independent manner. It is on-line to the host when a query is made to the host data base for specific data that are not available locally; and (3) tight—the distributed node's operation depends on the central processor. The on-line node-to-host connection is required to complete almost all transactions.

- *Base of distribution*. The elements of the applications are distributed to the local processors from entire applications to some specific transactions.

All of these attributes affect a system's availability to an end user and therefore should be carefully considered.

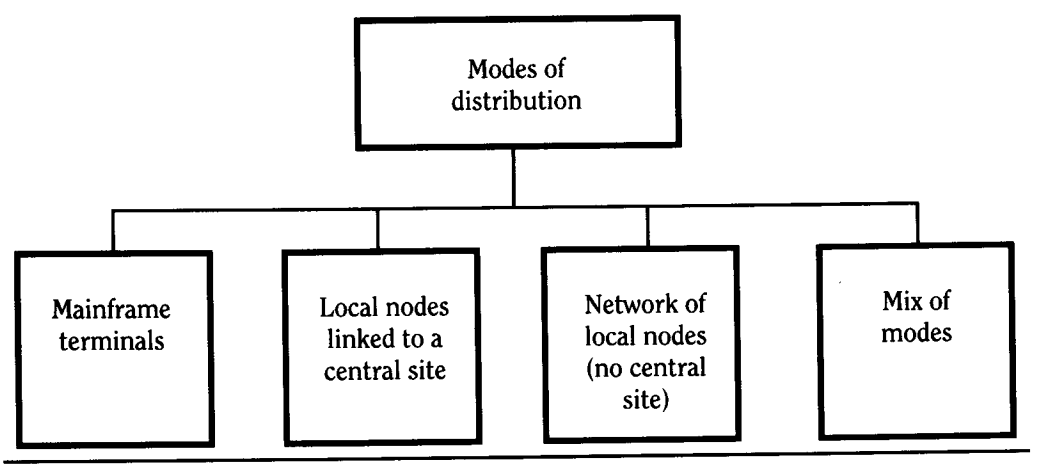
Analysis of the distribution alternatives in view of the needs and according to these attributes will enable an evaluation process that determines their applicability to an institution's application support base. The final configuration may comprise any combination of distribution modes and be tailored to specific attributes of particular applications within an institution.

Conceptual Data Base Design

While the process of distributing organizational information systems enlarges the circle of users and increases the computerization level of lower organizational levels, it might weaken central control of data (Sewell 1987). It is, therefore, important to carefully plan the structure of an organizational data base.

The primary objective of an integrated HIS is to provide timely and accurate data that are consistent throughout a hospital for all applications. Following a distributed philosophy, this objective can be best accomplished using a combination of centralized core data and distributed specialty-oriented data at the nodes.

Figure 2
Common Modes of Distribution



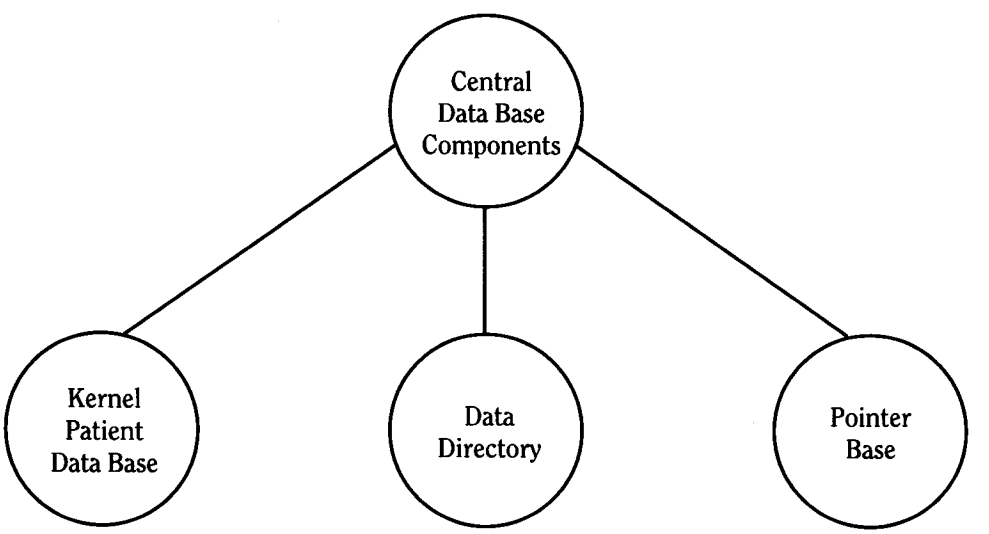
The basic need here is for a centralized data base system to support coordinated patient care and administrative functions. Since individual patients are treated by different hospital departments, a centrally controlled data base is a tool to provide basic data and serve as a mechanism for data sharing among distributed nodes.

