VALUING HEALTH INFORMATION SYSTEMS

by

Gregory Alan Patton

A thesis submitted to the faculty of
The University of Utah
in partial fulfillment of the requirements for the degree of

Master of Science

Department of Medical Informatics

The University of Utah

December 1999

THE UNIVERSITY OF UTAH GRADUATE SCHOOL

SUPERVISORY COMMITTEE APPROVAL

of a thesis submitted by

Gregory Alan Patton

This thesis has been read by each member of the following supervisory committee and by majority vote has been found to be satisfactory.

Chair: Reed M. Gardner

R. Scott Evans

THE UNIVERSITY OF UTAH GRADUATE SCHOOL

FINAL READING APPROVAL

To the Graduate Council of the University of Utah:

I have read the thesis of Gregory A. Patton in its final form and have found that (1) its format, citations, and bibliographic style are consistent and acceptable; (2) its illustrative materials including figures, tables and charts are in place; and (3) the final manuscript is satisfactory to the supervisory committee and is ready for submission to The Graduate School.

Reed M. Gardner
Chair: Supervisory Committee

Approved for the Major Department

Reed M. Gardner
Chair

Approved for the Graduate Council

David S. Chapman
Dean of the Graduate School

ABSTRACT

Health information systems are networks of computers employed by health care enterprises to facilitate the delivery of their health care product. Computers originally entered the medical domain solely as tools aimed at the business functions of the hospital. Having demonstrated their utility in this area, computers were perceived by certain innovators to have usefulness in the clinical domain. As clinical computer applications were successfully developed and implemented, they have over time been merged together into systems offering multiple areas of functionality directly impacting the clinical aspects of health care delivery. Such health information systems have now assumed major importance in the provision of health care in a complex medical environment.

Although the focus of substantial investment for development and implementation, relatively little work has been done to assess the value of such health information systems. The business information technology literature and the medical informatics literature each include only a small number of published reports examining the value question in an incomplete manner. No generally accepted valuation strategy has been developed for information systems in either the business or health care domains.

Several valuation methods with potential applicability to health information systems have evolved: cost-effectiveness / cost- benefit analysis, return on investment,

information economics, measurement systems, the Strassmann approach, the Japanese approach, and the strategic value approach. None of these valuation strategies is clearly superior; each has different strengths and weaknesses. A matrix comparing these strategies on the bases of explicitness and ease of implementation is proposed.

Intermountain Health Care (IHC) has been instrumental in the development of health information systems and a leader in the application of such technology in clinical health care delivery. IHC's HELP system has played a seminal role as a catalyst to the development of the health information system industry. Although both historically and functionally important, detailed financial information regarding HELP's origins and implementation no longer exists. Current IHC budget information demonstrates the major financial commitment underway within this health care enterprise totaling approximately $157 million over the last decade and with additional expenditures of $47 to $61 million projected annually through fiscal year 2004. The complex budgetary relationships between HELP and the other health information systems at LDS Hospital further obscure the magnitude of the information technology investment within this institution. Benefits of health information systems are potentially most substantial within the domain of clinical integration.

IHC has not implemented any formal valuation strategy for its health information systems, but the *ad hoc* measurement systems valuation approach applied to date is practical, flexible, and the most appropriate of the available systems. Adequate valuation of health information systems cannot readily be achieved given the existing traditional hierarchical accounting structure; an alternative accounting framework patterned after a relational database is proposed.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Table | Page

LIST OF ABBREVIATIONS AND ACRONYMS

ACIS	Ambulatory care information systems
ADE	Adverse drug event
ADR	Adverse drug reaction
ADT	Admission, discharge and transfer data
AHIS	Automated hospital information system
ARDS	Adult respiratory distress syndrome
ASN.1	Abstract Syntax Notation 1
ATM	Asynchronous transfer mode
AV	Alta View Hospital
BC/BS	Blue Cross and Blue Shield of Utah
BICS	Brigham Integrated Computing System
BWH	Brigham and Women's Hospital
CABG	Coronary artery bypass graft
CAT	Computed axial tomography
CBA	Cost-benefit analysis
CBIS	Computer-based information system
CDC	Control Data Corporation
CDDSS	Clinical diagnostic decision support system

CEA	Cost-effectiveness analysis
CHIME	College of Healthcare Information Management Executives
CIO	Chief information officer
CIS	Clinical information system
CPR	Computerized patient record or Computer-based patient record
CQI	Continuous quality improvement
CRIS	Clinically related information system
CT	Computed tomography
CVP	Cost-volume-profit analysis
CW	Clinical work station, Cottonwood Hospital
DBMS	Database management systems
DHCP	Decentralized Hospital Computer Program
DM	Disease management
DP	Data processing
DRG	Diagnosis related group
DSS	Decision support systems
ECG	Electrocardiogram
EIS	Executive information systems
EMR	Electronic medical record
ER	Emergency room
FPO	University of Utah Faculty Practice Organization
FTE	Full-time employee
FUD	Fear, uncertainty and doubt

FY	Fiscal year
GIS	Geographic information system
HCFA	Health Care Financing Administration
HCIS	Health care information system
HEDIS	Health Evaluation and Data Information Set
HELP	Health Evaluation through Logical Processing information system
HIMSS	Healthcare Information and Management Systems Society
HIS	Health information system, hospital information system
HL7	Health Level 7
HMO	Health maintenance organization
IAIMS	Integrated Advanced Information Management System
ICU	Intensive care unit
IDN	Integrated delivery network
IDS	Integrated delivery system
IDX	IDX scheduling application
IE	Information economics
IHC	Intermountain Health Care
IHIPS	Integrated hospital information processing system
IS	Information system
IT	Information technology
JCAHO	Joint Commission on Accreditation of Healthcare Organizations
JD	Juris Doctor
KPNW	Kaiser-Permanente Northwest

LAN	Local area network
LDR	Longitudinal data repository
LDS, LDSH	LDS Hospital (prior to 1972 known as Latter Day Saints Hospital)
LIS	Laboratory information system
LOS	Length of stay
MARS	Medical Automated Record System
MBA	Master of Business Administration
MCO	Managed care organization
MD	Doctor of Medicine
MeSH	Medical subject heading
MIS	Management information system, medical information system
MISPA	Medical Information Systems Physicians' Association
MMI	Master member index
MR	Magnetic resonance imaging
MRI	Magnetic resonance imaging
MStat	Master of Statistics
NA	Not available
NCQA	National Committee for Quality Assurance
NPV	Net present value
NHS	National Health Service
NIS	Nursing information system
OR	Operating room
PC	Personal computer

PCIS	Patient care information system
PCMC	Primary Children's Medical Center
QALY	Quality-adjusted life-year
QI	Quality improvement
QMR	Quick Medical Reference
PE	Professional Engineer
PhD	Doctor of Philosophy
RIS	Radiology information system
RMRS	Regenstrief Medical Record System
RN	Registered Nurse
RPh	Registered pharmacist
ROI	Return on investment
SI	Scottsdale Institute
SIS	Strategic information system
SLVAMC	Salt Lake Veterans Administration Medical Center
TCO	Total cost of ownership
TMIS	Technicon Medical Information System
UU	University of Utah
UUHN	University of Utah Health Network
UVRMC	Utah Valley Regional Medical Center
VBAC	Vaginal births after Cesarean section
VHA	Veterans Health Administration
Y2K	Year 2000 problem

ACKNOWLEDGMENTS

This work has been partially supported by National Library of Medicine Training Grant 1T15LM07124 as well as by the Department of Radiation Oncology at the University of Utah.

Multiple current and former employees of Intermountain Health Care served as perceptive and generous sources of information. One person deserves particular mention: Ron Jensen of LDS Hospital provided invaluable access and insight to Intermountain Health Care financial information without which this thesis would have remained only an intriguing idea.

Permission to reprint copyrighted materials has been graciously provided by the following:

Mark R. Anderson, The META Group, Inc.

Watson A. Bowes, III, M.D.

Paul D. Clayton, Ph.D.

Reed M. Gardner, Ph.D.

Howard Rubin, Ph.D.

The Computer-based Patient Record Institute

The Health Information Management Systems Society.

INTRODUCTION

As a relatively young and emerging field, medical informatics has focused on the interrelationships between medicine and computer science (Figure 1). The complexities of the issues involved in establishing common ground between these two disciplines have been substantial, and many difficult issues remain to be definitively resolved. The rapid pace of change within the medical and computing domains has also been complicated by the rapidly shifting business climate, accentuated by the advent of managed care and an abortive attempt at legislated health care reform. Given the massive expenditures and continuing growth of the health care sector, such change will continue and likely accelerate. The business sector thus assumes a position of importance relative to the discipline of medical informatics.

Health information systems have been hailed as crucial tools to equip health care enterprises for this new competitive climate. Notwithstanding the massive expenditures that have been and are still being made in such systems, the *value* of such systems to the health care enterprise remains uncertain and a point for controversy. This thesis seeks to illuminate this question, and in so doing, strikes out in a different direction from those medical informatics graduate theses which have preceded it. Answers are sought not within simply the overlap of medicine and computer science, but rather within the terrain defined by the intersection of medicine, computing and business (Figure 2).

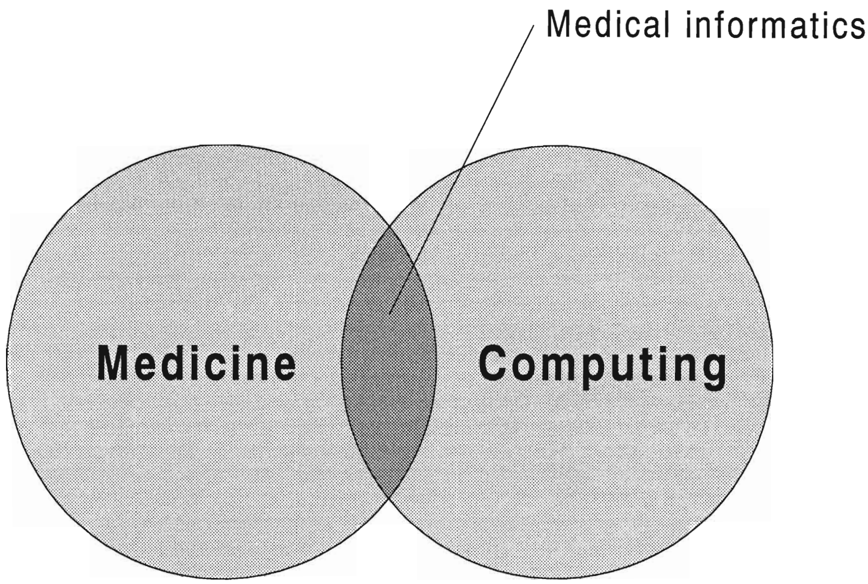


Figure 1
The Origin of Medical Informatics

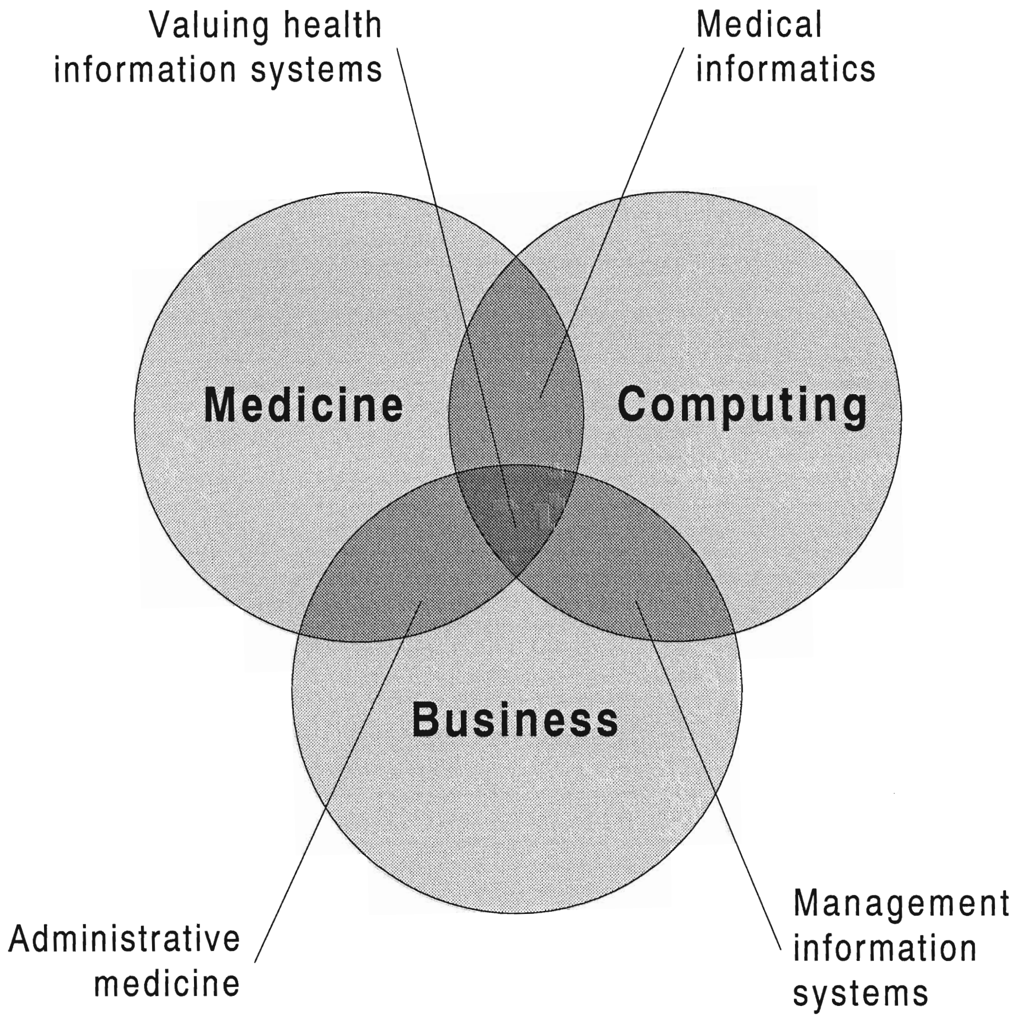


Figure 2
Interrelationships of Medicine, Computing and Business Domains

HEALTH INFORMATION SYSTEMS

Where is the wisdom we have lost in knowledge?

Where is the knowledge we have lost in information?

-T.S. Eliot, "The Rock", 1934[1] (page 1004b)

Data

Any consideration of information and the systems involved in its manipulation must begin with the fundamental building blocks, namely data. A collective noun most often used with a singular verb, data has been variously defined:

- "The raw material that is processed by a computer system." and "Raw as opposed to meaningful information" [2];
- "Facts or are believed to be or are said to be facts that result from the observation of physical phenomena" [3];
- "Raw facts which are meaningless by themselves (such as names or numbers)" [4];
- "Plural of the Latin *datum*, meaning an item of information," [5] a cyclical definition of limited usefulness.

Data represent the most atomic level of pure facts that without structure lack meaning. Data elements may be combined according to data models into data structures to confer meaning.

Information

There was a time when the term information simply meant news, intelligence or the communication of facts, but information has now transformed to embody the concept of data which has been processed in order to make it useful.[6] This relationship may be stated formulaically as data + meaning = information.[7] While this latter definition is a commonly accepted one, there is no universal agreement about what information actually is; few books concerning information actually define it clearly.[8] Turban defines information simply as data organized in a meaningful way.[4] Rose more explicitly refers to information as "a collection of facts or data with very specific characteristics – comprehensibility, relevance, availability, completeness, clarity, and comparability – in the possession of those who will use it"[9] (page 234). Yovits takes an similar but more succinct approach, defining information as data used in decision-making.[3] Taylor and Wacker espouse a supporting point of view: "Information is only germane in the presence of a decision to be made"[10] (page 118). Rogers employs a more global and philosophical approach, referring to information as "a means to reduce uncertainty in a situation where a choice exists among a set of alternatives"[11] (page 6).

If data are considered as the atomic level, information may then be viewed as the molecular level, comprised of combinations of data according to certain rules which confer meaning. Information exists in a wide range of varieties and is commonly categorized both for ease of retrieval and to facilitate comparison with other information of similar type. Within the healthcare domain, patient information is a fundamental commodity for which methods of generation, acquisition, storage and dissemination are developed within every organization. Healthcare organizations additionally possess information regarding their sphere of operations. Such environmental information may be categorized as technological, social, political, regulatory, economic, or competitive.[12]

Despite the elusiveness of the fundamental nature of information, little debate exists about its importance.[7, 13-24] Scott notes that "over the past 20 years data" (used generically in this quotation with the same connotation as the term *information* in the present thesis) "has made the leap from being a building block of basic company functions to being one of the primary sources of competitive advantage"[20] (page 200). Drucker makes a similar observation:

> So far, for fifty years, Information Technology has centered on DATA – their collection, storage, transmission, presentation. It has focused on the "T" in "IT." The new information revolutions focus on the "I." They ask, "What is the MEANING of information and its PURPOSE?"[22] (page 97).

He additionally predicts that this shift in emphasis which has already begun in business will come to embrace health care as well. Beyond the importance of mere information itself, information quality is now appreciated as an essential element.[25, 26] Amidst this background of increasing emphasis on information and an appreciation of the importance of information quality, a contrary point of view objecting to our immersion in an excess of information has emerged.[27]

Information processing has increasingly transformed from a mere support function into a fulcrum for re-engineering core business processes. As a result, methods and systems have evolved of necessity to generate and to handle information. The value of such information systems in the health care domain will be the focus of this thesis.

Knowledge

Knowledge represents a more abstract concept interrelated with the fundamental ideas of data and information. Turban defines knowledge as "Understanding, awareness, or familiarity acquired through education or experience. Anything that has been learned, perceived, discovered, inferred, or understood. *The ability to use information*" (italics added),[4] (page 862). Devlin espouses a similar point of view, defining knowledge as internalized information + the ability to utilize this information, and specifically notes that "knowledge ≠ information"[7] (page 14). Extending the chemical analogy further, if data are atomic and information is molecular, knowledge may be conceptualized as a polymer, a collection of molecules into an ordered pattern which confers special properties to bestow utility in specific applications. Just as single atoms or molecules have limited usefulness while an ordered collection of molecules into a polymer transforms a compound into a more useful manifestation of the material, so too is knowledge the useful end product of its less useful constituents data and information.

