Current Information Systems Applications in U.S. Health Care Delivery

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Introduction

Information Systems (IS) have a key role in shaping the delivery of health care in the United States. In combination with decision- and model-based support systems, IS contribute to improvements in decision making, quality of patient care, productivity and reduction of cost. Improvements in decision making have allowed managers to conduct extensive strategic planning, market analysis and technology assessment, and to forecast institutional needs. These improvements have also allowed for risk assessment of new services, technologies, and facilities, and modification or elimination of old. Clinicians, nurses and other providers can now call on protocols, algorithms, expert systems and other models to aid in prognoses, diagnoses and treatment. IS have likewise improved quality of care by reducing waiting time for orders, information and results; eliminating unnecessary services; reducing errors; and increasing provider and patient satisfaction. IS also improve productivity by refining staffing patterns, scheduling, and appropriate use of equipment and materials, and by eliminating redundant systems and actions. Finally, all the above benefits affect costs -- in some cases reductions in management, administration and patient care delivery costs are greater than the costs of installation of support systems. In a few cases where costs incurred exceed costs saved, the non-monetary benefits are worth the expense. Unfortunately, however, for most applications the actual ratio of costs to benefits is not usually calculated or known.[1]

The role of computers in fulfilling health care information needs has emerged in the past three decades and is evolving rapidly. In the 1960s the high cost of equipment limited computer use in health care to administrative systems such as payroll, billing, registration and admissions in large institutions. In the 1970s, on-line systems were developed at many large medical centers. Smaller hospitals, physician practices, HMOs, health agencies and long-term care institutions followed as hardware power increased and costs dropped. Clinical software developed during these years includes CAT images, ICU monitoring, ECG, and lab tests. Knowledge-based systems such as MYCIN were still little used for clinical purposes, but decision support systems were gaining popularity in management and administration for such tasks as staffing and surgery and recovery suite scheduling.

The PC revolution of the 1980s (Figure 1), which made enormous electronic storage capacity available on a desk top, made feasible the development of large decision support systems (DSS), integrated hospital IS and knowledge-based systems for general use. Many of these systems are still at the research level, due to implementation costs and the reluctance of clinicians to adopt the technology, but there is a growing group of software firms which market clinical DSS and IS, as well as some knowledge-based management and administrative systems. The lower cost of PCs has also allowed small hospitals in rural and suburban areas to own and operate their own systems. In addition, telecomputer networks let small hospitals, physician offices, home health agencies, and long-term care institutions retrieve information from library sources and exchange laboratory reports and clinical protocols. Improvements in software have also encouraged clinicians, nurses and other providers to use systems previously used primarily by management and administrative personnel.

The benefits of computerization of health care applications are becoming clearer, and they are widely believed to exceed transitions and operating costs and to be essential to maintaining competitive advantage. These benefits of IS, as succinctly summarized recently by Moidu and Wigertz,[2] include quality, quantity, availability, and accessibility of information, and multiple utility and ease of updating.

The U.S. health care system today

Possibly the greatest factor influencing new managerial and administrative computing endeavors in the United States today is the emergence of the prospective payment system (PPS), largely in the form of Medicare's diagnosis-related groups (DRG). Although originally conceived as a productivity-enhancing tool by its authors, the DRG has become the leading factor in the federal government's efforts to control Medicare costs. Other payers, such as Blue Cross and other insurance companies, also view DRGs as cost-cutters. With the retrospective reimbursement systems of the past, DSS and IS were designed to maximize reimbursement with little or no concern for costs. Now there is the real possibility that a hospital or other health care center could lose money consistently and go out of business or be forced to merge or otherwise change its way of delivering care. For this reason a hospital must minimize its costs, deliver quality care, and, as much as possible, maximize revenue. Consequently, the hospital must now know who its customers are and where its markets will be, and what it actually costs to treat each patient. Hospitals therefore must know all about their patients and services from a product-line perspective. To do so means installing extensive case mix-based IS and DSS which can be used in all phases and areas of strategic planning and operations.[3]

The shift to prospective payment is closely followed in importance by the current emphasis on the effectiveness and quality of care. Today's health care customers are becoming "prudent buyers." They want to know that they are receiving the highest quality care at the lowest prices. Consequently, they are asking for detailed data on case mix, morbidity, mortality and clinical outcomes.[4] They are beginning to use these data in IS and DSS of their own to compare quality-price relationships among institutions and change their payments, insurance coverage and preferred institutions for diagnosis and treatment. Entrepreneurial providers have recognized this change by creating new types of health care organizations, such as ambulatory health centers, HMO chains, preferred provider organizations, home care and managed care organizations, long-term care chains and many other vertically and horizontally integrated care delivery institutions. The United States today presents a very pluralistic systems of payers (individuals, companies, and governments), providers (public and private, for- and not-for-profit) and care delivery settings (ambulatory, acute and long-term). The information needs required to understand, manage and deliver care in this system are enormous.