Regarding patient data, three major components are proposed in the central data base, as outlined in Figure 3: (1) a kernel patient data base, consisting of basic information about the patients—personal and demographic, registration and billing; (2) a comprehensive data directory, indicating which additional patient-related data are stored in each of the distributed nodes; and (3) a pointer base, serving as a communicating mechanism to all occurrences of each patient's data that are distributed among the various nodes. In addition to these patient-related data, the central data base could contain additional data for specific applications that reside and operate in a central site.

The distributed portions of an organizational data base are those specific data that are used by each distributed application. Data are stored and maintained locally and related to a patient's record in the central data base via the pointer base. This mode of data distribution provides maximum response, flexibility, modularity, and system availability.

The operational merits of a distributed data base are demonstrated in the following example.

Figure 3
Components of the Patient Data Base



Patient Smith was hospitalized for chest pains. At first he was admitted to the emergency room where an ECG was performed, blood pressure was measured, a blood sample was taken for hematology and blood chemistry tests, and a chest x-ray was taken. Based on the results of a physical examination and these tests, his physician suggested hospitalization for further observation. After registration (data in the central mainframe), Smith was admitted to an ancillary ward for observation. On the next day, routine measurements of body temperature and blood pressure were taken and an ECG was performed at the department to which Smith was admitted and stored on the department's local computer. The results of these blood tests and x-ray procedures were stored at local nodes in the department, laboratory, and radiology departments respectively. On the morning of the second day Smith's physician checked the patient's condition through an on-line query to the departmental computer. The distributed integrated system acts as follows.

1. Data from local (departmental) data bases were formatted and presented. These included basic patient history (replicated from the central data base), doctor's orders, and all diagnostic results.
2. The local application "asks" Smith's physician if more data are needed from other sources. Upon a positive response, the local system issues an inquiry to the central host.
3. The central host processes the local inquiry through the pointer-base part of its data base and provides the local system with information about the specific nodes that have additional data about the patient and the type of data (through the data directory).
4. Based on this information, the doctor can ask for the specific information residing at remote distributed nodes (laboratory and radiology).
5. Upon the physician's selection, a request for data is issued to specific distributed nodes via the central host. The requested data are forwarded to the requesting node and presented to the doctor.

In conclusion, the organizational data base consists of a central portion and distributed data. The central data base contains basic patient data that are of common use throughout the hospital, and it serves as the communicating mechanism to the distributed data bases using a data directory and a pointer base. The distributed data bases are tailored to specific needs of each node to support its activities on a local basis. Specific data base design considerations

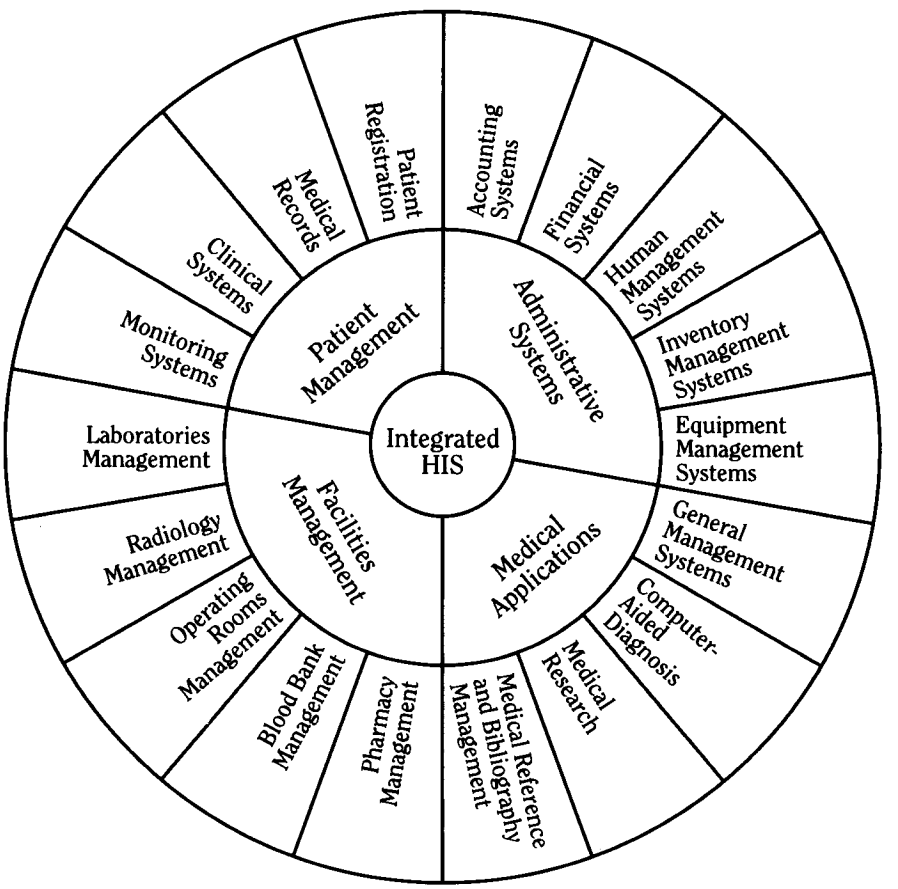
include data base control (central control versus distributed control), data distribution policy (replicated or partitioned), accessing method, updating mechanism, and controls and data administration.