Nonaka and Takeuchi have described two distinct forms of knowledge, explicit and tacit.[15] Explicit knowledge is formal and systematic, is readily expressed in words and numbers, and is easily communicated in the form of hard data, scientific formulae, codified procedures, or universal principles. Tacit knowledge, by contrast, is not readily evident or expressible and is poorly communicated by words and numbers. Where explicit knowledge is discrete and tangible, tacit knowledge is highly personal, amorphous and intangible. Explicit knowledge is typified by a textbook, a computer program, a recipe, or a procedure manual; tacit knowledge is personified by the skill of a surgeon, an appreciation of aesthetics, or by a sense of direction. When tacit knowledge is converted to explicit knowledge, difficult to express concepts or feelings are communicated via reliance upon figurative language and symbolism, giving rise to learning.

Although the existence of knowledge is widely recognized and specific types of knowledge such as explicit and tacit have been characterized, methods for the measurement and management of knowledge remain rudimentary. No widely accepted method exists by which knowledge may be quantified, nor are methods to store or manage knowledge well developed. Few enterprises have inventoried and categorized the knowledge assets (also termed intellectual capital) contained within their employees, procedures, and processes. Intellectual capital remains an incompletely evaluated corporate asset but one which is coming under increasing scrutiny with the advent of computers.[17, 18]

The Information Hierarchy

These three concepts – data, information, and knowledge - combine and interrelate to form an *information hierarchy*, a framework to allow consideration of the place of each of these elements relative to the others.[28] The three concepts may be considered as distinct levels within a pyramid, each level resting upon a foundation provided by its predecessor (Figure 3). Data represent the foundation, the most basic element of the structure. Information represents the central layer of this hierarchy, as meaning is extracted from the diverse data elements. The third and highest level of the hierarchy, knowledge, does not exist in isolation but rather is derived from application of the lower two levels; Turban's definition of knowledge as "the ability to use information" is particularly germane.[4]

It is upon each of these strata that the present thesis focuses with the underlying premise that information systems (*vide infra*) can and do have a impact upon the delivery of health care, and that health care organizations may extract value from their use of health information systems.

Systems

A system is defined as "a collection of interrelated objects interacting in order to meet certain defined objectives",[2] as "a set of elements or components that are formed and interact to accomplish goals or objectives,"[29] or as "an organized set of procedures for accomplishing a task."[30] From these similar definitions, the basic formula for a system may be discerned:

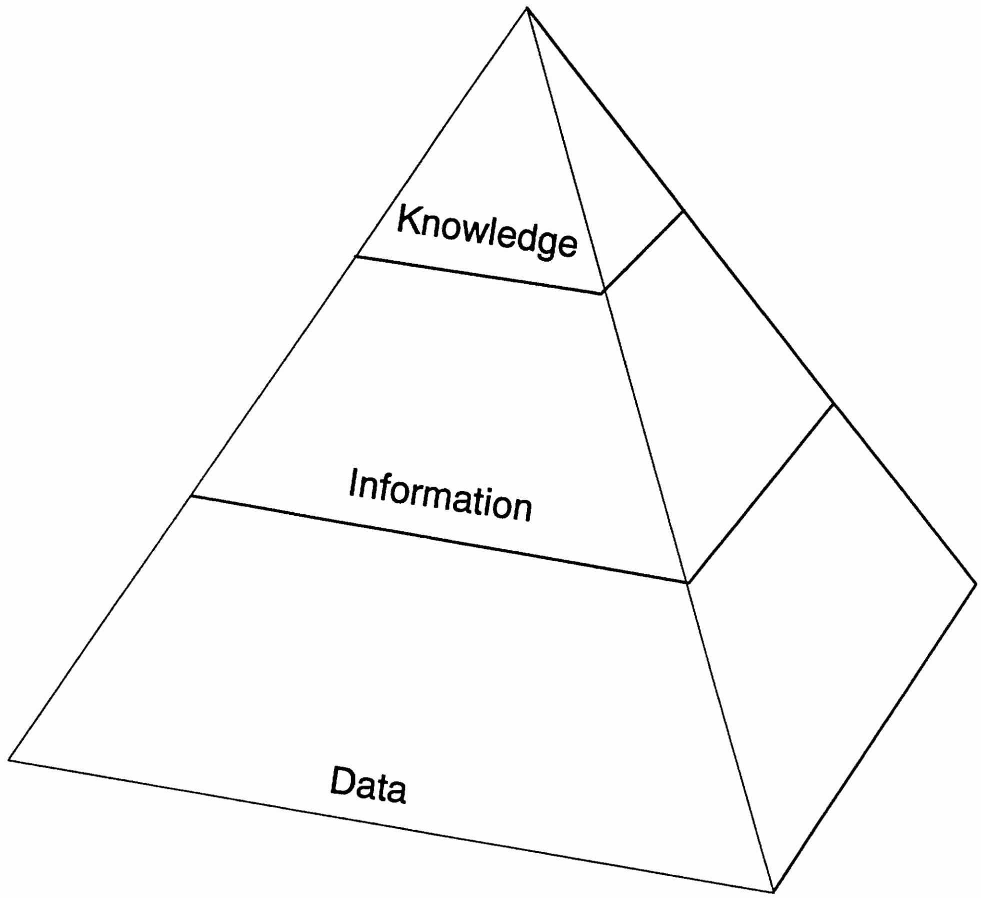


Figure 3
The Information Hierarchy

1. One or more parts, plus
2. Interactions between or among these parts, plus
3. Direction of the interactions toward an objective.

Diagrammatically, a system may be illustrated from a functional standpoint of inputs, processing mechanism, and outputs (Figure 4).

A system possesses certain characteristics:

1. Properties belonging to the system but not to the component parts (technically referred to as *emergent properties*);
2. Hierarchy, with a system being composed of layers of systems within systems; and adaptability, i.e., processes of communication and control that allow the system to change and survive in response to a changing environment.[2]

Systems may be classified as simple or complex, open or closed, stable or dynamic, adaptive or nonadaptive, permanent or temporary. The systems of interest in the present thesis are computer-based systems which combine both manual and automated processes. Medical computer systems perform several basic tasks:

1. Data acquisition, the collection of a wide range of patient-related data.
2. Record keeping, collecting and processing data as well as producing reports.
3. Communication and integration, making health care data available to the multiple members of the health care team.
4. Surveillance, monitoring data for significant events and highlighting situations requiring action.

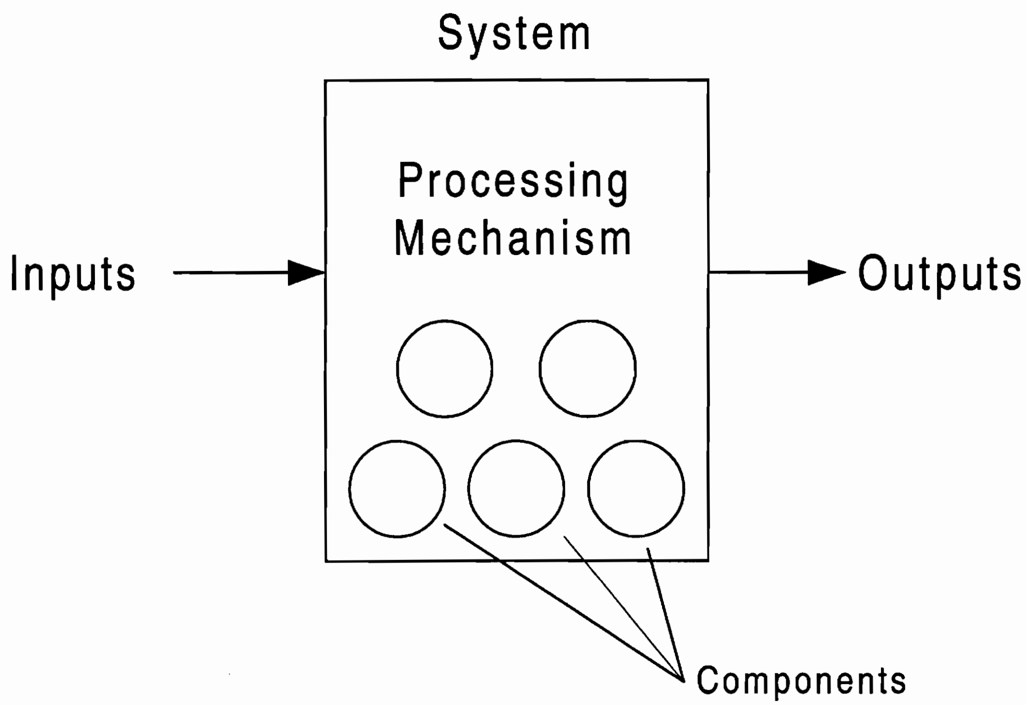


Figure 4
Functional System Diagram

5. Information storage and retrieval, the archiving of data in such a way as to facilitate subsequent query and retrieval.
6. Data analysis, the presentation of data in a more understandable form derived by methods such as graphing or by calculation of secondary parameters such as statistical analysis of raw data.
7. Decision support, the interpretation and presentation of data and recommendations for patient-specific actions.
8. Education, the presentation of information to allow health care professionals or patients to acquire and to maintain knowledge and skills.[30]

Systems specialized to specific applications exist across a wide variety of domains, from the environment to government to education to industry.

Information Systems

One example of such specialized systems is an information system (IS), generically considered to be any system that processes information.[2] From the more specific viewpoint of information technology, an IS is a collection of components that collects, processes, stores, analyzes, and disseminates information for a specific purpose.[31] Strictly speaking, any system handling information may be labeled an "information system," and for many years manual information systems were the standard mechanism by which information-intensive enterprises such as business, military intelligence or health care (among others) were operated. Only in recent years since the advent of the computer has the common usage of the term "information system" come to specifically imply a system based on information technology, also known as a computer-based information system (CBIS).[31]

Information systems are not generic and widely applicable to a spectrum of uses but rather exist in a variety of different forms specialized to particular tasks. Specific types of information systems include:

- Accounting information systems
- Auditing information systems
- Criminal history information systems
- Education information systems
- Engineering information systems
- Environmental information systems
- Geographic information systems (systems dealing with geographic and cartographic information; also referred to as GISs)
- Legal information systems
- Management information systems (systems dealing with various forms of information to allow business managers to make informed decisions; also referred to as MISs)
- Multimedia information systems
- Strategic information systems (SIS)
- Health information systems.

Health Information Systems

Medical Records

Historically, medical care was delivered informally with little or no documentation. Health care and medical practice transformed in the latter half of the nineteenth century with the emergence of scientific medicine, and hospitals and medical specialties emerged to support the increasingly technical aspects of medical care.[32] As medical care increasingly underwent a division of labor to incorporate a variety of specialized professionals, documenting care in medical records became an important vehicle for intercommunication between the numerous participants.[33] Medical records also became crucial in the adoption and administration of professional standards, as well as for the purposes of clinical research.[34] Over time, the uses of medical records have steadily broadened to encompass a range of applications including:

- Forming the basis of the historical medical record;
- Supporting communication among health care providers;
- Anticipating future health care problems;
- Recording standard preventive measures;
- Identifying deviations from expected trends;
- Providing a legal record; and
- Supporting clinical research.[35]

The net result of these concurrent forces is general agreement that the medical enterprise, comprised of the practice of medicine and the broader application of health care delivery, is properly regarded as "information-intensive."[36] This information intensity comes at substantial cost. Jydstrup and Gross studied three New York hospitals and established that approximately 25 percent of these hospitals' total operating costs arose from information handling.[37] Workers in administrative departments spent approximately 73 percent of their time handling information, those in radiology averaged 42 percent, and nursing averaged 25 percent.

The breadth and depth of information necessary to care for the health of an individual is formidable. Even on the scale of the individual patient, "all medical personnel quickly learn that the idealized view of the medical record is complicated by a bevy of logistical and practical realities that greatly limit the record's effectiveness for its intended purposes."[35] The paper-based medical record's utility is constrained by a variety of limitations. These shortcomings include but are not limited to:

- *Availability:* The patient's record is often unavailable to the health care provider at the time and place that new services are provided. Paper-based medical records are used in a solitary fashion: a patient record in use by one provider is simultaneously unavailable to others.
- *Completeness:* The paper-based medical record contains only that information which has been recorded and filed in the patient's chart.
- *Organization:* A given item of patient information is useless if it is submerged and camouflaged amid reams of other pages or separate volumes and thus rendered unfindable and unavailable to the provider.
- *Legibility:* An unreadable entry is little better than no entry at all.
- *Timeliness:* Paper records are typically not current and lack information which has not yet been recorded, transcribed or filed.

- *Redundancy:* The same information is often recorded in multiple places in the patient record, and the same patient frequently exists in multiple records in different departments or among different practitioners.
- *Inefficiency:* Similar information is generally recorded in different ways on different forms in different institutions.
- *Passivity:* Paper-based medical records are useful in health care delivery and clinical research only in proportion to the willingness of providers to invest the time and effort to extract the information contained therein. The paper record lacks an active dimension, i.e., the ability to prompt the provider to provide specific information or to provide feedback which may impact patient care.[35, 38, 39]

The Institute of Medicine Report on The Computer-Based Patient Record groups the shortcomings of paper-based patient records into 4 categories:

1. Content;
2. Format;
3. Access, availability and retrieval; and
4. Linkages and integration.[39]

This same report additionally acknowledges five strengths of paper-based patient records from the perspective of users:

1. Familiarity to users;
2. Portability;
3. Once obtained, no problems with “downtime” such as are experienced with computer-based systems;

4. Flexibility in recording data; and
5. Ease of browsing or scanning.

As the scale of health care delivery escalates beyond the individual to encompass groups of individuals (such as hospital inpatients or enrollees in a certain health plan or HMO) or populations (such as residents in a given locale), information demands quickly exceed the abilities of even a team of skilled professionals to manage the information required to address health care needs. As stated by Eddy, "the complexity of modern medicine exceeds the inherent limitations of the unaided human mind"[40] (page 1272). This reality provides the impetus for health information systems.

Decision Support

Medical records demands alone, however, do not constitute the whole of the impetus behind the development of Health Information Systems (HIS). The other major force which has driven HIS development – and arguably the greater one – is the desire and the need to facilitate and to systematize medical decisionmaking. As the confluence of science and art, medicine is an inherently complex discipline. Given man's acknowledged limitations as an information processor, this complexity generates three unsurprising byproducts, uncertainty, variability and error.

- Despite the large body of scientific information and evidence upon which modern medicine is based, much remains uncertain or unknown. Practicing medicine requires that physicians routinely process limited information and deal with uncertainty as they arrive at a diagnosis and select treatment.

Such underlying uncertainties require that physicians rely to an extent on subjective judgment.[41-47]

- Striking variations in medical care evident across the United States have been well established.[41, 44, 45, 47-54]
- Medical errors are remarkably common and have important consequences including frequent injury and occasional death.[55-61]

The quality of medical care suffers as a direct result of these shortcomings.[62-64]

Eddy has noted that our main methods to deal with complexity are to simplify and to think qualitatively.[65] Information systems offer an additional approach as a tool to manage this complexity in a logical and reproducible fashion: "...though the individual physician is not perfectable [*sic*], the system of care is, and ... the computer will play a major part in the perfection of future care systems "[55] (page 1355).

Once methods had been created to acquire and to store medical information electronically, it became apparent that it was not enough to simply archive data. Huge collections of isolated medical information suffered from the same shortcoming as paper records, i.e., their inherent passivity and failure to impact health care delivery. The real potential of medical computing lay in the use of the collected data to help address the problem of complexity (and its offspring uncertainty, variability and error) by assisting health care providers to make better, more informed and more timely decisions about medical care.[4, 55, 66-71] This revelation is an important one, setting HISs apart from vast unintelligent medical records archives.

A decision support system (DSS) may be defined as a computer-based information system that combines models and data in an attempt to solve nonstructured problems with extensive user involvement.[4] Such a DSS oriented toward assisting in medical diagnoses may also be referred to as a clinical diagnostic decision support system (CDDSS). HIS (*vide infra*) increasingly incorporate DSS functions to extend their functionality and enhance their ability to reengineer clinical care.[72-79]

Nomenclature of Health Information Systems

As a result of the overwhelming information needs of health care delivery, specialized forms of information systems known as health information systems (HISs) have emerged in the health care domain to develop, collect, and process the diverse information necessary to deliver healthcare services. A health information system is defined both by what it *is* and by what it *does*:

- An integrated set of files, procedures, and equipment for the storage, manipulation, and retrieval of healthcare information.
- "A system of hardware, software, networks and users, of which the last are the major component, that functions to collect, communicate, and evaluate data and transform them into information that supports the goals of the organization"[9] (page 234).
- ".... used to collect, store, process, retrieve and communicate patient care and administrative information for all hospital-affiliated activities and to satisfy the functional requirements of all authorized users"[80] (page 576).

- "…. supporting the delivery of patient care by aggregating relevant information from different sources and providing access to that information in a form that supports health care providers in making decisions about a patient's care"[81] (page vii).

At the most superficial level, an HIS is any computer system working in the health care domain. A number of synonymous terms have emerged, each seeking to distinguish this type of information system from those others located in hospitals but restricted to administrative and financial functions, i.e., the nonclinical realm. These pseudonyms include:

- Clinical information system (CIS)[28, 82]
- Patient care information system (PCIS)[81]
- Medical information system (MIS)[83]
- Integrated hospital information processing system (IHIPS)[84]
- Health care information system (HCIS)[85]
- Automated hospital information system (AHIS)[86]
- Computerized patient record or computer-based patient record (CPR).[39, 87]

The key features which distinguish a health information system from its business-oriented counterpart employed in the same medical domain include:

1. The integration of patient data from multiple sources and knowledge bases;
2. The provision of decision support for evidence-based health care; and

3. Use directly by caregivers as the primary source of information for patient care.[87]

The relationship between clinical and nonclinical information systems is shown in Figure 5. The distinguishing feature of health information systems is their *clinical* orientation.