The U.S. population is undergoing major demographic change. The consequences of an aging population for health care delivery are not well understood nor have they even being seriously addressed. The amount of money spent on nursing care in 1987 was $38.1 billion; with the growth of the elderly population, this amount is expected to be $129 billion by the year 2000 unless the nature of care delivery changes. Funding and treatment systems must also be developed to accommodate the large segments of poor and immigrant populations which are uninsured.

The phenomenal rate of technological change today is the primary factor driving health care costs higher. Other factors aside, technology has raised health care costs at a 5% to 6% real rate annually.[5] Besides the cost of improved tests and equipment, many technologies require computer specialists as well as new types and levels of skill for physicians and other clinicians. Of course, the "technology imperative" includes the drive toward use of IS and DSS in health care delivery.

Overview of current computation efforts in U.S. health care

The issues and forces shaping U.S. health care delivery today have profound effects on many of the current computation efforts. In Management Systems the emphasis is now on planning and strategy in a highly competitive environment. In Administrative Systems, the focus is on cost cutting, error reduction, productivity enhancement and the improvement of the timeliness and usefulness of information and decision support. Clinical or Patient Care Systems emphasize decision support and knowledge support to provide correct and appropriate diagnosis and treatment in an error-free, timely and less costly manner. In several large research-oriented medical centers and a few large hospital chains, emphasis is on highly integrated systems which combine Management, Administrative, and Patient Care Systems in a distributed, largely decentralized network of databases, IS, DSS, and knowledge systems (KS).

Figure 2 illustrates an Integrated System on a network within a hospital. The core of this integrated system is the patient identification (PID) and patient medical record (MR). Almost every service or unit of the hospital must have access to this information and orient its activities to the PID and MR.[6] The MR receives inputs from the clinical departments, administrative departments and support services. Consequently, it can be used in decision analytic models to conduct utilization review; productivity and cost assessment studies; tracking of patient diagnoses, therapy and location; and billing and other purposes. It is central to all patient care and most administrative activities. It is also used in aggregation in strategic planning and market research.

The integrated system is also capable, with the present and forthcoming computer network systems, to have tools centrally available for database management, productivity and reports and graphics, and the capability for free text entry. This effectively means each department will have many work stations to support multi-window, multi-terminal emulation; large storage capacity; integrated telecommunication capability; and extremely high speed computing and data access power.

Another point to note in Figure 2 is that although PID and MR are the core of hospital IS, every service and unit will also have its own databases, IS, DSS and KS. Later we will illustrate this decentralized integrated system with examples from each area: management, administration and patient care. Before doing that it will be convenient to discuss each area in turn and its integration needs.[7]

Management systems

As mentioned previously, the health care system in the U.S. has become very complex, very competitive and very dynamic. To cope with this system, strategic planning is not only useful, but also essential to success and survival. This planning must be based on a thorough knowledge of a hospital's product lines as manifested in its case mix and services. For its role in the community it must know clearly its particular mission and goals, its strengths and weaknesses, and its competition, and must assess its present and future environment accurately. IS support market research analysis and forecasting, risk management assessment, performance measurement and analysis, resource acquisition, and capital and budget planning. Some of the elements of these IS are the hospital's own patient case mix (by severity and resources consumed); competitors' case mixes and resources; present and future regional demographics; income and resource cost patterns; market surveys of patient attitudes and preferences; private physician specialties, location and practice in the region; and competitors' known plans for the future. Using this information, different units at the management level construct models based on statistics, operations research, management science and expert systems in order to make and support the hospital's strategic decisions. These decisions may involve expansion, contraction, new technology, mergers and acquisitions and diversification.