Application Portfolio

The third design consideration addresses the application portfolio. The portfolio proposed here is modular in nature and comprised of four functional groups—administration, patient management, facilities management, and medical applications, as shown in Figure 4.

The first group of applications in the proposed portfolio consists of the administrative systems. A partial list of applications within this category in-

Figure 4
The Hospital Information System Application Portfolio



cludes accounting, financial, human resource management, inventory, equipment management, and general management systems. Most of these applications are similar in nature and scope to those used in nonhospital systems and need only to be customized to a hospital environment.

Patient management systems are the chief source of personal and clinical information about a patient. Applications within this group gather demographic and personal information during registration and update a record with diagnoses, treatment plan, and doctors' orders.

A third category of systems aims to provide better management of a hospital's facilities, which include managing the laboratory, radiology, operating room, blood bank, and pharmacy.

Medical applications systems support the work and research of a medical staff. Typical applications in this classification are computer-aided diagnosis, medical reference and bibliography management, and medical research support systems.

This proposed portfolio has three characteristics that emphasize its importance in planning for integrated HIS: (1) it attempts to provide an overview and classification of the various applications comprising an HIS; (2) it covers the core issues and applications needed to operate and manage a hospital; and (3) it portrays applications in a structured manner to facilitate customization according to each hospital's needs.

When reviewing the generic content of the building blocks in this portfolio, it may appear that most of them are known and even implemented as standalone applications; nevertheless, the contribution of this portfolio is in providing a comprehensive framework for designing the integrated HIS, rather than suggesting ideas for new applications. When putting the proposed application portfolio to work, system designers should examine a specific hospital's structure and information needs and then tailor the specific application portfolio to these characteristics.

Development and Implementation

Once a specific application portfolio is determined, a development and implementation approach must be selected. First, how is the relevant software acquired? The alternatives are purchasing a commercially available product, contracting for a tailor-made application, or performing the programming task in-house. Each has advantages and disadvantages that must be considered in the decision process, but experience indicates that many health care institutions tend to prefer the purchasing alternative (Jacobs 1982). Buying software has proven to cost less than developing it in-house since the product is immediately available and, therefore, implemented with minimal lagtime.

If the first alternative is selected, the hospital must evaluate commercial packages to select the one that best fits its needs.[2] Since such a package may not meet the exact requirements of the hospital, adaptive changes and modifications have to be planned, designed, and carried out before implementing the system.

If the hospital selects to contract for a tailor-made system or perform the programming task in-house, two alternatives must be considered—the total system approach versus the staged development approach.

The total system approach requires a one-time development of a full-service, full-scale HIS and an organizational unit to manage such a project. Developing a total HIS is a lengthy process that is likely to result in an efficient and comprehensive HIS with effective integration of all individual applications, but may take several years to develop. As a result, success and visibility are delayed, and there is a risk of technological obsolescence.

In a stage development approach, specific applications are gradually constructed after planning the integrated system and implemented upon completion. During construction and implementation, considerable efforts should be devoted to meet the specific requirements for a system's integration.

Evaluation of the characteristics of the total development approach versus those of the staged approach suggests that the latter might better fit the needs of a hospital. Staging the development process will focus development efforts on specific applications according to their priorities and lead to early payoff by completing modules of the entire system. Moreover, since applications development is a lengthy process, a hospital can more easily adopt newer information technologies and reduce the risk of technological obsolescence.