As such information systems first evolved in major hospitals during the 1960s and 1970s, the acronym HIS was initially used to refer specifically to Hospital Information System. As health care has in recent years increasingly moved out of the hospital to embrace the entire spectrum of locations where health care is delivered, the hospital has lost its solitary position in the health care universe. Contemporary usage of HIS now refers to Health Information System or Healthcare Information System, and the two terms are often used interchangeably. The more current and global term Health Information System will be employed in the present thesis.

Health information systems did not appear in a fully developed state, but rather they have evolved subject to and as a result of a variety of influences. In any consideration of the value of HISs, it is important to have an appreciation of their history and evolution to provide perspective on how and why existing systems have developed in the manner that they have. The evolution of HISs can be viewed from three different perspectives: relative to technology, relative to the health care industry, and relative to information technology management.

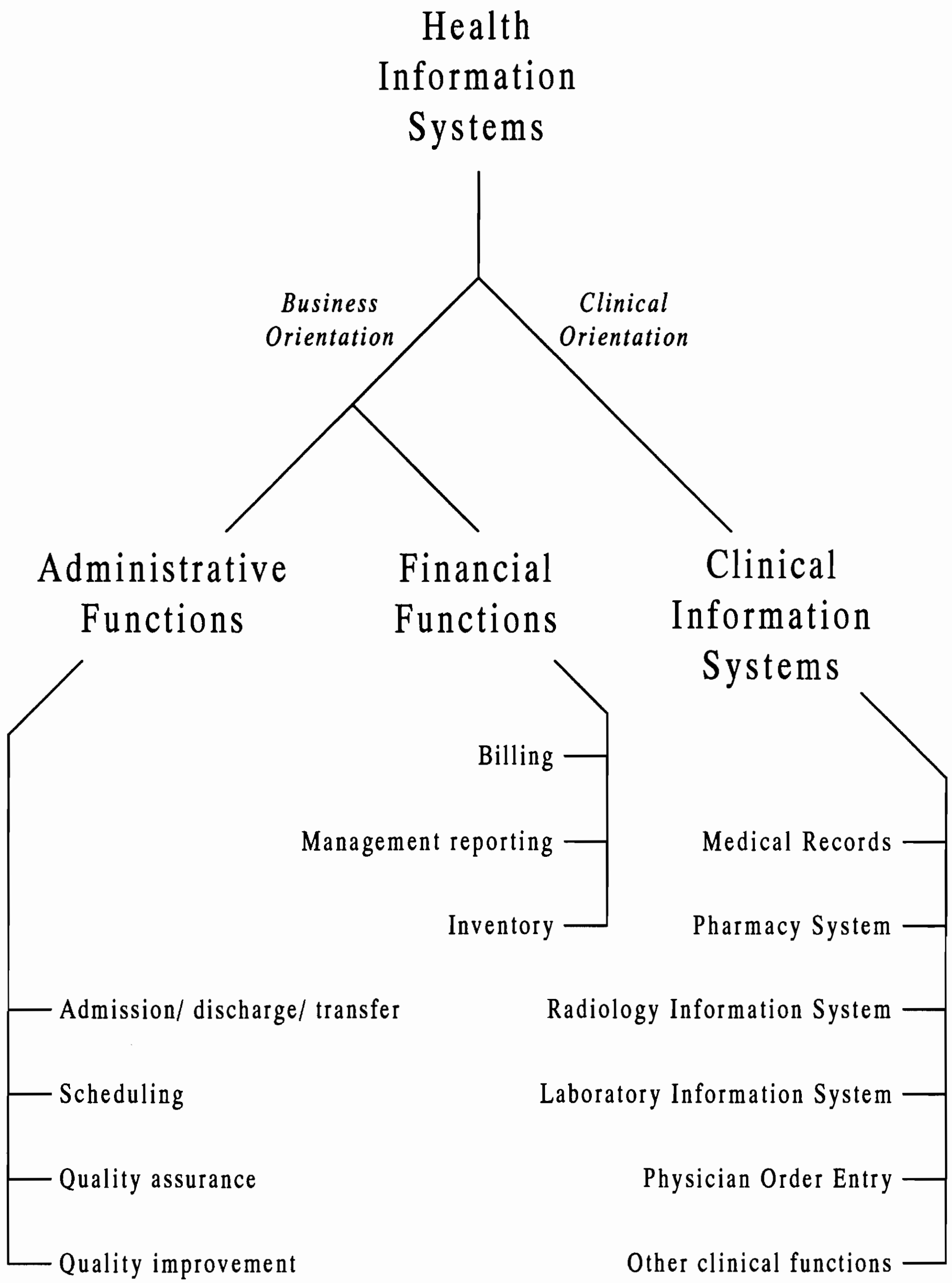


Figure 5
A Taxonomy of Health Information Systems

Evolution of Health Information Systems

from the Technology Perspective

Health information systems have evolved just as computing in general has evolved at a pace defined by the development and advancement of the underlying technology. When reviewing the accomplishments of medical computing, Blum categorizes development from his 1986 vantage point into four phases according to the objects being processed (Table 1). His organization of medical computing provides a framework to allow consideration of the broad field in digestible pieces.[28] Phase 1 (basic experimentation and orientation) is followed by three subsequent phases:

Data oriented applications (Phase 2). At this least-complex level of abstraction, computers were exploited to perform those tasks for which computers were themselves first conceived, i.e., mathematically intensive computations. Medical applications allowed a quantified approach to physiology, modeling of biological systems, and the emergence of bioengineering as well as automation of clerical tasks. Some of the common initial uses of computers in patient care included:

- Business data processing, an application focusing more on administrative data processing than clinical information management;
- Clinical laboratory automation and data processing;
- Patient monitoring, including data acquisition and processing as well as event detection;
- Diagnostic systems, such as ECG processing and reporting; Graphical applications, such as radiation therapy treatment planning;

Table 1
Evolution of Clinical Medical Computing

Phase	Era	Hallmark	Accomplishments
Phase 1	1955-1965	Experimentation and orientation	Conceptualization of data processing in the clinical laboratory and of the needs of medical computing with few practical applications.
Phase 2	1965-1975	Data processing success	Accomplishments in the collection and analysis of medical data; attempts to implement information systems with limited success.
Phase 3	1975-1985	Information processing success	Integration of medical data with other information needed for patient care; appearance of first viable information systems.
Phase 4	1985-	Knowledge processing success	Successful implementation of knowledge-based systems for patient care with the ability to suggest diagnosis, therapy and maintenance.

Adapted from Blum.[28] Used with permission.

- Imaging applications, such as computed axial tomography (known as CAT or CT scanning), magnetic resonance imaging (MRI or MR), and other forms of digital imaging; and
- Implantable microelectronics, such as telemetry sensors or cardiac pacemakers.

Information oriented applications (Phase 3). Information oriented applications take the extra step beyond simple data orientation to synthesize collections of data elements into a pattern from which meaning may be extracted. Emphasis must be placed not simply on collecting diverse data elements but also on coordinating and presenting these items in a manner comprehensible to the user. In this sense, an information system differs from a process control system (in which the output from one module serves as the input to another) by virtue of the interjection of the human element. The output from an information system is directed to a human user who integrates the information so obtained with other knowledge to determine subsequent actions.

Just as information systems in general are found in a variety of application-specific forms, so too are health information systems found in a range of specialized types. Commonly identified types of health information systems bearing distinctive names include:

- Hospital information systems (HIS)
- Integrated Advanced Information Management Systems (IAIMS)
- Management information systems (MIS)
- Ambulatory care information systems (ACIS)

- Clinical laboratory information systems (LIS)
- Clinical pharmacy information systems
- Database management systems (DBMS)
- Decision support systems (DSS)
- Medical record and coding information systems
- Nursing information systems (NIS)
- Personnel staffing and scheduling information systems
- Pharmacy information systems
- Radiology information systems (RIS).

Knowledge oriented applications (Phase 4). Knowledge is the third and highest level of the hierarchy. In one sense at the level of *data* orientation, our knowledge is encoded in the algorithms that allow the processing of data such as contained within an ECG tracing. In another sense at the level of *information* orientation, an information system allows the extraction of additional information from the database by the use of query tools or the ability to regroup data in different ways and to perform analysis. Although powerful, such techniques are inherently limited by the information contained within the database. Knowledge is limited to what is encoded in algorithms and to what the user explicitly provides in the query or analysis. Knowledge generation cannot occur in a vacuum; knowledge cannot emerge *de novo* without data and information.

At the level of *knowledge* orientation, an added dimension comes into play, that of inference. The ability to take fact A and fact B and apply logical rules to make a judgment and arrive at fact C – to *infer* - represents a powerful synergism of computer systems. Such a capability leverages the data and information functions of the computer to derive potentially powerful conclusions. The logical rules brought to bear clearly are of crucial importance in deriving valid judgments. A variety of reasoning methods have been identified, including deductive, inductive, analogical, formal, procedural (or numeric), and metalevel reasoning.[4]

Two classes of medical systems are considered to be knowledge-oriented. Bibliographic knowledge bases are organized to allow retrieval in ways maximizing the ability of the user to identify and extract the knowledge; Medline and HealthSTAR are two examples of this type of database. Artificial intelligence/ expert systems such as embodied by the diagnostic applications Iliad and Quick Medical Reference (marketed as QMR) attempt with partial success to arrive at medical diagnoses from input history and physical data.[88-92]

Evolution of Health Information Systems from the Health Care Industry Perspective

An alternative point of view from which to consider how health information systems have evolved is from the perspective of the health care industry. Health care has been a continuously changing field from its inception, and there is little debate that the pace of this change has accelerated in recent years. Computers have been in use for less than 50 years, a period which has been marked by substantial turmoil within the health care field. Bourke has broken down the development of health care information systems into five phases corresponding with discrete eras in health care delivery (Table 2).[93] The underlying theme is the response of health information systems to

Table 2
Health Information Systems by Industry Phase

Phase	Era	Industry Phase	Technology	Data
Phase 1	1945-1965	Government sponsored growth.	Virtually none	Manual. No DRG entity.
Phase 2	1965-1973	Introduction of Medicare and Medicaid.	Mainframes. Standalone machines. No standards.	Patients viewed as "accounts".
Phase 3	1973-1983	Certificates of need and disenchantment.	Minicomputers. PCs. DBMS on mainframes.	Patients still viewed as "accounts". Utilization data. Profitability reporting.
Phase 4	1983-1991	Introduction of DRGs.	PC networks. PC databases.	Data collection dictated by external organizations. Insurance preauthorization. JCAHO and HCFA data. Cost.
Phase 5	1991-present	Prospects for national health care.	PC networks and databases. Artificial intelligence. Data interchange.	Product line. Market segment. Patient viewed as a patient, not an account. New emphasis on enterprise data.

Adapted from Bourke.[93] Used with permission.

assist health care enterprises in their attempts to cope with a shifting competitive environment

Evolution of Health Information Systems from the Information Technology Management Perspective

The third perspective from which to consider the evolution of health information systems is that of Information Technology (IT) management. Bourke discusses three generic approaches to IT management which he classifies into "eras" (Table 3).[93] Just as the health care market has changed, so has IT management transformed from an initially narrow-based and rigidly controlled culture to a more distributed, broadly based function.

Overview of the Evolution of Health Information Systems.

Considering health information systems from each of these three perspectives, the common theme which underlies each is change. As the health care industry and information technology have transformed, the application of IT to health care delivery has evolved in response to multiple outside forces. To some extent, the advancement of IT and its application in the health care marketplace have also themselves facilitated change, making possible administrative and clinical innovations which would have not been possible in the era of manual data processing.

The other theme to be extracted from the evolution of health information systems is the time lag of evaluation behind development. Information systems have been in a constant state of development from their inception. Amidst such a climate,

Table 3
Generic Approaches to IT Management

Era	IT Administration	User	Justification
Era I	Regulated monopoly	Department	Cost
Era II	Free market	Individual	Individual effectiveness
Era III	Regulated free market	Enterprise	Achievement of strategic goals

Adapted from Bourke.[93] Used with permission.

evaluation has been relegated to an afterthought and has typically been performed late, incompletely or not at all. Design and implementation of information systems has failed to incorporate evaluation mechanisms from the start, making evaluation that much more difficult later. As noted by Frisse, early work in medical informatics has emphasized feasibility to the detriment of assessing value.[94]

Comparison of Health Information Systems with Information Systems in Other Industries

Notwithstanding the crucial importance of information in health care delivery, the health care industry has as a whole been slow in its adoption of information technology.[95, 96] A time lag for health care computing of 5 to 10 years behind other industries has been commonly quoted.[93, 97] Beyond this delay, the magnitude of information technology expenditures in health care (averaging 2.6 percent of revenues according to Crowe) has been exceeded by those in other industries such as manufacturing (5 percent) or banking (7 percent).[97] Among the reasons cited to account for such discrepancies are a lack of business acumen among technically-oriented IS management, a lack of appreciation for the potential of IT among upper management, a lack of standards, a poor track record for system implementation and utilization, and the drag on technological progress resulting from the need to support legacy systems.[93] Valuable lessons may be derived from observation of IT outside of health care such as how to manage complexity, create and deploy standards, empower individuals, emphasize scalability, and apply techniques of mass customization to reduce uncertainties in clinical decisions. The gap between IT inside and IT outside of health care is expected to narrow and eventually disappear.[98, 99]

Rubin has collected some of the most extensive data on IT investments across different industries. He notes that the health care IT investment of 2.77 percent of gross revenue is positioned between the outer extremes of banking (6.33 percent) and food/beverage processing (0.86 percent) and slightly below the unweighted mean IT investment among these 20 industry sectors of 2.87 percent (standard deviation 1.61 percent) (Tables 4 and 5).[100] The distribution of IT budgets across the 20 industries is shown graphically in Figure 6. Rubin's figures for health care and banking are comparable to those of Crowe, although the much more specific use of the manufacturing category in Rubin's analysis of 20 industries makes his 1.70 percent manufacturing figure not truly comparable to Crowe's more global 5 percent value bearing the same label. Rubin's data must also be viewed in proper context as a coarse measure of average IT spending within various industry sectors. These data offer no insight into the actual level of benefit seen by the individual companies or the variation in IT expense within each industry sector, nor is there implied any cause and effect relationship between IT expenditures and corporate performance. Nevertheless, the substantial differences between industries are noteworthy.

Although some data has appeared about the gross levels of IT expenditure of various industries including health care, much less information is available about how this money is being invested within each given industry sector and the resulting degree of computerization within each sector. One report addressing these considerations for the health care industry demonstrates a wide range in the level of computerization

Table 4
Information Technology Investment by Industry

Industry Group	IT Budget as % of Gross Revenue
Aerospace	3.00
Banking	6.33
Chemical	1.92
Consumer products	1.75
Electronics	3.00
Energy	1.11
Financial services	5.11
Food/ beverage processing	0.86
Health care	**2.77**
Information technology	3.03
Insurance	2.75
Manufacturing	1.70
Media	2.96
Metals /natural resources	1.21
Pharmaceuticals	2.86
Professional services	3.28
Retail	0.87
Telecommunications	6.24
Transportation	4.45
Utilities	2.12
Mean	2.87

Source: Rubin.[100] Used with permission.

Table 5
Rank Order of Information Technology Investment by Industry

Industry Group	IT Budget as % of Gross Revenue
Banking	6.33
Telecommunications	6.24
Financial services	5.11
Transportation	4.45
Professional services	3.28
Information technology	3.03
Aerospace	3.00
Electronics	3.00
Media	2.96
Pharmaceuticals	2.86
Health care	**2.77**
Insurance	2.75
Utilities	2.12
Chemical	1.92
Consumer products	1.75
Manufacturing	1.70
Metals /natural resources	1.21
Energy	1.11
Retail	0.87
Food/ beverage processing	0.86
Mean	2.87

Adapted from Rubin.[100] Used with permission.

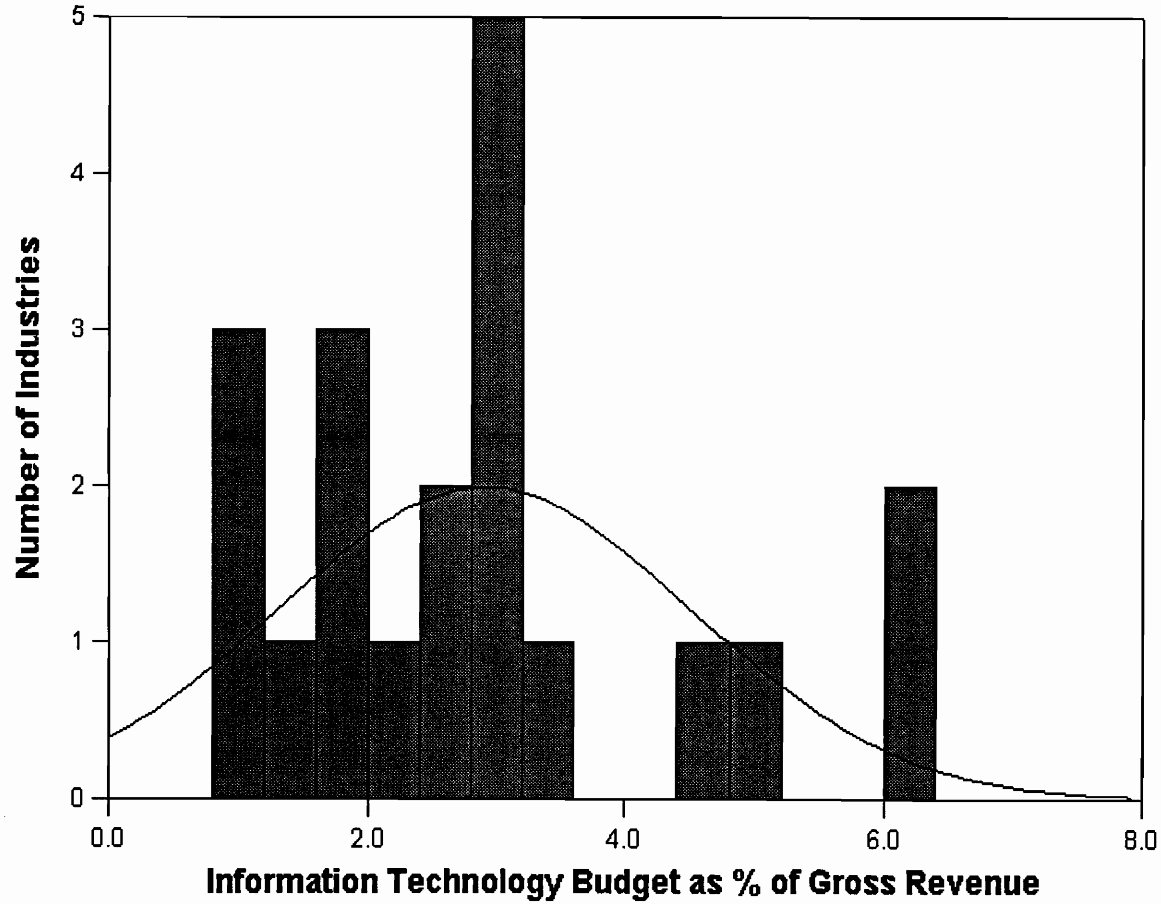


Figure 6
Distribution of Information Technology Budgets Across 20 Industries

among 4,829 surveyed hospitals and integrated delivery systems.[101-104] Based on a report from the META Group, a Stamford, CT technology consulting firm, the survey assigns hospitals and integrated delivery systems (IDSs) a score from 1 to 6 reflecting their highest level of information technology attainment based upon a six-level technological scale:

Level 1	Basic billing applications
Level 2	Ancillary department applications
Level 3	Clinical orders applications
Level 4	Point-of-care clinical charting
Level 5	Enterprise-wide data repository
Level 6	Clinical outcomes, disease management.