The problem of resource allocation has been addressed using various mathematical programming DSS techniques, one of the most recent and promising of which is Data Envelopment Analysis (DEA). Even without the benefit of standardized measurements this method can calculate relative efficiency ratios based on various managerial inputs. Generally speaking, a hospital with a high ratio of output to given input is more efficient. So far, DEA has been used primarily in public institutions such as public schools and criminal courts, but recent studies have affirmed the possibility of health care applications. Two of the most promising aspects of DEA are the ease with which it can be combined with other methods of analysis for selecting inputs, such as correlation and stepwise regression, and the use of coefficients generated by DEA in goal programming models.[8]

Market planning (an example)

A strategic issue facing all hospitals in the United States today is the assessment of its patient base. Knowledge of who the patients are, where they come from, what physicians they use, and what services they need are critical in order for a hospital to plan its services and mixes of care delivery. Hospitals need to plan ambulatory care facilities to determine whether they should diversify or consolidate activities. New services and locations may then be provided and older services may be terminated or sold to other health care delivery institutions. It is also essential to anticipate what physicians and staff skills will be needed in the future. Finally, it is important that the hospital know in which markets its competitors are most capable, where they have the most market share, and their reactions to any new ventures the hospital may take.[9] The underlying information needed in order to do this market planning hinges on the patient, the physician, and the hospital. In general, the patient will go to a physician when he or she has an acute or chronic illness. Sometimes this physician will be one which the patient has seen before; other times it will be an entirely new physician, depending upon the illness, the patient's knowledge of physicians in the area, and the physical location of the patient and the relevant physicians' offices. The choice of going to a hospital for treatment depends upon, among other factors, a physician's affiliation with that hospital, the patient's interest in attending it, and the services available. Table 1 indicates some of the data which are useful in regional market planning analysis. It is necessary for a hospital doing either its own patient analysis or that of a competitor to have these data in great detail. In many cases the latter data are more difficult to obtain, but sources are available for much of the information. Some information which is not available may be replaced by proxy or surrogate data which are available. This information is integrated into a decision support system to do market planning and forecasting.

A decision support system designed for use in a health care setting in Rhode Island is a multi-hospital, probabilistic, disaggregate decision choice model using a multinominal logit approach to predicting utilization by service and patient types. It is disaggregate because it works at the patient level rather than at total demand for the service. It is probabilistic because it computes probabilities that patients and doctor combinations will choose a particular hospital for that service. An example is shown in Figure 3, which is a special illustration of three hospitals, one physician office and one patient. The patient goes to the physician, and, based on attributes of the hospital, the patient and the physician, decides whether to be treated in hospital one, two or three. It is frequently a joint decision, with the physician acting, in many respects, as an agent for the patient. But, because of past familiarity or other knowledge, the patient also may have a significant input into the choice of hospital. Of course, the physician could not put the patient into a hospital at which he or she did not have attending privileges to perform medical care delivery.

The decision support system also predicts the case mix demands for each hospital in the region. If a hospital wishes to change services, add different physician mixes to its staff, or open new facilities in different parts of the region (e.g., establish an ambulatory care facility), the DSS will recompute and predict the service utilization for each facility by case mix. Similarly, if a competitor made any of these changes, the DSS would also predict the resulting change in the mix of patients for each hospital in the region. Models such as this are in use by the large investor-owned chains of hospitals in the United States and by some of the large not-for-profit chains. A few of the large medical centers and teaching hospitals also may have similarly sophisticated models. Smaller hospitals, on the other hand, tend to use more primitive models to predict their patient utilization or rely on those DSS furnished by hospital management consulting firms.

The particular model discussed above has been used in Rhode Island to predict utilization patterns for different subpopulations based on sex, race, socioeconomic status and age. The predictions been broken down by individual physician services, such as general medicine, obstetrics, pediatrics, psychiatry and general surgery, and could of course be produced for other services if sufficient data were available. In this application the different subpopulations -- requiring different services and physician attributes -- determine the pattern of utilization of the hospitals in the region. As hospitals change services and/or physician relationships these demand patterns shift. Under the new case-mix method of reimbursement, it is important for a hospital's long term survival that when the demand patterns shift it be made well aware of the projected effect on its revenues and performance.[10]

Administrative systems

Administrative systems were the first IS to be instituted in hospitals. Although the systems in the current generation are more complicated and sophisticated than earlier versions, some still provide only an IS function while others have incorporated DSS and KS. However, some changes stand out. Payroll systems now easily incorporate the newest changes in the tax codes and benefit packages. Accounts receivable and payable have adopted some DSS, mostly for stimulating or slowing payments, respectively. On-line billing systems have become very sophisticated, in order to handle the great variety of rules and requirements from the various payers. Budget planning and analysis are highly integrated into strategic planning systems so that the operating departments' activities are kept in line with the fiscal goals of the institution. General ledger accounts can now accommodate the vast array of new accounts which are added daily. But the biggest changes are in the cost accounting systems being implemented.