Based on the priority scheme that was set by the planning group, specific timetables for each stage have to be worked out, and the system will be developed gradually according to these stages. The stage of implementation follows systems development and addresses the actual installation of the applications portfolio in a hospital. This stage is, in fact, a potpourri of issues such as system installation, integration, testing, training, and procedural changes—each of which requires a delicate and careful treatment. Most of them involve users of various occupations and ranks who might not be familiar with information technology and therefore could be sensitive or even hostile.

The main issues of system installation aim to achieve smooth functioning of the system and full integration with existing applications. No matter which alternative is selected for the development of the application portfolio, a staged approach is highly recommended for the implementation phase, suggesting gradual installation of applications according to the organizational priority

scheme. Nevertheless, this gradual installation requires careful integration of the various applications at the time of installation.

To enhance the likelihood of a successful implementation, a hospital should work out a comprehensive training and motivation activity that will include the involvement of senior management in system's implementation; "ideological" training for managers and those who are in command of the operational staff, the major components of which include system goals and objectives, system constraints and limitations, and organizational and functional implications; motivation sessions for operational staff; and operational training that should familiarize operational staff with the system's operational aspects that pertain to their tasks. The combination of successful installation and system integration together with comprehensive training is the key to the success of the entire system and therefore should be carefully planned and administered.

Hospital Information System Design: From Theory to Practice

The selection of an appropriate design for a particular situation depends on organizational characteristics such as a hospital's internal and external environment, systems objectives, and desired characteristics. A variety of alternatives for an integrated HIS design is technically available and presents a problem of selecting one specific system design. Table 1 lists the design issues for an integrated HIS, the problems affiliated with each, and the major alternatives. Using this table as a guide for the design process can help managers to systematically analyze desired systems characteristics and complete the design phases effectively.

Having narrowed the field of basic design considerations and alternatives to a manageable number, a hospital should take the following course of action in designing its own HIS: (1) form a design team comprised of functional managers and MIS experts; (2) analyze the hospital's information needs; (3) set the objectives and desired characteristics for an integrated HIS; and (4) follow the checklist provided in Table 1 to design the systems major characteristics. Using these guidelines, along with the application of the design considerations summarized in Table 1, should provide a hospital planning team with helpful guidance when designing an integrated HIS.

Conclusion

The web of electronic information is spreading beyond traditional boundaries into hospitals. With growing computing capabilities and decreasing hardware

Table 1
Design Considerations for an Integrated Hospital Information System

Design Issue	Decision Problem	Major Alternatives
Hardware design	level of distribution	• centralized • distributed • decentralized
	distribution architecture	• mainframe terminals • local nodes linked to a central site • network of local nodes (no central site) • mix of the above
	functions distributed	• simple display to • full interactive processing
	data location	• fully centralized to • totally distributed
	type of coupling	• loose • demand • tight
Data base concept	data base control	• central control • distributed control
	data distribution pattern	• replicated data • partitioned data
	accessing method	• transaction switching • split processing • remote access
Application portfolio	applications to be developed	specific applications for the following areas: • administration • patient management • facilities management • medical systems
Development and implementation	software acquisition	• commercial package • tailor-made applications • in-house development
	development and implementation	• total systems approach • staged development

costs, a natural result is an increased interest in integrating all HIS applications. As a model for designing systems, distributed data processing is not new. The concept has existed in various incarnations since the early 1970s. The recent proliferation of powerful and low-cost microcomputers and local area networks has brought new opportunities to distributing both computing power and data throughout a hospital. Nevertheless, a proper design of an integrated HIS is the key to its success and can contribute to meeting a system's objectives.

Today's technology level is best suited for building integrated HIS through distributed technology. In the distributed environment, each institution, as well as its individual departments, can review the specific application requirements and determine the distribution attributes. Moreover, each hospital may decide on its specific application portfolio, and the distribution of data and system functions makes it possible that each hospital department can have its own unique set of applications and data to meet its individual requirements.

The opportunities of a distributed information system in a hospital are too great to be ignored. A well-designed integrated HIS, tailored to the specific needs of a particular hospital, can improve the productivity of a hospital's staff, allow each department and service center to control its own information processing, and contribute to the quality of patient care.

Acknowledgments

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Notes

1. For a full discussion of the advantages and disadvantages of centralized and distributed systems, see Chapter 5 of *Corporate Information Systems Management: The Issues Facing Senior Executives* by Cash, McFarlan, and McKenney (Irwin, 1988).

2. Jacobs (1982) provides a list of commercial packages for HIS.

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