An enterprise with a Level 4 score, for example, would possess the information technology capabilities at Level 4 and below, while having not attained those qualifications at Levels 5 or 6. The distribution of results for the entire group of surveyed institutions is shown in Figure 7. The report demonstrates a remarkably wide spread in technological sophistication across hospitals and IDSs, with only one seventh (14 percent) reaching the top two tiers. Based upon comprehensive incorporation of IT into its operations, Intermountain Health Care would be ranked in the top tier at Level 6.

While different strata of computerization unquestionably exist among healthcare organizations such as hospitals or integrated delivery systems, and while different healthcare organizations commit differing levels of funding to IT, there exists no formal or necessary connection between the two concepts. The fundamental

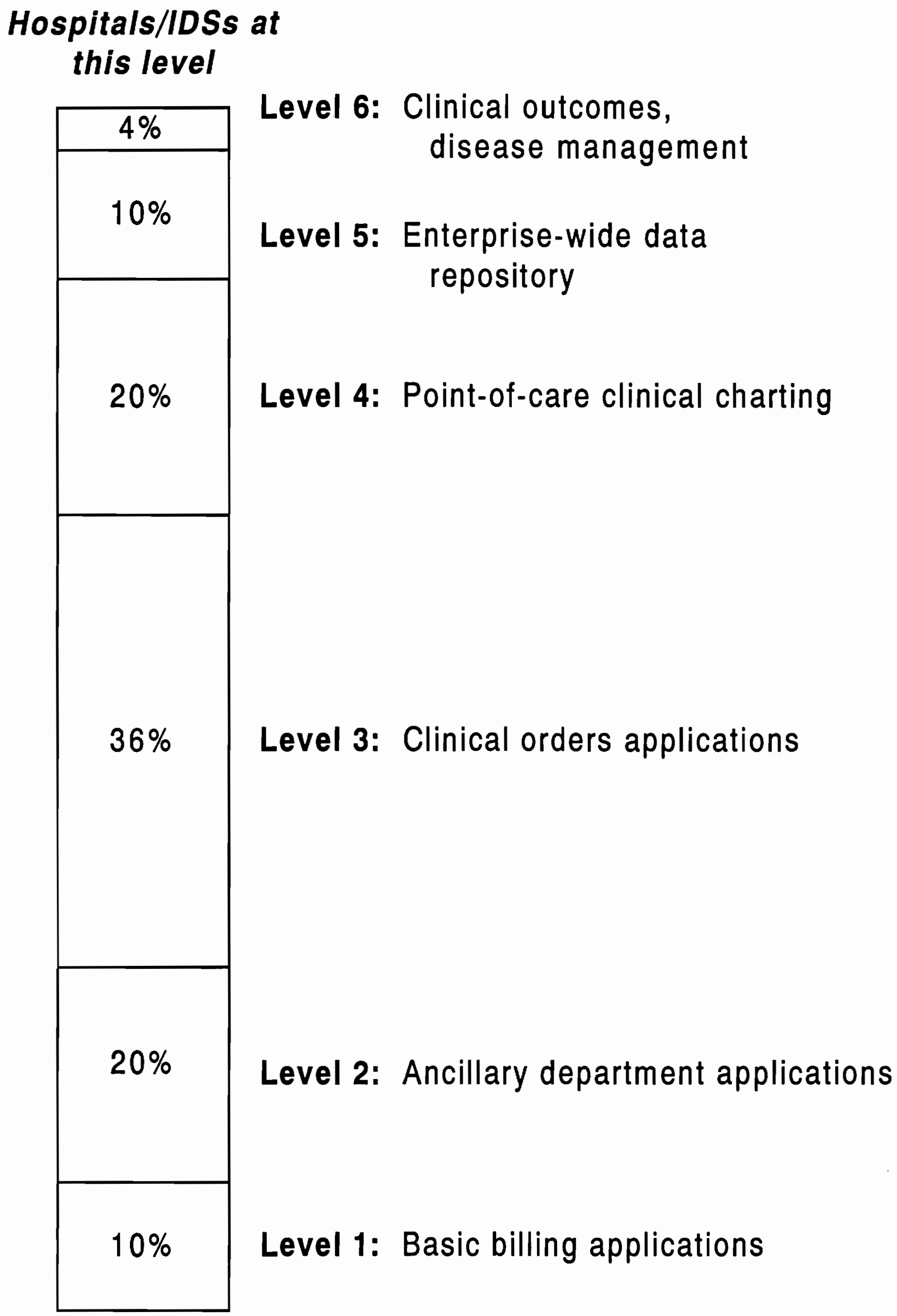


Figure 7
The Information Technology Spectrum Among Hospitals and Integrated Delivery Systems

question may be briefly stated: what is the proper level of IT investment which a healthcare enterprise should commit to derive a given level of technological benefit?[70] Considered in the context of the META Group model discussed above, how much IT investment is necessary to take an organization to Level 3 or Level 6? Such a question is not a trivial one. The META Group reports IT operating expenditures as a percent of total expenditures ranging from >6.5 percent for Level 6 institutions to <2 percent for Level 1 institutions (Figure 8). Not shown in this figure is the stratification of META's data by institutional size: larger institutions tend to spend more on IT than smaller institutions within the same level.

The missing element from the META Group data is functionality. The six levels of IT provide only the coarsest stratification of institutions by their information technology capabilities. Within each stratum will lie multiple institutions possessing a range of capabilities. Not all institutions within Level 6, for example, can be expected to possess identical degrees of sophistication in their use of clinical outcomes and disease management. Although the benchmark data cited above regarding average levels of IT operating expenditures at given levels, no cause and effect relationship exists nor should one be implied. A health care enterprise earmarking 5.5 percent of operating expenses cannot expect that a Level 4 IT capability will necessarily follow. What functional results stem from an institution's IT investment will vary greatly depending upon multiple other factors including corporate vision, leadership, IT staff experience, creative health care application development, system implementation, and engagement of clinical staff. It is just such intangible factors which account for wide

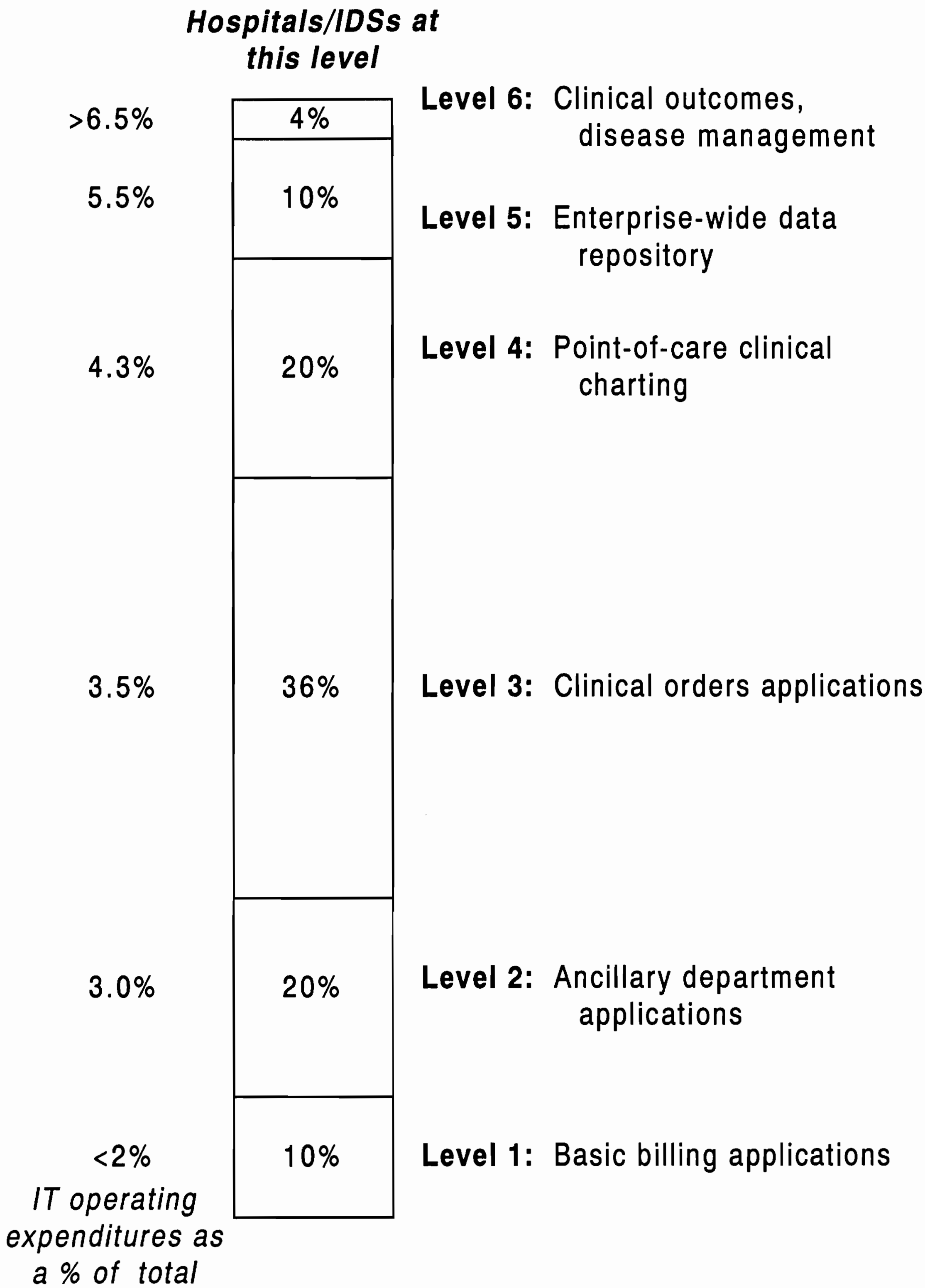


Figure 8
The Information Technology Spectrum Among Hospitals and Integrated Delivery Systems Relative to Information Technology Spending

variability in the successful adoption of clinical information systems across the health care domain and from which competitive advantage stems.

Components of Health Information Systems

1. Computer systems in general and health information systems in particular incorporate three separate components: Hardware, the physical equipment ;
2. Software, the computer programs which direct the hardware to perform specific tasks; and
3. Users, the people who interact with the hardware and software of the system.[30]

Rose proposes an alternative view of health information systems:

1. One major component, i.e. users; and
2. Four minor components:
    - Hardware
    - Software
    - Networks
    - Information.[9]

The importance of users is noted by each of these authors as well as by others.[105] No information system, no matter how elegantly conceived and executed, will prove useful to the organization without engagement of those who are to use it. The design of such systems thus assumes critical importance.

Important Design Considerations for Health Information Systems

The bigger picture above the level of hardware, software and interlocking technologies is that of automation. Although computers have increasingly had a place in modern health care delivery, they have not in themselves been the answer to the nationally recognized health care problems of cost, accessibility or quality.[106] Automation incorporates the processes that involve both computers and the people who use them to systematize health care delivery. The important concept is neither the application of technology for technology's sake nor technology at any cost, but rather what has been termed *appropriate technology*, technology tailored to fit the psychosocial and biophysical context prevailing in a given location and period.[107] The proper stance for automation is one that incorporates practical considerations and reality in the total process of how computers may be employed to change the cost, access or quality of health care.

The usefulness of any HIS relates directly to the design considerations underlying its structure and function. Metzger and Teich have detailed those criteria found to be critical in achieving PCIS acceptance among those providers who must use them by drawing upon the published literature, upon PCIS evaluations and planning projects performed by a major consulting firm, and upon the experience of clinical applications developers at Brigham and Women's Medical Center in Boston.[108] Successful systems should:

- Be available to manage patient care whenever users need them.
- Be available wherever decisions about care are to be made.
- Provide quick and value-added access to information.

- Be designed to fit actual patient care processes and work situations.
- Be designed to be so easy to use that they require little or no training.
- Maximize incentives and minimize time to engage physicians with direct entry.

The importance of these design precepts and of the process of implementation lies in their acting as stepping stones to the extraction of *value* from health information systems.[109] Systems designed with these considerations in mind are advantageously poised to win user acceptance, and in the final analysis whether a system is used or not is more than simply one aspect of information system evaluation, it in fact represents a crucially important factor.[105, 110, 111] Actual use of an information system is the uniform path by which value may be obtained (Figure 9). Although use alone is not itself a guarantee of deriving value, use does constitute a necessary prerequisite for achieving value. An unused health information system is rendered devoid of value to the user, to the patient, or to the enterprise.

Having established a foundation of what a health information system is, how it evolved, and what it does, we now turn to considering such systems from the perspective of value.

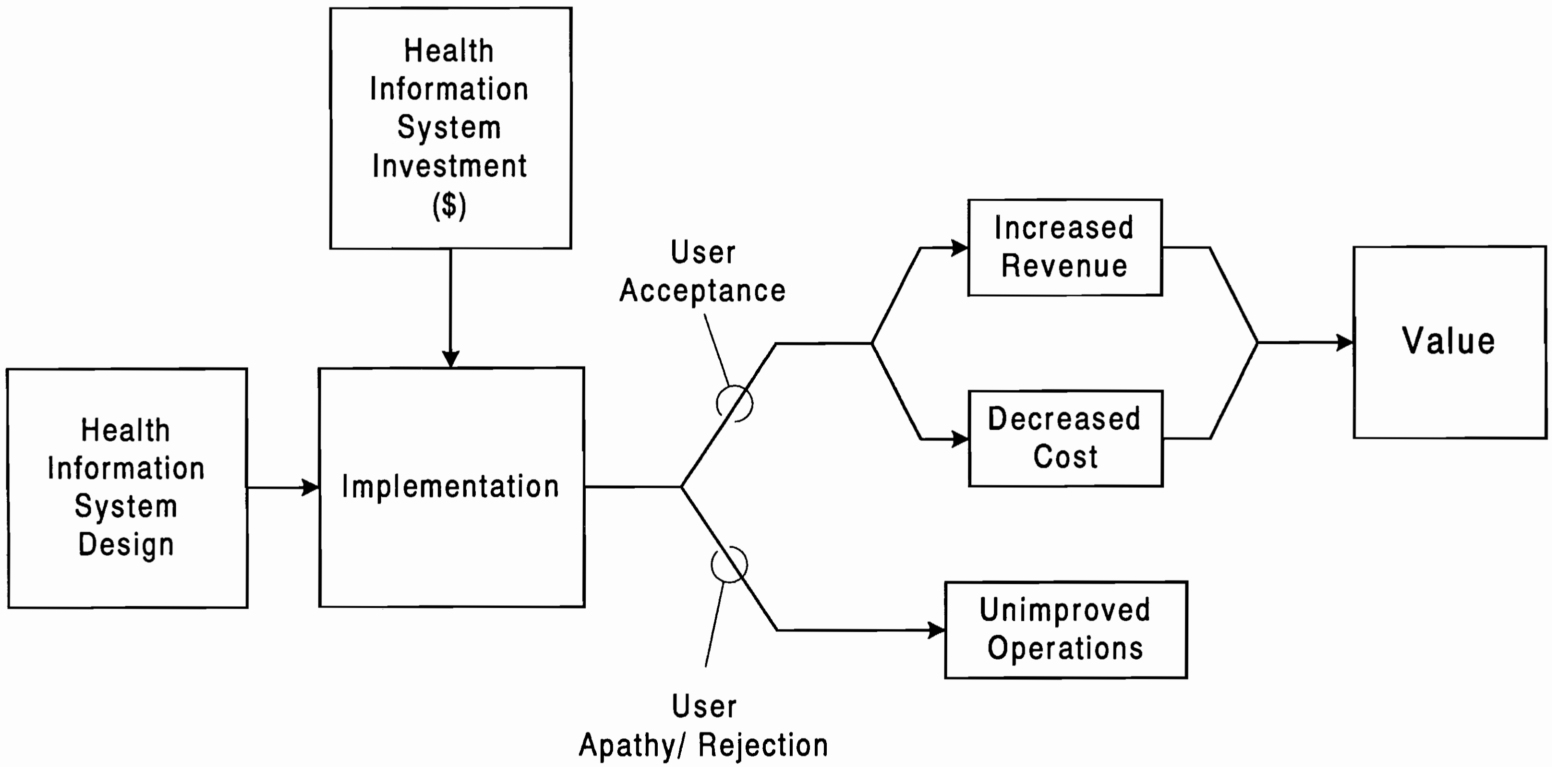


Figure 9
User Acceptance Mediates Health Information System Value

VALUATION OF HEALTH INFORMATION SYSTEMS

The worth and value of knowledge is in proportion

to the worth and value of its object.