Prior to prospective payment's introduction, cost accounting was merely "charge accounting" and had little to do with actual product costs. Total cost allocation schemes had been devised and agreed to by the payers to reimburse the hospital for each case. Any errors in these allocation schemes were adjusted the next year to recover losses or return surpluses. Surpluses were rare because hospitals were always trying to increase their costs in order to increase their reimbursements. Now, under prospective payment, the hospital receives a fixed fee for each case. Losses and surpluses are not readjusted. Consequently, the hospital manager's new incentive for maximizing surpluses is to make certain the actual cost of a case is below its reimbursement fee. To do so, sophisticated cost accounting for each DRG is required. A record of actual nursing time and costs by skill level for each patient are needed, as are the actual costs of specialists' time, patient movement and such testing materials as radiographic plates. Similar discreet costs must be measured in the laboratories, pharmacy, dietary departments and all other services contributing to the diagnosis and treatment of each DRG.

The cost accounting system may be closely integrated with many of the other information systems in the hospital, themselves interconnected. The Admissions, Discharge and Transfer (ADT) system records the patient's first entry into the hospital's computer systems, and, through the patient identifier, it initiates or renews the medical record for use in the other information systems. Typically, after registration an inpatient is assigned to a nursing unit, from which he or she may later be transferred and is eventually discharged. In between, the patient ID has allowed the coordination of work orders from many clinical and supporting departments.

Other administrative scheduling systems are in use in both administrative and clinical departments. For example, surgery and recovery room scheduling[11] and nurse staffing and scheduling are complex DSS which are often used outside the ADT system. These systems are carefully coordinated with other systems, again via the patient ID. Finally, most large hospitals have outpatient scheduling and appointment systems for handling large numbers of outpatients and their interaction with the inpatient systems of the hospital.

For many years administrative systems have been operating in purchasing, inventory control and maintenance. Recently, many inventory items have been used to place automatic orders and some clinical systems order directly from the supplier via dedicated computer networks. The purchasing department receives computer updates to standing orders but does not have human interface with the ordering system or the supplier. Maintenance of machines and equipment is also DSS-controlled in order to minimize the costs of prevention and repair.

Administrative personnel systems were installed early, but have recently been greatly expanded in data and scope. The employee record has not changed much, but new data have been added as required under changing laws, regulations and societal trends. As mentioned above, new systems to capture labor analysis for each department have been added. These systems capture the various skill inventories of the hospital and have led to the construction of DSS for productivity and quality control by employee, as well as by unit or department.

Nurse planning and scheduling (an example)

In the United States, the nursing payroll, including all registered nurses, licensed practical nurses, nursing aids and nursing ward clerks, accounts for 45-50% of a hospital's total costs. Indeed, in most U.S. hospitals there are more nurses than beds. This is true not only because nurses are required 24 hours a day, 7 days a week, but also because much of the recent growth in technology has been nursing-intensive rather than cost-saving. Consequently, in order to ensure the effective utilization of this very large human resource, it is important to achieve optimal staffing and scheduling of the nursing units. Nurse staffing and scheduling has been examined extensively, but only in the last decade, and more particularly the last two years, has it been effectively handled using IS and DSS. The nurse staffing and scheduling information base must include many variables from the hospital and the nursing unit. Because a typical medium-to-large hospital will have from 500 to 1500 nurses, these variables comprise a significantly large database which is constantly changing. Furthermore, this database must be linked very closely to a patient classification database, which measures each patient's acuity every day, and to a workload-measuring system which classifies the patients by work loads and other resource needs. The workload measurement categories for each patient classification are correlated to standard workload levels to determine nurse staffing and other health care personnel needs.

In scheduling nurses it is important to find the optimal set of schedules which meets all of the patient care needs on the unit as well as each nurse's desires and needs for work stretches, time off, classes and other activities.[12] The schedule is usually developed during a four or six week period during which each nurse will know what shifts he or she works and has off. Because the hospital operates 24 hours a day, 7 days a week, these schedules must be computed for all shifts -- day, evening, and night -- and all nursing units of the hospital.

The primary problem of nurse staffing is to make sure that on a daily basis each nursing unit has the appropriate types of nurses to handle the unit's particular nursing needs in a cost effective and appropriate manner. Thus, the nurse staffing system must use nurse scheduling information to see which nurses are available that day, adjust that information for sick calls and other contingencies, combine nurse availability with the daily acuity information on the patients and thus calculate what units are over- or understaffed. The staffing DSS then makes appropriate adjustments by transferring nurses between units, calling in other nurses who are off that day, or paying overtime to nurses already on duty.

The decision support systems for scheduling and staffing are quite complex and vary from very simple systems which only furnish information and rosters of people to systems for actual decision making. These latter DSS might specifically assign all of the nurses for all of the units on every particular day. In most cases the nursing administrator does not need to make adjustments, since the schedules should have been optimally determined.

The type of nurse staffing and scheduling system which is frequently available is shown in Figure 4. The service schedules are usually compiled every four weeks, while the staffing DSS is run daily. These two large decision support systems interact with other DSS concerning personnel hiring and training, budget planning, cost accounting, patient billing and nurse payroll. The two systems are usually run by nursing administrators who have been taught to handle them. Most of the commercial systems are turn-key type systems, so there is not a great deal of knowledge needed for their operation. This explains their rapid diffusion in the large hospitals in the United States. The systems generally operate on a network. Each nursing unit sends data from a work station (microcomputer) to a minicomputer in the nursing administration office which performs the actual scheduling and staffing. Results are then downloaded to the microcomputers on each nursing unit.[13] Because the cost of computing has dropped dramatically, even small hospitals are now beginning to install these systems. Most commercial systems now run on large microcomputer work stations which are quite cost-effective.

Clinical/patient care systems

Perhaps the greatest growth in IS and DSS in the 1970s and 1980s has been in patient care systems.[14] Certainly they have seen the greatest variety and complexity of software development. Computers are ubiquitous in the clinical departments; almost any new machine or other piece of equipment purchased in recent years contains one or more computers. However, although most are digitized, many are still analog devices. They are still used in such testing apparatus as the ECG, EEG, MRI, CT, PET and X-ray to support analysis and interpretation and to point out exceptions and patterns. These systems have become so useful to the clinician that they are in widespread use and are constantly being enhanced in scope and depth of analysis. Similar uses for computers have been implemented in the emergency, operating and recovery rooms and in the intensive care and critical care units, to monitor, control and alert for changes in patients' vital signs.

From a systems perspective, some of the most exciting efforts at present are in the areas of medical decision making. Several decision analytic systems have been built to aid in the diagnosis of disease. This work started in the early 1970s for gastrointestinal illness and has now been extended to many other diseases. Indeed, a model at Harvard-Massachusetts General Hospital covers over 75% of internal medicine diseases. Most models are still in research and development, but a few have migrated to other research institutions and are being used in both the clinical arena and the medical classroom. Some less sophisticated decision analytic models, in the form of protocols and algorithms, have long been in use for non-clinician personnel in the emergency room and on ambulances. Often these DSS are linked to hospital emergency rooms via mobile telephone. Similar protocols and algorithms are found on the nursing units and other clinical departments.

Starting in the 1970s, several Stanford University computer scientists and clinicians built what has since become the most extensive set of expert systems for diagnosis and therapy selection for specific diseases. Perhaps the best known are MYCIN, PUFF and ONCOCIN. Most of their expert systems and development tools are still in the research and development stages and have not been widely adopted. PUFF, used to interpret measurements from respiratory tests for pulmonary function, is in use but has not seen wide dispersion. One of the best uses for these and other expert systems is their ability to rule out improbable diseases so the clinician may concentrate on the more likely possibilities.

In general, clinicians still hesitate to use expert systems or other DSS models for diagnosis or treatment. Of course, there are many possible reasons why some innovations are adopted while others may only stay in the research mode. It is a goal of present and future research to study this clinician-system process in order to understand the dynamics of adoption and diffusion. As this knowledge grows, knowledge systems will become more useful to the practicing physician.

Some hospitals are experimenting with the installation of bedside terminals. These terminals would be used primarily for nurse and physician order entry. Other clinical departments making significant use of DSS models are the medical and radiation laboratories, pharmacy, infectious disease control, and respiratory and physical/occupational therapies. These departments have systems to automate scheduling, testing, reporting, and recording of sessions and/or results. The systems check for errors, test duplication, wrong test/treatment time, allergic reactions, and incompatible drug protocols, and often state the correct actions to be taken or procedures to be followed and may suggest alternatives. These systems enable hospital personnel to reduce errors, increase timeliness, reduce costs, and make appropriate diagnostic and treatment decisions, thereby reducing risk and increasing satisfaction and successful outcomes.