-Samuel Taylor Coleridge[112] (page 474)

Nomenclature Regarding Valuation

In considering the valuation of health information systems, certain terms form the foundation of the discussion and will appear multiple times. Basic definitions of these terms will lay the groundwork for the discussion.

Value

Dictionaries define value as:

- "the real or estimated worth of something", or "the proper price, usefulness or importance of the item in question"[113] (page 2311);
- "a measure of worth or efficiency"[114] (page 765); or
- "an amount, as in goods, services, or money, considered to be a fair and suitable equivalent for something else"; or "in health care, a judgment based on the inverse relationship between the perceived quality of an organization's service and the cost of that service"[115] (page 814).

In business terms, a commonly used definition of value is accepted to be the amount of money which changes hands when a willing seller trades a good or service with a willing buyer. In a more global business sense, value is the end product of a cascade originating from the basic competencies of a firm as tempered by market conditions and culminating in the firm's financial performance (Figure 10).[20] Value is thus a molecular rather than atomic concept, dependent upon other factors to confer meaning. The business literature relative to pricing notes that value is a function of :

1. the utility of the product's several attributes to the buyer,
2. the options the buyer has and is aware of (such as competing products or no purchase at all), and
3. the extent to which the buyer perceives price itself as a measure of product value.[116]

The value chain is another related business concept addressing value. Originally described by Porter, the value chain conceives of any business enterprise as a chain of activities transforming inputs into outputs that customers value.[117, 118] The entire process is composed of a number of sequential primary and support activities, each of which adds value to the product (Figure 11). A firm's value chain and the way it performs these individual activities reflects a variety of factors including its history, its strategy, its approach to implementing its strategy, and the underlying economics of these individual activities. Porter points out that competitive advantage cannot be understood by looking at the firm as a whole, but rather stems from the many discrete activities that it performs.[117] This reality underscores the importance of examining firm performance on the narrower scale of its individual

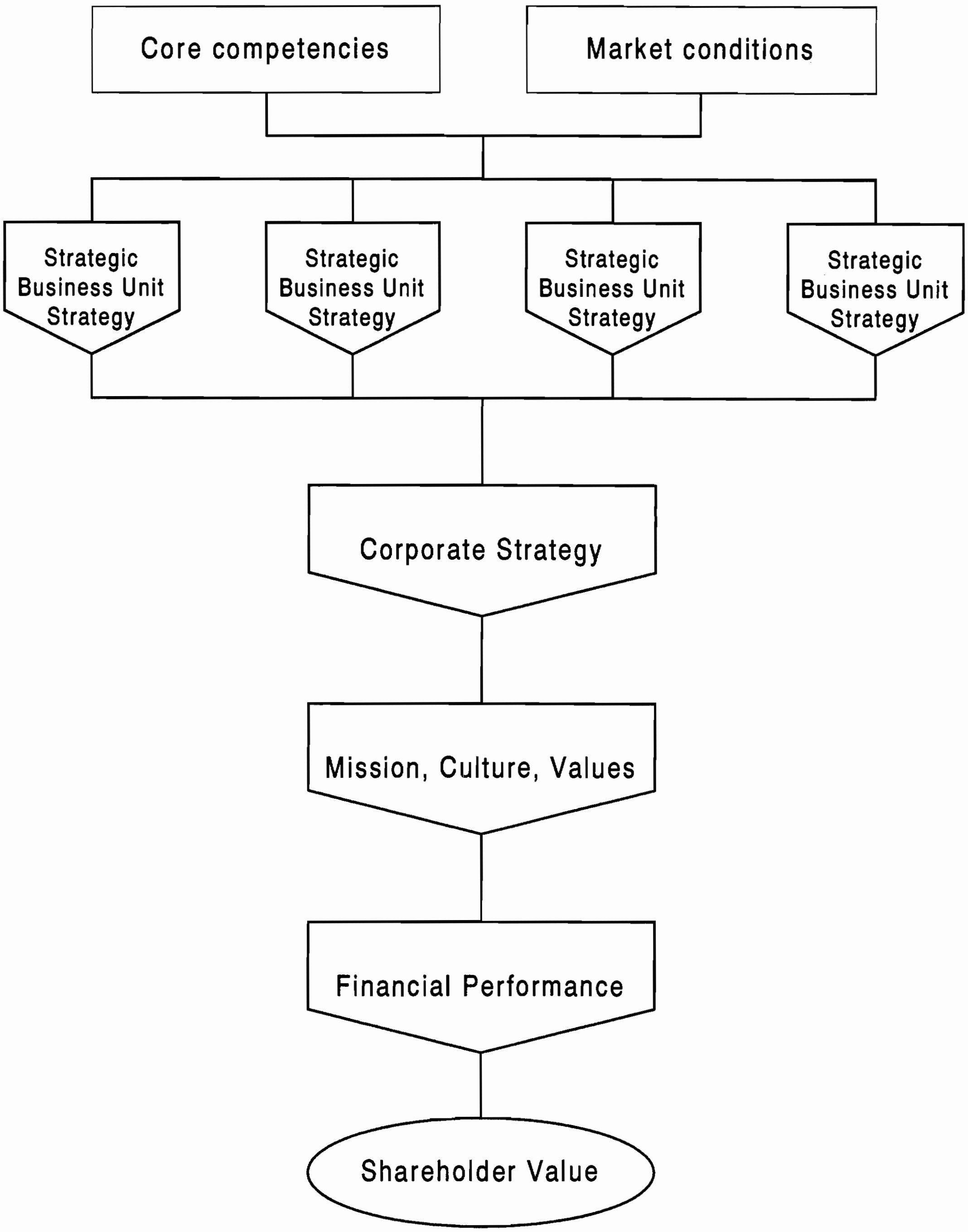


Figure 10
The Shareholder Value Cascade

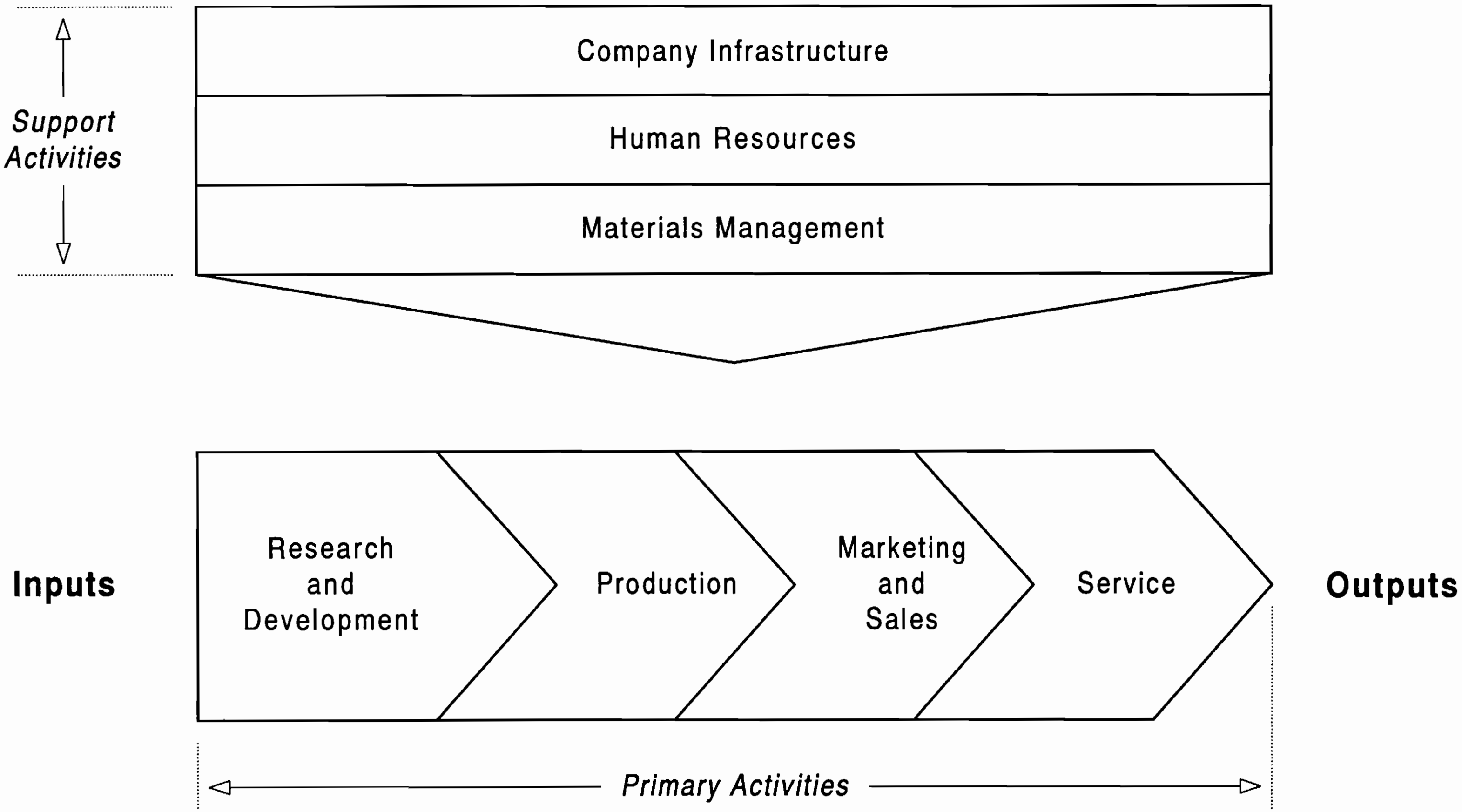


Figure 11
The Value Chain

components rather than simply assessing the overall performance of the firm *vis-a-vis* its competitors.

In the realm of computers, Strassmann has succinctly and cynically defined the value of a computer as being "worth only what it can fetch at an auction"[119] (page 519). In actual business practice, however, a good or service need not be auctioned to earn a place on the firm's balance sheet as a valued asset. The value of an information system may be viewed as the amount that an organization would be prepared to pay for the system, but the system's value to the firm reflects not so much the purchase price but rather the amount which the organization believes it earns from the use of the system.[120] Consistent with Porter's view of the value of an organization reflecting what people are willing to pay for its goods and services, information systems create value by enhancing the value of those same goods and services.[13] Several specific mechanisms by which value is enhanced by IT have been identified by Band:[121]

- Streamlining the business
- Responding rapidly to changing market conditions
- Responding more rapidly to customer requests
- Using resources more flexibly and economically
- Innovating more quickly
- Expanding breadth of product line
- Improving product quality
- Expanding the geographic scope of its customer base.

Grochow identifies similar value-enhancing mechanisms:[122]

- New products

- New services
- Decreased costs
- Improved customer service
- Increased revenue via employee empowerment
- Increased competitive flexibility.

Grochow also observes that negative as well as positive value may be generated by IT; on balance, a positive effect is necessary for IT to benefit the firm. Scott discusses from a business perspective those drivers which give rise to shareholder value.[20] He examines value drivers in each of the steps of the firm's value chain, and in the information technology area he identifies four main drivers:

1. IT spending as a fraction of revenue
2. Communications networks
3. Knowledge sharing
4. Value chain integration.

Lastly, Parker identifies six ways in which an organization derives value from IT:[123]

1. Enhanced return on investment (ROI);
2. Strategic match: alignment with strategic corporate goals;
3. Competitive advantage: conferring an advantage in the marketplace relative to the firm's competitors;
4. Management information: the contribution to management's needs for information on core activities (as distinguished from accounting or support activities);
5. Competitive response: corporate risk in *not* undertaking a project; and

6. Strategic IS architecture: compliance with the organization's overall information systems plan.

Distilling these different but related and similar views to their bare essence, the final common pathway to value is via *improved profitability*, a goal achieved through two and only two mechanisms: increased revenue and/or decreased cost (Figure 12). Although from a philosophical point of view it may be argued that value may in fact exist in the absence of improved profitability, from the real-world perspective of the business enterprise profitability remains the ultimate arbiter of success or failure. Value that is revenue-neutral, if it exists, will be of little practical concern to the firm.

Value is a broad and potentially slippery concept. Value is *user sensitive* and reflects perception: something which may hold great value for one person may be of little or no value to another. Value has not typically been a consideration of those designing, implementing or using computers, whether in health care or elsewhere. Value is also *context sensitive*: something which may be of considerable value to an individual in one setting may be valueless to that same individual in another. The setting whose variation alters the value of something may be geographic, temporal or related to ancillary factors which govern the realization of value.

Within the present context of information systems, valuation is such an elusive concept that no dominant method of establishing the value of a computer or computer system has emerged. Different approaches to the valuation of computers exist and will be discussed.

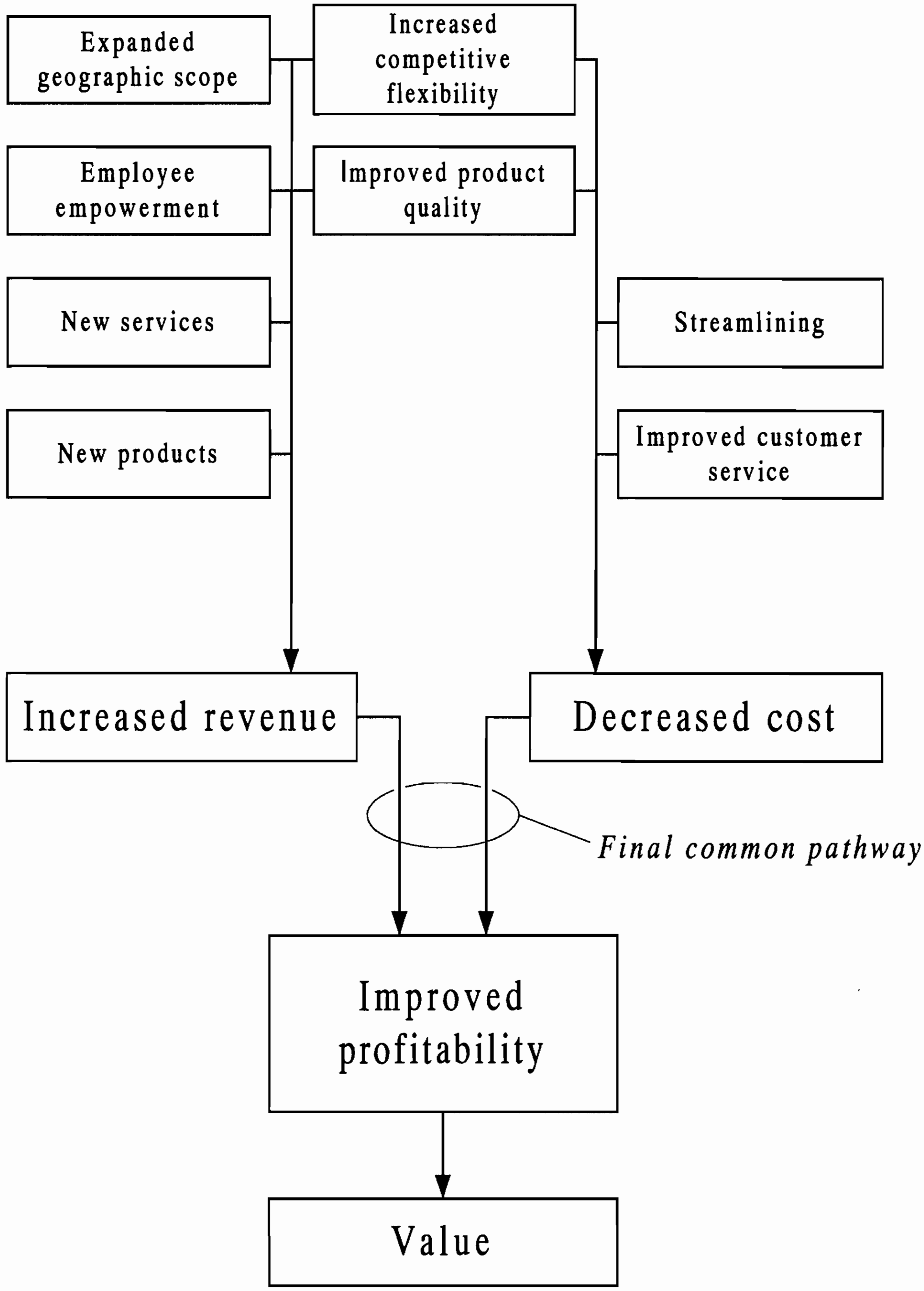


Figure 12
The Information Technology Value Pathway

Impact

An impact is any discernible effect attributable to an information system. Impacts may be favorable or unfavorable, positive or negative.

Cost

Cost is defined as "an amount of money paid or required in payment to acquire something," or as "the total expense incurred to produce a good or service"[115] (page 220). Cost is a more narrow concept that value. Cost refers to the amount paid for something and is usually considered in discrete fiscal terms, such as the number of hours of labor or the number of dollars paid. Variations in cost exist, such as incremental cost, cost reduction, or opportunity cost, but each is grounded on this fundamental concept of a discrete amount invested in something. In the present context of information systems, cost exists in the form of the amount of money paid for the computer hardware and software, in the time and expense to train users, and in the number of hours required to program computer applications.

Benefit

Benefit is a term used to identify any favorable impact. Just as with cost, benefits tend to be thought of in discrete fiscal terms. An IT benefit is an advantage or good produced with the assistance of computers and for which a firm would be prepared to pay.[120] In the present context of information systems, benefit may exist in terms of reduced employee hours to accomplish a given task, a reduced error rate in accomplishing a task, faster results arising from improved communication of information, or the ability to perform tasks not previously possible without an information system.