HIV testing in the blood bank (an example)

The prevalence of the human immunodeficiency virus (HIV) in blood donors and its transmission via blood and blood products require that blood donors be screened for markers of HIV infection. At the blood collection center of the hospital the decision must be made whether to keep the donated blood for transfusion or to discard it. If the unit is accepted, there is the possibility that it will be infected and that infection could then be transmitted to the patients receiving the blood in the hospital. If the blood is discarded, the costs of recruiting and drawing the donors and processing the blood are lost. However, the development of an optimally efficient screening program is a complex proposition. It involves consideration of the biology, epidemiology, natural history and manifestation of HIV infection; the performance of available diagnostic tests; and the effectiveness of donor registries and counseling programs in removing test-positive people from the donor population. Other information needed for the decision support system includes the prevalence and incidence rates of HIV infection among the general population and various donor subpopulations, such as gays, drug abusers, and other groups, as well as variations in the screening effectiveness of the various antibody tests by sex and by time since infection. A final factor may be the combination of two or more tests. Each test has its own set of specificities and sensitivities, and when sequential tests are used of the same or similar type there are high correlations between the test outcomes.

There are various decision points in the process of testing donated blood. They are depicted in Figure 5. The first decision is whether to accept a person from his or her particular donor subpopulation. The second is whether to run one, two or more tests and which tests they should be. Given the outcome of the tests, the third decision whether to transfuse, discard or retest the blood. The fourth decision is whether notification should be given to the donor and/or whether to place the donor on a registry. Each of these decisions will affect the donor's reentry into the donor pool.

A decision support system built to address HIV testing has been used at the national level to establish a general policy for blood donor testing. It may subsequently be used in blood centers to determine the risk of HIV infection following different testing and donor pool strategies. As a result of these elaborate testing strategies, the rate of HIV infection through transfusions has dropped significantly in the United States. And, though HIV is a rapidly changing virus, new information may be incorporated into decision support systems to model the series of states the virus can go through. As these states change, different probabilities of detection through these tests can be computed from the DSS.

The data for the IS used in this DSS were collected from various sources over the United States and concern disease incidence and the sensitivity and specificity of the test at different disease states. These data are continually being upgraded and modified for the various regions in the country so that blood testing remains optimal.[15]

Clinical expert systems (an example)

Expert systems have long shown promise in clinical care, but have generally not diffused into actual practice. Although the reasons for this are multifaceted and complex, slow diffusion has not stalled research and development of progressively more sophisticated systems. For a comprehensive review of expert systems, see Schwartz and Szolovitz.[16] [17] One ongoing example of such a program is Pathology Consultation System (PCS). This system handles billing, tracking, and storage of reports, as well as laboratory data. The lab data can either be entered into the system manually or downloaded directly from the Laboratory Information System. The data for each case can then be printed on cards which, for convenience, are in the same format as the data entry screen. PCS can be continually updated by editing the databases, in order to assure maximum efficiency and diagnostic accuracy.[18]

Future uses of computing in hospital management and patient care

Computing trends in hospital management, administration and patient care will depend on many factors. The delivery of care, as well as the gathering and uses of information, will be greatly affected by the aging of the United States population; new technologies in bioengineering, genetics and medicine; alternative health care delivery systems; new forms of competition; informed consumers; and an increase in liabilities for care delivered or neglected.

The drop in computing costs and rise in computing power, storage and network capabilities enable hospitals to implement integrated information systems. Although this trend is at present limited to a few of the large research medical centers and a few of the large hospital chains, it will rapidly move to large teaching hospitals. As commercial software is developed for smaller hospitals, integrated systems will be installed there, also. The timing is now right for decentralized network systems, to be based on powerful work stations and share centralized PID and MR systems, as well as powerful software tools.

Networks will also allow different hospital departments to link information systems. For example, orders and results from the nursing unit will immediately flow to the order filling department, to medical records, to billing, to transportation, or to scheduling without delays and backlogs of paperwork. These orders will be checked by DSS and expert systems for correctness, bottle-necks, unnecessary costs, and delays.

Networks might eventually link physician offices, ambulatory care centers (including a hospital's own ER and outpatient department, as well as HMOs and surgi-centers), home care, hospice and long term care centers to the PID and MR. Thus, managed care will be performed in vertically integrated and linked institutions; it is expected to reach 15% by the year 2000. At present some medical school centers are already linked to their teaching hospitals and attending and other physician offices for electronic mail, on-line literature searches and consultative advice.[19]

Implementation of these changes depends on strong medical and management support. There will also need to be agreements between institutions on protocols, algorithms and cost sharing.

Many administrative applications are mature and will continue to be developed in performance and scope. Perhaps the greatest advances will come in DSS and protocols to reduce processing errors, improve overall performance and link diverse departments and functions. Many management science models, as used in business in general, might be integrated into these systems.

Management systems will continue to import models for strategic and financial planning from business. Because of continuing pressure to contain costs, hospitals will also require decision support models for performance measurement, risk management, market forecasting and service and product evaluation. All of these will be based on a product-line analysis. These models will rely on both the MR databases and regional and competitive demographics.

The most important research will continue in Clinical/Patient Care Systems. As mentioned earlier, more and more clinicians are becoming conversant with computers, DSS and decision analytic models. Many of the leading medical schools offer classes on these topics. So far, however, there are only a few notable successes in the use of diagnostic or treatment systems for clinical practice. Expert systems that can be included in new equipment and machines will continue to find rapid adoption if they contribute to the ease or accuracy of diagnosis or therapy. The examples of imaging devices; blood cell and products analyzers; and genetic materials analyzers stand out in this regard. DSS will also enable more rapid adoption of treatments for rare diseases and diseases which have rapidly changing treatment protocols. For patient care on the unit there will be more integration of all relevant patient data in a single work station (charts, tests, images, insurer coverage, etc.). This work station will be tied into bedside information terminals and monitors -- even in non-intensive care units -- as this technology becomes cheaper and more versatile.

Sometime in the future it is quite likely that patients will carry their own medical records on a laser card in their wallets or have national access to their records via their primary care physician or HMO. The technology is already here; it is not yet cost effective to issue and maintain the information. Furthermore, except for certain parts, most MRs in the United States are not yet computerized. And it will still be some time before clinician-friendly software will be available for broad general use.

There are already national registries for body organs and rare bloods and arthritis and other diseases. These information systems will continue to grow in number and scope. Furthermore, DSS software will be developed both to determine who receives organs or blood and to study the epidemiology of disease. Then, when the entire pathological process of a disease is understood, it should be possible to build comprehensive protocols and algorithms to diagnose and treat it.

From simple data processing computing has progressed to the development of extensive information systems supporting large decision support systems. Useful knowledge systems in health care delivery are now in the beginning stages, but demand continues to rise because of major institutional and patient care growth, mergers and vertical and horizontal integrations, all of which demand ever more information for clinical, administrative and management decision making. The health care industry in the U.S. is in an unprecedented period of change in biological, medical and institutional knowledge. Only through new methods of storing, analyzing and synthesizing the vast amount of data generated will it be able to accomplish health care's primary purposes: disease prevention, amelioration and cure.

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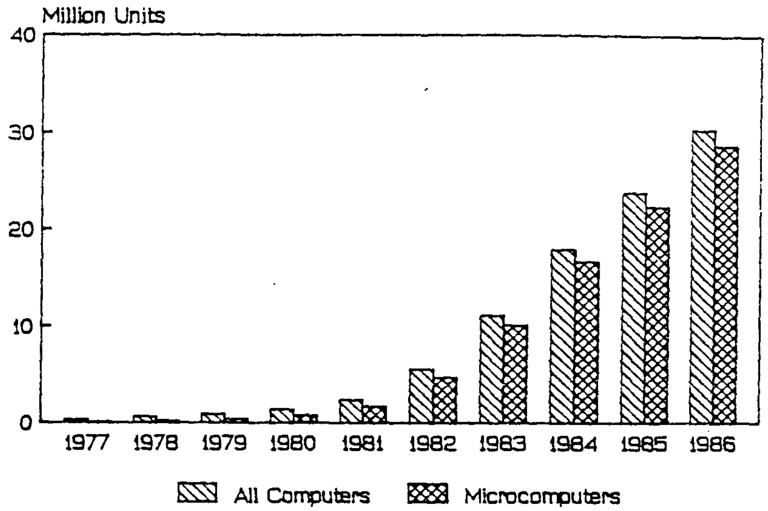
Figure 1.



Source: Predicasts Basebook

Figure 1. Computers in use (manufactured and sold in the United States).

Table 1.

Table 1. Data and Sources for Market Planning

Source	Subject	Data
PAS hospital discharge data	Patient	Census tract of residence
		Hospital attended
		Socioeconomic class
		Sex
		Age
		Race
		Admission date
		Hospital service
Physician information survey	Physician	Office location
		Principal specialties at office location
		Hospitals with full admitting privileges
Facilities data base	Hospital	Licensed bed capacity
		Number of admissions
		Inpatient days
		Occupancy rate
		Census tract of location
		Facilities and services offered
		Number of full-time equivalent employees
		Teaching/nonteaching
		Urban/small town/rural
Statewide planning agency	Census tracts	Travel time between census tracts

Figure 2.