Worth

Worth is defined as "the inherent value of a commodity, good, service or other economic factor"[115] (page 827). Worth is a broader, less discrete concept than cost or benefit. Worth acknowledges that certain aspects of value exist which may not be readily quantitated by the usual measures of hours of labor or dollars. Despite this measurement difficulty, these certain impacts do unquestionably exist. E-mail is an example of a service with worth comprised of tangible benefits (the savings of postage and paper costs) plus intangible benefits (the immediacy of communication, the promotion of communications which might otherwise not occur or occur under different circumstances via less precise media). In the present context of information systems, worth may be considered to represent the sum of tangible benefits plus other less readily measured benefits.

The Value of Computers

The last 40+ years have witnessed a dramatic transformation with the introduction of computers into every facet of business and commerce. This paradigm shift has come at considerable financial cost. Several facts place the magnitude of computer investment into perspective:

- The 1996 estimated world-wide corporate and governmental spending on information technology was $1,076 billion, of which the United States share was approximately half.[124]
- Information technology now consumes 41 percent of total business spending on capital equipment and represents the largest single capital expense for U.S. companies, exceeded in overall magnitude only by the noncapital expense of labor.[125]
- In the healthcare sector alone, over $13 billion was projected to be invested in information technology in 1998.[126]

Notwithstanding the large amounts of money that have been invested in computers, considerable debate and skepticism remain regarding their actual value. The underlying uncertainty in the *value* of such massive investments transcends different domains and reappears across a diverse range of publications.

Lay Press

When questions about the value of computers appear in the popular journals of the lay press rather than solely in the business or technical literature, the pervasiveness of the issue becomes apparent. *Time Magazine* reviewed this controversy, discussing the recognized difficulty in evaluating systems and measuring improvements.[127] Publications as diverse as *The Atlantic Monthly* and *Scientific American* have similarly addressed questions about computer productivity.[128, 129]

Business Literature

The business literature similarly raises questions about the value of computers.

The productivity paradox. The most well-known critique about the value of computers is termed the productivity paradox. Briefly stated, despite massive investment in information technology over the last 30 years, proof of improved productivity is lacking. Also known as the computer paradox, the facts and statistics leading to this conclusion have been detailed and debated by a number of different authors.[21, 124, 127, 128, 130-132]

Despite the large number of articles demonstrating the productivity paradox, there has been in recent years a flurry of interest in "new evidence" of an IT payoff.[133-135] The impetus for these articles was a widely quoted report by Brynjolffson and Hitt examining the IS spending for 367 large firms. These authors found that gross return on investment (ROI) for computer capital averaged 81 percent, leading them to the conclusion that the productivity paradox had disappeared by 1991.[136] Strassmann disputed this conclusion, noting that the underlying assumptions and approximations as well as the accumulating imprecisions in the calculation methods rendered Brynjolffson and Hitt's interpretation untrustworthy.[124] Strassmann also cited a later report by the same authors using the same data set to arrive at quite different conclusions.[137] In the final analysis, the productivity paradox remains alive and well.

Keyes points out that IT failures more often reflect inefficient technology design than inefficient technology implementation, and that such failures play an important role in the emergence of the productivity paradox.[130] Strassmann takes a global view, noting that considering IT a primary driver for productivity gain exaggerates its potency. He observes that the productivity paradox is an unsurprising outgrowth of economists mistakenly treating IT as a capital asset instead of a tool with potential utility. Strassmann advocates an alternative stance of evaluating what effective management can accomplish with the cooperation of computer-empowered information workers.[124]

Strassmann. Paul Strassmann has written extensively on information management, information worker productivity, and the relationship between information technology and the profitability of firms.[119, 124, 138, 139] His conclusions may be briefly summarized:

- There is no demonstrable relationship between computer spending and corporate profits.
- Conventional analyses that apply revenue ratios or return-on-investment measures are unreliable.
- The effectiveness of information technology is difficult to evaluate because it predominantly supports unmeasurable managerial work.
- There exists no generally accepted method for evaluating computer expenditures.
- IT will remain an indispensable business function, but will increasingly be subjected to tough examinations of its measurable contribution to demonstrate where it produces economic value added.

Other business literature commentary regarding computer value. Silverman comments directly on electronic medical record (EMR) systems, noting their obvious advantages of a complete and up-to-date medical record immediately available to medical caregivers, but at the same time with significant potential drawbacks including prospects for breaches of patient confidentiality via unauthorized access to medical records, the enormous capital investment, and problems with system maintenance.[140]

Even such influential business publications as *The Wall Street Journal* have raised questions about the value of computers, observing that some firms are "de-engineering" after failed attempts to implement costly information technology.[141]

Computer Literature

Although the literature of computer scientists focuses more on the technical issues than on less tangible considerations such as cost, benefit and value, some work on the implications of computerization does exist. Rochlin has written about the large-scale impacts of computerization, describing the process as "autogamous", i.e., "self-pollinating and self-fertilizing, responding more and more to an inner logic of development than to the desires and needs of the user community"[142] (page 15). He notes that tools have repeatedly shaped history in ways totally unanticipated by their inventors. Realization of the benefits of computers has necessitated increased networking which required standardization of machines, processes and procedures to ensure reliability. The net result has been the superficial appearance of empowerment and decentralization against a backdrop of steadily increasing control of user behavior as well as increasing reliance upon systems. User commitment has led to dependence and in turn to demands for compatibility and continuity. Lastly, he notes that the long-term implications of such forces remain ill-defined and renders society vulnerable to significant disruption in the event of a systems breakdown. The impending Year 2000 (Y2K) problem threatens to validate this argument.[26, 143] Rochlin's points are germane to the present consideration of the value of health information systems, illustrating that technology always has not just benefits but also costs, both fiscal and otherwise, which will dramatically impact the ultimate value of a system.

Medical Informatics Literature

As a medical informaticist, Frisse notes that the idea of a computer-based patient record (CPR) is being widely embraced with expectations that greater productivity and clinical efficiency will lead to better patient outcomes at lower cost. He observes that there is no proof that such results will be seen and that considerable risk exists in the design and implementation of such expensive and highly complex systems.[144] Frisse also points out that early work in medical informatics focused on feasibility rather than value.[94] Barnett has observed the sense of frustration among those working with computer-based clinical data management systems who ask why government and industry have spent so many millions of dollars with so little visible payoff. He proposes Ten Commandments to guide the use of computers for such purposes.[145] Stead comments that information is not explicitly valued in the health care domain, at least in part because the connection between information and improved financial outcomes has not been clearly and conclusively demonstrated.[146]

Literature Search Regarding Value

When searching the medical literature, "information systems" represents a discrete concept with its own Medical Subject Heading (MeSH) term. A search on this term in the MEDLINE database (the National Library of Medicine's bibliographic database covering the fields of medicine, nursing, dentistry, veterinary medicine, the health care system, and the preclinical sciences[147]) using either the PubMed or Grateful Med search engines yielded 29,123 citations dating back to 1966. This literature search was narrowed by combining the "information systems" MeSH term in turn with each of 6 other terms relating to valuation: benefit, cost, cost-benefit, cost-effectiveness, value and worth.

A similar search was performed using the HealthSTAR database (another online bibliographic database providing access to the published literature of health services technology, administration, and research; produced cooperatively by the National Library of Medicine and the American Hospital Association; and focusing on the clinical [emphasizing the evaluation of patient outcomes and the effectiveness of procedures, programs, products, services, and processes] and the non-clinical [emphasizing health care administration, economics, planning, and policy] aspects of health care delivery[148]). The HealthSTAR search retrieved 14,526 citations dating back to 1975. A focused search on the 6 terms relating to valuation was also performed as with the MEDLINE search. All HealthSTAR citations were filtered to exclude those also included in MEDLINE. The results of both the MEDLINE and HealthSTAR searches are presented in Table 6. Of the six valuation-related search terms, cost is by far the most commonly associated term with information systems in

Table 6
Literature Search Results Regarding Valuing Health Information Systems
Number of literature citations retrieved[1]

Search engine	PubMed	Grateful Med	Grateful Med
Database	MEDLINE	MEDLINE	HealthSTAR[2]
Citation time frame	1966-1998	1966-1998	1975-1998
Search criteria:			
Information systems (IS)	29,123	29,123	14,526
IS +benefit (% of IS)	408 (1.4%)	673 (2.3%)	761 (5.2%)
IS + cost (% of IS)	2,429 (8.3%)	3,892 (13%)	3,635 (25%)
IS + cost-benefit (% of IS)	256 (0.9%)	368 (1.3%)	570 (3.9%)
IS + cost-effectiveness (% of IS)	288 (1.0%)	414 (1.4%)	178 (1.2%)
IS + value (% of IS)	455 (1.6%)	956 (3.3%)	279 (1.9%)
IS + worth (% of IS)	28 (0.10%)	41 (0.14%)	37 (0.25%)

[1] Accession date January 8, 1999.
[2] Unique HealthSTAR citations excluding those also in MEDLINE.

the published literature, with from 8.3 percent to 25 percent of information systems citations also including a cost consideration. Not surprisingly, the HealthSTAR search showed the highest association of cost with information systems at 25 percent, a finding compatible with this database's particular emphasis upon the administrative and economic literature. The other five valuation-related terms (benefit, cost-benefit, cost-effectiveness, value and worth) were found in association with information systems much less frequently, ranging from 5.2 percent of IS citations (IS + benefit / HealthSTAR) to 0.1 (IS + worth / MEDLINE).

The conclusion to be drawn from these data is that while information systems represent many thousands of published articles in the medical literature, cost is considered in only a minority of these publications. Other value-related considerations such as benefit, cost-benefit, cost-effectiveness, value and worth are very infrequently discussed in the information systems literature. Despite the extensive body of publications dealing with health information systems, considerably less attention has been paid to the benefits which accrue to those health care enterprises investing in these systems and to the value which may be derived from these systems.

Another approach to assess the magnitude of interest in information system costs, benefits and value is to examine citations in the proceedings of the largest medical informatics meeting, the annual symposium of the American Medical Informatics Association, as well as the citations in the Yearbook of Medical Informatics, published by the International Medical Informatics Association (Table 7). The very limited amount of interest in value-related concepts is mirrored by the

Table 7
Medical Informatics Symposia Citations Regarding Valuation

	Proceedings, AMIA Annual Symposium		Yearbook of Medical Informatics	
Year	1997	1998	1997	1998
Reference	149	150	151	152
Articles	357	345	60	55
Publication size	1059 pages	1155 pages	641 pages	534 pages
Index terms....	-	-	-	-
Benefit	-	-	-	-
Cost analysis	-	1	-	-
Cost-benefit analysis	-	1	-	1
Cost control	-	1	1	1
Cost-effectiveness	4	1	-	-
Cost efficiency	-	1	-	-
Cost savings	-	2	-	-
Valuation	-	-	-	-
Value	-	-	-	-
Value of information	1	-	-	-
Worth	-	-	-	-

scarcity of index citations addressing various permutations of cost, benefit, value and worth.

Published Reports Regarding the Value of Information Technology

A number of publications have considered the cost, benefits and value of computers in general:

1. Boddie in 1993 examined the role of information in data processing organizations.[153] He observes that data processing is ultimately not a technical choice, but rather a business choice mandated by the rapidly shifting competitive environment. Given that no universally recognized and easily applied formula exists to determine the value of information, he proposes a multiple-perspective approach incorporating the various costs involved with quality and revenue enhancement. Boddie notes that tying data processing activity to specific projects limits the ability of the enterprise to extract maximum benefit from available information, and he additionally criticizes traditional cost-benefit analyses as political documents created to advocate certain points of view when competition for funds exists. Of the entire range of proposed metrics to evaluate the enterprise's information function, his view is that only two count: data quality and information access.
2. Remenyi, Money and Twite discuss a basic framework for an understanding of the economic issues of information.[120, 154] The authors note that "no comprehensive economics of information has been developed"[154] (page 3). They observe that IT decisions share many characteristics with core business

decisions but involve high risks and large amounts of capital, for which reasons IT investment decisions cannot be seen as materially different from other investments nor may they be safely abdicated to specialists by senior management.

Costs associated with computer systems can be notoriously difficult to accurately measure, as are IT benefits and "dis-benefits" (negative effects). Benefits may be viewed generically as composed of both tangible and intangible components: a tangible benefit directly affects the firm's profitability, while an intangible benefit has a positive effect of the firm's business without necessarily influencing profitability. Benefits may also be categorized as quantifiable or unquantifiable depending upon their ability to be objectively measured. Combining these two concepts, Remenyi et al generate a benefits matrix to illustrate IT benefits and additionally suggest the types of measurement techniques which lend themselves to each of the benefits lying in the four quadrants of this matrix (Figure 13). These authors also discuss a dozen different methodologies available to assess the performance of IT, only a few of which have been commonly employed in the evaluation of health information systems (Table 8). In the aggregate, measuring and managing IT benefits remains a complex and difficult task but also a central business management issue.

3. Van der Zee transformed his Ph.D. dissertation on IT measurement and management into the 1996 book In Search of the Value of Information Technology.[155] He proposes a framework for IT measurement and

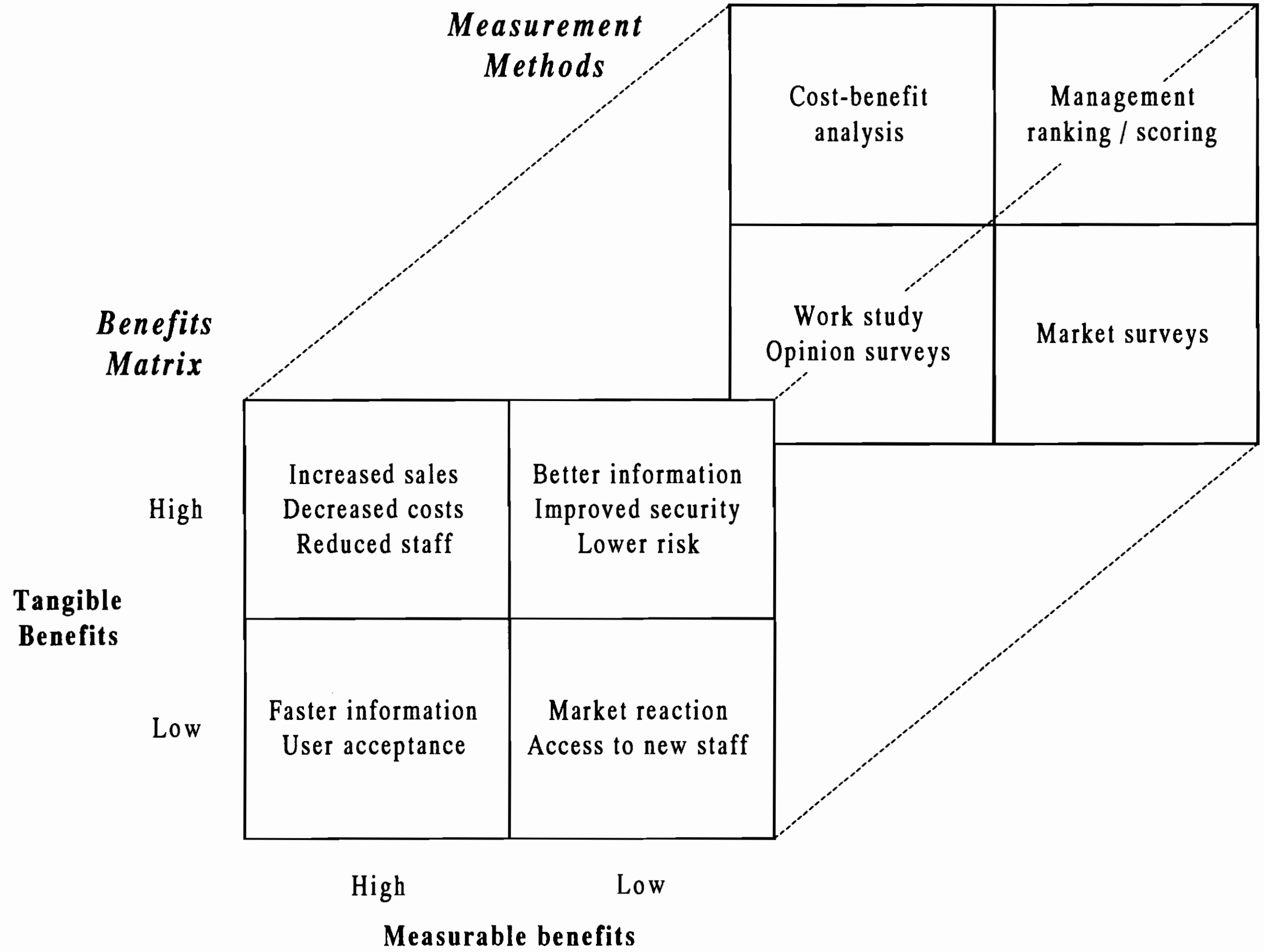


Figure 13
Information Technology Benefits and Measurement Techniques
Adapted from Remenyi.[154] Used with permission.