HOSPITAL INFORMATION SYSTEM

PID/MR

Centralized Database
- network
- census data
- medical records
- DRG data

Patient Care

Nursing
- order/entry

Labs
- microbiology
- hematology
- pathology
- chemistry

Imaging
- scheduling
- NMR
- XRAY
- EKG, EEG

Pharmacy
- distribution
- allergic reactions
- dosages

Surgery
- anesthesiology
- protocols/ algorithms

Emergency
- triage
- primary

Outpatient
- scheduling tests
- triage

Inpatient
- ICU/CCU
- dietary
- treatment protocols/ algorithms
- diagnostic systems

Ancillary Services
- rehab medicine
- resp. therapy

Expert Systems
- diagrams
- laboratory

Administrative Systems

Scheduling
- ADT
- census
- registration
- surgery/OR
- outpatient

Financial
- payroll
- accounts rec/pay
- billing
- general ledger
- op budget
- case mix

Facilities
- purchasing
- inventory
- maintenance
- housekeeping

Personnel
- employee records
- skill inventory
- labor analysis
- nurse scheduling

Quality Control
- drug plans
- dietary

Management Systems

Strategic Planning
- budget
- facilities
- technology
- competition
- product mix

Marketing
- demographics
- utilization
- research
- case mix

Risk Management
- malpractice
- inf. consent
- incentives

Quality Control
- utilization review/PSRO
- organizational structure
- organizational processes

Figure 3.

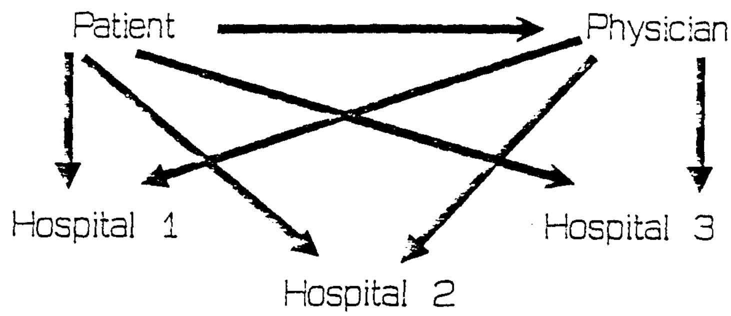


Figure 3. Market planning system: patient/physician choices.

Figure 4.

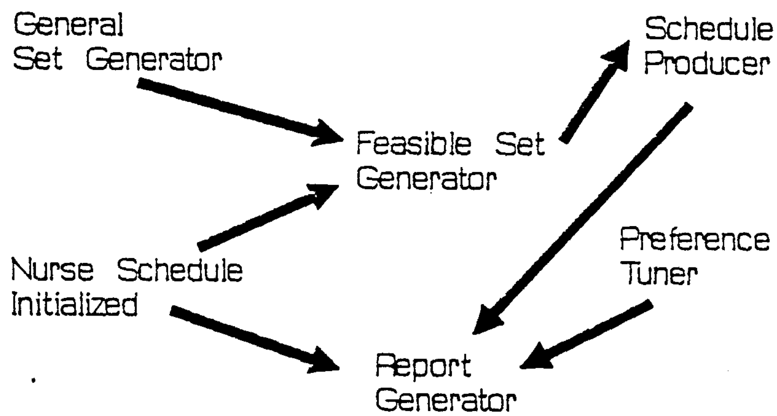


Figure 4. Nurse scheduling/staffing system.

Figure 5.

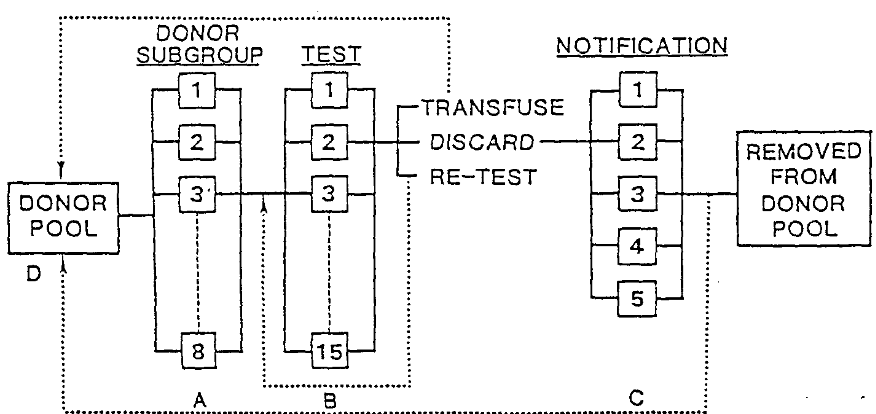


Figure 5. HIV antibody testing of blood and plasma donors.