Table 8
Information Technology Evaluation Methodologies

Methodology	Summary	Strengths	Weaknesses	Health Information System Examples
1. Strategic match analysis and evaluation	Ranking or scoring technique comparing IT systems to generic corporate strategy (typically differentiation or cost reduction)	1. Semi-quantitative 2. Attempt to align IT and corporate strategies	1. Very subjective 2. Issues not well understood 3. All but top management may be unaware of strategy	None
2. Value chain assessment	Ranking or scoring technique comparing IT systems to firm's value added chain	1. Semi-quantitative 2. Attempt to align IT and corporate value chain	1. Very subjective 2. Difficult to obtain hard data 3. Not well understood by management	None

Table 8 continued

Methodology	Summary	Strengths	Weaknesses	Health Information System Examples
3. Relative competitive performance	Ranking or scoring evaluations comparing firm to competitors	1. Semi-quantitative 2. Highlights differentiation form competition	1. Information available may be sketchy 2. Difficult to compare benefits of different systems 3. Uncertainty about competitors' plans	None
4. Proportion of management vision achieved	Ranking or scoring technique comparing results to original plans	1. Semi-quantitative, although less than previous 3 systems 2. Avoids problem of measures misaligned with management's goals	1. No hard data 2. Virtually no objectivity to this assessment approach 3. Difficult for top management to admit failure	None

Table 8 continued

Methodology	Summary	Strengths	Weaknesses	Health Information System Examples
5. Work study assessment	Reviews with quantitation of work volume and time required	1. Potentially objective 2. Focus on relatively tangible task level rather than more global, less tangible levels of strategy and vision	1. Objectivity may be relatively superficial 2. Work pattern changes may radically alter assessment 3. Most managers unfamiliar with these techniques	None
6. Economic assessment: I/O analysis	Requires development of mathematical model embodying inputs and output	1. Formulaic description of system which responds to varying inputs within a given range	1. Requires an understanding of economic analysis 2. Relatively abstract 3. Attempts to avoid quantification of monetary terms 4. Most managers unfamiliar with these techniques	None

Table 8 continued

Methodology	Summary	Strengths	Weaknesses	Health Information System Examples
7. Financial cost benefit analysis	Comparison of costs and benefits	1. Quantitative 2. Understandable 3. Appeals to managers comfortable with traditional accounting methods 4. Long established acceptance in business	1. Subject to manipulation 2. Requires a sound accounting infrastructure lacking in many firms 3. Financial accounting constrained to simple monetary terms, overlooking non-monetary value	156 157
8. User attitudes	Surveys of users	1. Client focus 2. Relatively easily measured	1. Technical approach 2. Few practitioners 3. Low relevance to operating managers	158 159 156 160 161

Table 8 Continued

Methodology	Summary	Strengths	Weaknesses	Health Information System Examples
9. User utility assessment	Counting the amount of activity sustained by the IT system	1. Client focus 2. IT activity readily quantifiable	1. Some user responses may be exaggerated or false 2. Users may have vested interests in presenting a particular viewpoint 3. Corporate culture may color user views and the interpretation of outcome 4. IT activity may or may not equate with achieving corporate vision	158 162 159 156 163 164 160, 165 161

Table 8 Continued

Methodology	Summary	Strengths	Weaknesses	Health Information System Examples
10. Value added analysis	Initial value assessment is followed by cost assessment, prototyping, and reassessment of benefits vs. cost	1. Outcome orientation 2. Feedback mechanism	1. Very practical approach 2. Keeps costs under control 3. Encourages prototyping	None
11. Return on management	Isolates management added value and divides by cost	1. Conceptually appealing 2. Useful to stimulate re-thinking	1. A major break with classical economics 2. Not easy to operationalize	None

Table 8 Continued

Methodology	Summary	Strengths	Weaknesses	Health Information System Examples
12. Multi-objective, multi-criteria methods	Assessment in terms of preferences of decision makers	1. Recognition that no single measurement is sufficient for evaluation 2. Permits multiple metrics 3. Useful to stimulate debate	1. Potentially complex and diffuse 2. No simple readily understandable universal measurement 3. Lack of comparability across systems	158 162 159 163 164 165 160 161

Adapted from Remenyi[154] (pages 87-97). Used with permission..

management which he labeled the "**BTRIPLEE**" framework. This name was derived from measuring the value of IT in its contribution to **B**usiness performance; in its **E**ffectiveness in the support of business processes, activities and users of IT; and in the **E**ffectiveness and **E**fficiency of the supply and development of IT services and products. A systematic and consistent measurement of IT value was judged to be based on two key attributes, an overall management framework and a set of key measures for value. Measurement was approached from the retrospective viewpoint of post-implementation evaluation. Van der Zee adopted the "Balanced Scorecard" approach popularized by Kaplan and Norton,[166] devising a selected panel of quantitative indicators addressing both financial and operational measures. The dozens of individual indicators are too numerous to reproduce here; examples of each type are shown:

A. Business Value	A1. IT costs / revenue (%)
	A2. Annual growth rate of IT costs
	A3. IT cost by individual resource
	A4. IT costs by individual activity
B. IT Effectiveness	B1. Mean time between failures
	B2. Correct data / total data (%)
	B3. Mean response time
	B4. User-friendliness (ratio scale)

C. IT Supply Effectiveness	C1. Overall client satisfaction score
	C2. Average time to respond to requests for new applications
	C3. Number of rings / seconds before support staff answer calls
	C4. Number of newsletters, help desk cards, telephone stickers, etc. distributed yearly
D. IT Supply Efficiency	D1. Employee satisfaction score
	D2. Employee turnover rate
	D3. Average number of project requests in backlog
	D4. Cost per generic unit of work.

4. The underlying theme of van der Zee's work is that everything is measurable in some fashion, a point of view shared by others.[125, 167-169] Hubbard disputes the point of view that IT is too intangible to be quantitated, observing that the misperception of "immeasurability" arises in three ways:

    - The thing being measured is not understood.

      The "Clarification Chain" is proposed as a mechanism to appreciate intangibles and replace them with something more measurable:

      "If something is better, then it is different in some relevant way.
      If it is different in some relevant way, then it is observable.
      If it is observable, then it can be counted.

If it can be counted, then it is measurable."

- The concept or meaning of measurement is not understood.

  Measurement is not an exact calculation, but rather a reduction of uncertainty about a quantity through observation.

- The methods of measurement are not understood.

  Different measurements exist, and the appropriate measurement tool(s) should be selected from the wide variety available.[169]

5. Carlson and McNurlin in 1992 discussed basic principles for measuring IT value, observing that the lack of accepted measurement frameworks has led to difficulties in quantifying the benefits of IT investments.[170] They emphasize the importance of measurement and note the predominance of firm-specific measurement systems with no standardized measurement framework applicable across multiple firms within an industry. They propose a five-part measurement framework similar in many respects to that of van der Zee:

   - The efficiency of IS activities;
   - The effectiveness of IS management in handling new demands;
   - The efficiency of operations;
   - The effectiveness of business units in remaining competitive and gaining market share; and
   - Company-wide quality programs.

Three other measurement frameworks devised by others are also noted.

Published Reports Regarding the Value of Health Information Systems

More specifically, those few published reports which do focus on the cost, benefits and value of health information systems in particular offer useful insights into the interplay of technical, clinical and economic considerations.

1. Historically, the CIS that received the earliest attention was the first comprehensive medical information system implemented for patient care in a community hospital, the Technicon Medical Information System (TMIS) installed at El Camino Hospital in Mountain View, California in 1971.[171, 172] Review of six years of operational data obtained with the TMIS in use at El Camino demonstrated:
   - A 5 percent reduction in nursing costs per patient;
   - A 4.7 percent reduction in length of stay resulting from improved productivity;
   - Increased support services costs but an inconclusive impact on total hospital expenses; and
   - An estimate that 60 percent of the cost of TMIS was offset by productivity gains.

   It was concluded that more reliable information on the cost-effectiveness of hospital information systems should be generated before promoting widespread implementation.
2. The TMIS system was among those considered in Drazen's 1984 report on methods for evaluating costs of automated hospital information systems

(AHIS).[86] In summarizing the 11 articles that comprised the extant literature on cost and cost impacts of AHIS in 1984, she concluded that few rigorous studies had been conducted, most of this work was prospective in nature, and little work had been done to validate predictive methodologies. As a result, there was at that time very little documentation of actual AHIS impacts on the productivity of hospital staff or on overall cost changes. The cost implications of improvements in quality of service delivery needed exploration. Three models were developed for cost analysis:

- Actual savings based on before/after studies,
- Potential savings based on assumptions that all labor savings were realized (using task analysis, job content analysis, work sampling or trend analysis methods), and
- An interhospital comparison model in which the growth of labor costs over time was compared to other similar local hospitals.

Only the third of these models demonstrated savings when evaluating the TMIS at El Camino Hospital.[173]

3. Bradley and Campbell in another 1984 report examined methods for quantifying and comparing service benefits as an important criterion to aid system selection.[174] They proposed three alternative models to create a single composite measure of service benefits:

    - A point scoring approach,
    - A market approach, and
    - A labor equivalent approach.

Quantification of service benefits offered data for assessing the merits of different systems, although the authors appreciated that unquantified factors would always figure into the final selection of an information system.

4. Forsythe and Buchanan in 1991 compared current medical informatics evaluation models to controlled clinical trials incorporating certain tacit assumptions.[175] These assumptions included a technical bias, deletion of the social dimensions leading to a decontextualized evaluation, a quantitative bias leading to the deletion of phenomena not readily quantified, a bias toward formality in evaluation, and an assumption that a single correct answer exists and is findable. They recommend that all systems be evaluated from both technical and nontechnical perspectives.
5. Drazen in 1991 predicted a renewed interest in information system evaluation amidst a climate of reduced reimbursement for capital costs, and observed a misalignment between existing cost and benefit analysis tools and the nature of current systems and the objectives of evaluation.[176] She described a new HIS evaluation approach based on Total Quality Management (TQM) concepts, incorporating benefits realization and reflecting a "bottom line" business orientation.
6. Clayton reported in 1991 Columbia Presbyterian Medical Center's experience with an Integrated Academic Information System (IAIMS).[327] Incorporating clinical, administrative and library applications, the estimated annual amortized cost for IAIMS totaled $2.8 million, or 0.3 percent of the medical

center's annual budget. Benefits were identified without detailed estimation of cost impacts.

7. Nauright and Simpson in 1994 reviewed the benefits of HIS from the perspective of front-line users, namely nurses and other non-nursing general hospital staff.[177] They observed that benefits related to quality of care were realized to a greater extent and were considered more important to front-line users than those related to cost/ savings/ productivity or to professionalism/ recruitment/ retention.
8. Woodward and Boxerman in 1994 noted the potential benefit of executive information systems (EISs) in generating risk-reducing information, a capability which could conceivably justify an otherwise unprofitable EIS.[178]
9. The University of Texas M.D. Anderson Cancer Center in Houston, Texas justified its major investment in a CPR by using a cost-benefit analysis which yielded a positive net present value (NPV) after consideration of estimated annual costs and anticipated quantifiable and unquantifiable benefits projected over 10 years.[157]
10. In 1995 van der Loo et al discussed an approach to classifying evaluative studies of automated information systems in health care.[179] Seventy-six published evaluation studies of automated information systems in health care were examined. Each of these studies was classified according to a matrix which incorporated five axes:
    - Type of automated information system,
    - Study design,

- Data collection methods,
- Effect measure, and
- Type of evaluation.

Certain types of study designs, data collection measures and effect measures were commonly employed, while others such as randomized controlled trials or simulation and modeling were infrequently used. Only 10 of these 76 studies (13.2 percent) evaluated both costs and consequences. The authors found it remarkable that there had been so few attempts to demonstrate the cost-effectiveness of automated information systems.

11. Intermountain Health Care's achievements with its clinical information system as recognized at the First Annual Nicholas E. Davies CPR Recognition Symposium in 1995 are discussed in the subsequent section (page 137).[158]
12. In 1995 the accomplishments of the Veterans Health Administration (VHA) with its Decentralized Hospital Computer Program (DHCP) were honored at the First Annual Nicholas E. Davies CPR Recognition Symposium.[180] A massive distributed health information system with unparalleled scope supporting 171 medical centers, 450 outpatient clinics, 131 nursing homes, and 35 domiciliaries, DHCP offered a broad range of functionality in clinical, fiscal, and medical management applications. As a system in the public domain, its use extended beyond the VHA to other government and private sector institutions both in the United States as well as abroad. Remarkably, no internal studies had been conducted to evaluate the cost impacts of DHCP, nor was any information provided regarding the obviously substantial costs

involved in the design, development and implementation of the system. A subsequent text extolling the system similarly offers no insight into such financial considerations; neither "cost" nor "benefit" is listed as an index entry.[181]

13. Wyatt in 1995 examined hospital information management in Britain's National Health Service (NHS).[182] He noted that among 166 acute hospitals the average expenditure on information systems was 1.8 percent of hospital revenue, although a fivefold variation in such expenditures existed with IS spending ranging up to a maximum of 4.1 percent of revenue. Noting that most money has previously been spent on administrative and financial systems, Wyatt recommended greater emphasis on clinical systems as well as on evaluation using a variety of methods.

14. Lock examined the Ł220 million (approximately $340 million US) annual expenditure by the British National Health Service (NHS) for information technology in its hospitals and noted that previously published evaluation information was scanty.[183] He observed that "the range of outcomes that might arise from computer systems is potentially huge, and as yet no measure of outcome has been universally recognized"[183] (page 1407). His review of the existing literature regarding the value of information technology in NHS hospitals showed a paucity of reports, demonstrating cases from only 12 hospitals, representing about 5 percent of the NHS's IT expenditure for the previous 5 ½ years. Four of these reports were limited to cost data alone. A

need for more research and evaluation of IT in hospitals was noted. In an accompanying editorial, Donaldson noted the irony of the NHS, which has been “constantly exhorted to strive for greater evidence based cost effectiveness,” spending Ł220 million annually largely unsupported by evidence of benefit[184] (page 1371). He noted the parallel irony that the output from such incompletely evaluated IT should serve as the source for data on cost, quality and outcome upon which objective assessments of health services themselves should be based. Donaldson echoed Lock’s call for more rigorous evaluation, particularly postimplementation evaluation studies of hospital information systems. In a replying letter to the editor, Heathfield and Buchan criticized inadequate evaluations based on premature and narrow economic analyses which overlooked important potential benefits.[185]

15. Balas in 1996 reviewed 98 randomized clinical trials addressing the efficacy of clinical information systems.[186] The study examined mainly outpatient rather than hospital information systems, and the impact of such systems was primarily apparent in improving the process of care (e.g., increased vaccination rates, increased cancer screening rates, more frequent blood pressure measurements, etc.). Four generic information interventions proved significantly successful in a family medicine setting:

    - Provider prompt/ reminder;
    - Computer-assisted treatment planner;
    - Interactive patient education/therapy; and

- Patient prompt/ reminder.

Five other interventions failed to demonstrate significant success:

- Provider feedback;
- Computerized medical record and information access;
- Prediction;
- Computer-assisted diagnosis; and
- Patient-computer interactive information gathering.

16. Glaser, Teich and Kuperman described in 1996 the impact of computer-based clinical event processing upon medical care at Brigham and Women's Hospital (BWH) in Boston.[187] The authors noted that medical computing offered opportunities to assist in medical care via several mechanisms including organizing, educating, standardizing, communicating, analyzing, surveying, and synthesizing. Examples of such assistance at BWH had been previously described by Bates, resulting in a 40 percent reduction in inpatient adverse events.[188] The cumulative financial impact of event processing was a cost reduction estimated at between $5 and $10 million annually.
17. The Second Annual Nicholas E. Davies CPR Recognition Symposium in 1996 honored the Brigham Integrated Computing System (BICS) at Brigham and Women's Hospital.[162] BWH placed considerable emphasis on measuring the impacts of BICS, detailing a broad range of 40 impacts with specifics regarding the mechanism of benefit, potential number of events annually, effects, and cost savings. BWH also identified impacts on organizational processes (such as care improvement teams), research, and education, as well

as noting a strategic advantage facilitating the marketing of BWH to the community as the preferred institution for patient referral.

18. The same Second Annual Nicholas E. Davies CPR Recognition Symposium in 1996 also recognized the Group Health Cooperative of Puget Sound for its work with the Clinically Related Information System (CRIS).[159] This report detailed increasing compliance with HIS-based advice rules making recommendations regarding management for 26 specific clinical situations. Cost benefits were not well characterized, although it was noted that CRIS development and installation costs were approximately triple what had been expected. Patient and provider satisfaction were monitored, as was consumer health status; only provider satisfaction improved during the study period. Contributions to research, epidemiology, and access to care were commented upon but not quantitated.

19. The final organization recognized by the Second Annual Nicholas E. Davies CPR Recognition Symposium in 1996 was the Jacobi Medical Center in New York City.[156] Jacobi took a different approach to evaluation than the other Davies award winners. To supplement traditional user surveys, Jacobi retained an outside consulting firm to perform a classic cost-benefit analysis. This study projected a net savings of $7.5 million over the 5-year time frame of the analysis, a return on investment of 49 percent.

20. Manning proposed using technology assessment methodology as a framework for evaluating nursing information systems.[189] Her recommended stepwise

approach included five dimensions: need, safety, efficacy and effectiveness, economic appraisal, and social impact.

21. The Third Annual Nicholas E. Davies CPR Recognition Symposium in 1997 recognized Kaiser Permanente of Ohio for its Medical Automated Record System (MARS), a health information system developed internally and used at 13 ambulatory care locations in and around Cleveland.[163] Impacts of MARS were assessed across a variety of areas. The effects of 30 individual clinical interventions were discussed (e.g., guideline compliance for aspirin use in coronary artery disease increased from 56 percent to 82 percent). Cost impacts were detailed, with the $10 million development cost partially offset by annual net savings of $2.1 million. Multiple other areas of MARS impacts were identified but not quantitated, including quality of care, population health status, epidemiologic research, access to care, and education.
22. Another health system honored in 1997's Third Annual Nicholas E. Davies CPR Recognition Symposium was North Mississippi Health Services, Inc.[164] Developed over 15 years on an Eclipsys TDS-7000 backbone, this HIS provides information services at multiple system facilities across a 22 county area in Mississippi, Alabama, and Tennessee. Impacts were reported in the context of a variety of specific applications similar to those reported for other systems including an adverse drug reaction (ADR) program, drug interaction and drug allergy screening programs, pharmacokinetic consult service, medication history program, automated discharge summary, anticoagulation

consult service, prescription ordering, care guides and resource utilization analysis. Cost impacts were not reported.

23. The third and final system recognized by 1997's Third Annual Nicholas E. Davies CPR Recognition Symposium was the Regenstrief Institute for Health Care.[165] Based in Indianapolis, Indiana, the Regenstrief Medical Record System (RMRS) serves four hospitals, 40 additional outreach facilities, and several institutions outside of the city. It is claimed to be the largest continuously maintained, computer-stored medical record employing coded data. Regenstrief was the first institution to study the computer-based medical record in randomized trials and accounts for a large proportion of published studies examining clinical computer systems. Impact studies have tended to focus on quality of care rather than cost. In a randomized study of tests ordered by physicians, for example, those physicians receiving suggestions from the RMRS complied 51 percent of the time versus 22 percent compliance for physicians not receiving such reminders. Several additional studies have examined optimal methods for such computer reminders and served as the foundation for other clinical information systems using such techniques.

24. McLean advocated using cost-volume-profit and net present value analysis methods together to make well-informed information system investments.[190] Cost-volume-profit (CVP) analysis, also known as breakeven analysis, allows determination of the volume of service at which total revenue equals total cost. Net present value (NPV) analysis compares the discounted value of future cash flows to the initial cash outflow required. These two methods approach the

investment question from different perspectives and are complementary. When used together, the resulting projections incorporate considerations of both the importance of volume as well as the time value of money.

25. The Fourth Annual Nicholas E. Davies symposium in 1998 was renamed the CPR Recognition *Award of Excellence* Symposium. Northwestern Memorial Hospital of Chicago was one of two systems honored for its health information system work.[160] Northwestern's NetReach system involved seven different clinical sites across the institution's distributed facilities in downtown Chicago and has been based on an EpiCare® CPR system. Impacts of the system have been reported in terms of a variety of functional measures such as availability of the patient record (average of 1.3 days to initiate and close a CPR patient encounter versus 5.2 days for a paper record) and influenza vaccination rates (77 percent increase over baseline rate for CPR users versus no change for nonusers). Additional data on other clinical interventions regarding ACE inhibitor therapy in patients with congestive heart failure and use of inhaled steroids in asthma patients is illegible in the symposium publication. Disease management and clinical research were commented upon as impacts without specific detail. A typical user survey reported generally favorable responses with improvement over time. Clinicians asked to estimate the clinical value of a CPR per year placed the "average perceived value" at $10,000; the rigor of such evaluation methodology is unproven.

26. The other CPR recognized by the Fourth Annual Nicholas E. Davies CPR Recognition *Award of Excellence* Symposium was that of Kaiser-Permanente

Northwest (KPNW) in Portland, Oregon.[161] The Kaiser CPR also employed an EpiCare® outpatient CPR system. KPNW noted that the impact of such a CPR system on its organization was multifaceted and pervasive. User surveys were performed with generally favorable results. A number of impacts were identified supporting improved processes of care including documentation, record availability, identification of patient special needs, access to care, efficiencies of care, and quality of care. Cost impacts were examined; the cost of implementing the CPR was $36.5 million, 1.2 percent of the enterprise's budget during the 1994-1997 fiscal years. Several limited examples of reduced costs of care (chest X-rays decreased by 20 percent, upper GI studies by 40 percent) were reported as redundant or unnecessary examinations were prevented by use of the information system to reinforce organizational guidelines. Unquantified IS benefits in research and epidemiology, patient education, and internal education were mentioned.

Valuation Methods

General Considerations Concerning Valuation of Computers

From the paucity of information in the medical literature regarding the valuation of health information systems and from reviewing that information which has appeared on this topic as summarized by the foregoing review of the literature, it is apparent that establishing the value of computers is a nontrivial task for which no clearly valid and generally accepted method has yet emerged. The Davies Award winners in particular demonstrate considerable variability in how impacts were reported (Table 9). There exist several competing schools of thought regarding valuation of health information systems.

Valuation Method 1: Cost-effectiveness Analysis / Cost-benefit Analysis

Cost-effectiveness analysis (CEA) is a method by which the comparative impacts of different expenditures may be assessed.[191-197] Such an analysis employs a *cost-effectiveness ratio* comprised of the cost in dollars to achieve a certain benefit defined in terms of a given unit measure of output:

$$\text{Cost-effectiveness ratio} = \frac{\text{Cost (\$)}}{\text{Output measure}} \qquad [1]$$

Output measures relate to the particular context under consideration. Common outcome measures employed to examine interventions in the health care domain are cases of a particular disease prevented, years of life gained, probability of survival 5 years after cancer treatment, or quality-adjusted life-years (QALYs). CEA has been employed in a number of disciplines including engineering, economics, and medicine. When the various interventions under consideration are all defined in terms of the same outcome measure, CEA allows ranking of the relative costs of different interventions to achieve the same unit of output and helps illustrate the comparative opportunity cost of different choices.[198] CEA represents an attempt to evaluate different interventions against a common yardstick and thereby provide an objective method to decide how scarce resources may be best allocated for maximum impact.

Table 9
Nicholas E. Davies CPR Recognition *Award of Excellence* Honorees
Methods Used to Evaluate Impacts of Health Information System

Symposium	Organization	Evaluation Methods Reported	
		Quantified	Unquantified
First (1995)	Intermountain Health Care	Quality of care: pharmacy alerts, laboratory alerts; blood ordering; antibiotics and infection control; adverse drug events; ARDS protocols. User acceptance. Cost impacts: ADEs, concurrent utilization review; pharmacy.	Quality of care: respiratory care. Population health status. Education.
	Columbia Presbyterian Medical Center	None	None
	Department of Veterans Affairs	None	Quality of care
Second (1996)	Brigham and Women's Hospital	Multiple quality and cost of care impacts reported; publications	Strategic advantage; organizational impacts; educational impacts

Table 9 continued

Symposium	Organization	Evaluation Methods Reported	
		Quantified	Unquantified
Second (1996)	Group Health Cooperative of Puget Sound	Multiple quality of care impacts reported; population health status; patient and provider satisfaction	Research and epidemiology contributions; access to care
	Jacobi Medical Center	User satisfaction survey; formal cost-benefit analysis; multiple examples of cost savings and cost avoidance	None
Third (1997)	Kaiser Permanente of Ohio	Multiple clinical reminders; outcomes; cost impacts	Quality of care; patient tracking; accreditation; management tool; health services research; evaluation of care; data availability; data collection
	North Mississippi Health Services, Inc.	Adverse drug reaction monitoring; drug and allergy interaction screening; anticoagulation consults; prescription generation	Automated discharge summary; care guides; resource utilization analysis; accreditation

Table 9 continued

Symposium	Organization	Evaluation Methods Reported	
		Quantified	Unquantified
Third (1997)	Regenstrief Institute for Health Care	Quality of care as demonstrated by physician decision support	None
Fourth (1998)	Northwestern Memorial Hospital	Availability of patient record; patient record completeness; continuous quality improvement; disease management; facilitation of clinical research; user satisfaction	None
	Kaiser-Permanente Northwest	User survey; documentation; record availability; access to care; population health status; cost impacts	Efficiencies of care; quality of care; research and epidemiology; patient education; provider education

Although a potentially powerful technique, CEA is complex and not without its pitfalls. Problems with cost-effectiveness analysis include:[195, 198, 199]

- Difficulties assigning financial costs to individual interventions;
- Difficulties defining a common unit of outcome measurement;
- Difficulties in estimating the amount of a given outcome resulting from an intervention;
- The need to discount future costs to present value and the choice of an appropriate discount rate;
- How to value intangible costs such as time;
- In health care, conflicts emerge between the differing perspectives of the population versus the individual practitioner;
- Inability of the CEA ratio to incorporate other less-tangible considerations such as urgency, medical necessity, experimental therapy, the standard of care, and distributive justice; and
- The inevitability that comparing different interventions against a common standard produces winners and losers.

A fixed set of CEA methodological standards that would help eliminate many of these problems does not yet exist.

Cost-benefit analysis (CBA) is closely related to cost-effectiveness analysis, but differs in one important respect: both the costs and the measure of output are in units of dollars.[195, 199] With a stronger connection to welfare economics, CBA requires that the outcome be measured in terms of dollars rather than in the form of a nonmonetary effectiveness measure as with the CEA. The ratio that results is unitless:

$$\text{Cost - benefit ratio} = \frac{\text{Cost (\$)}}{\text{Output measure (\$)}} \qquad [2]$$

In the health care domain where outcomes are typically in lives saved, probability of survival, or QALYs, CBA mandates assigning a specific dollar value to outcomes such as a person's life or a disability, a concept that offends the sensibilities of many. Although a weakness of the CBA method, assigning dollar values is potentially a strength in that it allows comparison of disparate outcomes which could not otherwise be cast into the similar non-dollar units required for a cost-effectiveness analysis.

The cost-benefit analyses of complex computer-based information systems are particularly sensitive to the definitions employed for "cost" and "benefit."[36] A simplified view of the problem would consider development, capital and operating costs of the system versus the direct savings in labor and other costs realized by the system over its projected lifetime. In reality, a number of items prove difficult to evaluate, such as the uncompensated time and effort of medical and hospital staffs during system planning and implementation. Meaningful measures of benefits are also difficult as replaced human labor typically contributes to unappreciated functions beyond those provided by the installed computer system. Other aspects of benefit such as reduced communication error rates, increased retrievability of data, improved readability of laboratory and other reports, avoidance of medication misadministration, and simple convenience are particularly intangible and difficult to quantitate. Indirect measures such as overall costs must be used, coupled with higher-level outcome measurements. The ultimate test may prove to be system success or failure and survival in the marketplace.

Cost-effectiveness and cost benefit analyses have been little used to evaluate information systems in the health care domain. Glandon and Buck have noted three primary reasons for this deficiency:[200]

1. Much information technology has been developed for its own sake during the era of cost-based reimbursement before serious financial consequences of such decisions emerged.
2. Institutions developing HISs typically faced financial constraints on the cost of the evaluation itself. The HIS was appreciated by administrators as a complex, interdependent technology whose costs and benefits spanned a wide range, defying effective evaluation at an acceptable cost.
3. Post-implementation evaluations found little support since the expenditure had already been incurred and there was no enthusiasm for undoing such a commitment after the fact even in the face of an adverse evaluation.

The above disincentives for HIS evaluation apply not just to CEA or CBA alone, but to any evaluation methodology. To these three should be added an additional explanation for the unpopularity of HIS evaluation:

4. The extremely rapid pace of change of both technology in general[201, 202] as well as of the health care industry in particular[203-206] have combined to create a sense of urgency among health care enterprises. The result has been overwhelming pressure to quickly adopt information technology

which is itself increasingly viewed as an essential tool to effectively compete in this fluid marketplace. Few organizations feel they have the time, money or expertise for the luxury of an evaluation of new information technology beforehand. The technological imperative possesses an inertia of its own, as few health care enterprises can calmly defer the adoption of IT when surrounded by competitors investing heavily in the new technology. The picture is complicated by what is colloquially referred to as “the FUD factor,” an acronym standing for Fear, Uncertainty and Doubt. FUD is a marketing technique common in the computer industry employed to retain market share by casting aspersions against competitors’ products.[207, 208] Coupled with the overriding sense of urgency, FUD has frequently been a contributing factor to hasty and imprudent technological decision making.

As the financial climate of the health care industry has been and continues to be fundamentally altered by the shift from cost-based to prospective reimbursement, the first of these four explanations is being transformed from current rationale into an historical observation. No health care enterprise today can make the substantial investment required for information technology without seriously considering the cost implications. The second explanation is not only still valid but also is becoming increasingly important as the scope and complexity of health information systems expand beyond simple clerical functions to embrace a broad range of processes within the modern health care enterprise. The third explanation remains as a powerful disincentive to evaluation of HIS technology, especially in the competitive climate characterized by the fourth explanation.

Those few studies evaluating health information systems with CEA or CBA have been reviewed by Glandon and Shapiro.[209] Eight of the ten cited reports that adhered to the CEA/CBA format found benefits to outweigh costs. A fundamental problem limiting the usefulness of such evaluation approaches is the broad range of scope, functionality, and configuration of these systems. No two systems are alike, making comparisons difficult. Glandon and Buck have attempted to address this difficulty by emphasizing commonalities among systems with categorization of systems into three types: operational systems, administrative systems, and strategic systems.[200] Additional problems identified with CEA/CBA methodology included questions of objectivity, narrow single-institution perspective, and outdated information regarding systems no longer up-to-date by current technological standards.

Valuation Method 2: Return on Investment

"Return on investment" (ROI) is a commonly employed phrase in the business literature discussing information systems.[125, 126, 210-212] Briefly stated, the underlying concept is that an enterprise investing \$X in an asset such an information system should generate a return on this investment of \$Y that may be expressed as a ratio and thus a percentage of return:

$$\text{Return on investment} = \frac{\text{Return (\$)}}{\text{Investment (\$)}} = \frac{Y}{X} \cdot 100 = \text{ROI (\%)} \qquad [3]$$

This simple definition stems from the relatively straightforward and explicit world of accounting, where complex concepts are routinely reduced to basic arithmetic methods; ROI employs a capital investment framework with which managers are familiar. Such a well ordered accounting frame of reference contrasts with that defining the complex health care domain. Convoluted economic relationships resulting from including multiple parallel systems for health care delivery, incompatible missions across for-profit and not-for-profit institutions, employer-provided health insurance existing side-by-side with 43 million uninsured (16.1 percent of the United States population), and the third party reimbursement system shape the health care domain.[213, 214]

Well suited to the assessment of the purchase of a new machine tool, the development of a novel product line, or the investment in a new factory, the ROI approach is not as readily applied to evaluating the impact of complex systems technology such as health information systems. ROI analysis is appropriate when considering relatively discrete investments whose costs as well as impacts are readily identified and measured in dollars. In this sense, ROI is similar to but an inverse of cost-benefit analysis, having relocated cost from the numerator to the denominator of the ratio. As with cost-benefit analysis, the broad range of HIS impacts is in many cases not easily quantitated in terms of dollars, limiting the utility of the ROI ratio. It has additionally been noted that a reliance on ROI tends to favor cost-cutting rather than revenue-generating projects because of the greater uncertainty involved with the latter, notwithstanding the greater profit leverage of those projects able to increase revenue.[125]

Valuation Method 3: Information Economics

"Information Economics" is a term popularized by Parker and her associates to refer to an overall framework for evaluating information systems technology.[123, 215, 216] Recognizing the inherent shortcomings in the traditional return on investment capital budgeting model, and additionally appreciating that the value of IT comes not from its mere existence but rather from its impacts on organizational processes, they proposed an extension of cost-benefit analysis to incorporate previously overlooked dimensions of information systems. Stated simply, the thrust of Information Economics (IE) is to augment established financial justification methodology by adding multiple factors quantitating the intangible costs and benefits of IT.

Starting with a foundation of traditional cost-benefit analysis, IE add four aspects to more completely define IT applications to a return on investment analysis:

- *Value linking*: techniques to assess costs and enable benefits realized by other departments within the organization;
- *Value acceleration*: causing benefits to be received more quickly, producing a measurable acceleration of cash flow;
- *Value restructuring*: estimating the effects or modifying an existing job function; and
- *Innovation valuation*: evaluating and choosing among new, untried alternatives.

The end result of this process is a summation:

Traditional cost-benefit

+ Value linking

+ Value acceleration

+ Value restructuring

+ Innovation valuation

= Input to simple ROI calculation. [4]

[123] (page 235)

The output from this equation is then input into an enhanced return on investment calculation (incorporating assessments of factors in the business and technology domains that are not included in the cost-benefit factors) to arrive at an overall estimate of the value of the IT project:

Simple ROI (i.e., benefits)

+ Business domain assessment

+ Technology domain assessment

= VALUE [5]

[123] (page 236)

Parker and associates observe that information technology has a fundamental impact on the firm through the changes IT produces in competitive strength and capability: without change, there can be no benefit.[123] Information Economics is an attempt to quantitate this change.[210]

Valuation Method 4: Measurement Systems

The fourth valuation approach is based on the truism that "you manage what you measure."[217, 218] Only by measuring are we able to make valid comparisons and confirm that IT is impacting the enterprise in the way intended. Potential IT impacts include:[122]

- Making systems easier to use
- Making systems more rapidly responsive to changing business situations
- Providing new mechanisms for communicating with customers
- Aiding the introduction of new products and services
- Providing new channels for delivering services to customers.

In any consideration of value, the first issue to be assessed is size. Size serves as a normalizing factor to prevent the misconception that one information system is more valuable than another when in fact they may be completely noncomparable. Some idea about system size is necessary to make comparisons between systems on the bases of productivity, operational efficiency, and value to the organization.

Once size has been dealt with to establish a baseline, the question about what should be measured to assess IT operations and how should the measurements be performed. A useful approach is measure value with several different instruments from several points of view. This measurement strategy has been popularized in the business literature by Kaplan and Norton as the "Balanced Scorecard."[166] These authors advocated studying organizational performance utilizing four perspectives:

1. Customer

2. Internal
3. Innovation, and
4. Learning.

Within each of these dimensions, specific measures are developed and reviewed regularly by management. Grochow advocates adopting a modification of the balanced scorecard for IT enterprises by employing four IT-specific perspectives:[122]

1. End-users: Value stems from enabling users to perform their jobs more efficiently and effectively.
2. Development process: Value stems from system functionality.
3. Organizational goals: Value grows out of IT systems' furthering of the organization's goals, both general and specific.
4. Financial: Value is mirrored by increased profitability via increased revenue, decreased cost, or both.

The individual measures devised for each of these four perspectives are basically productivity and quality measures.

Other authors have advocated measurement systems to assess the impact of IT in general[120, 154, 155, 170, 219] or HIS in particular[220].

<u>Valuation Method 5: The Strassmann Approach</u>

The extensive writings of Paul Strassmann relating to the value of computers in the business domain have been briefly summarized (*vide supra*).[119, 124, 138, 139] Supported by a remarkable corpus of analytical data, Strassmann's consistent theme is that simply spending money on information technology will not *per se* confer value upon the organization. It is rather through the intelligent application of IT to reconceptualize, reengineer and improve business processes that the potential for IT value is realized. In this sense, Strassmann's point of view parallels that of Parker and her associates with the Information Economics model.

From the perspective of methods to value health information systems, Strassmann does not propose an explicit formulaic methodology. He instead makes a large number of concrete recommendations (152 in The Squandered Computer alone[124]) which in the aggregate form a practical foundation for IT conceptualization, implementation, and evaluation. The underlying premise behind his recommendations is to eschew biased, incomplete, unverifiable, and anecdotal information as justification for the major expenditures required for information technology. Similar to the proponents of the Measurement Systems school of valuation, Strassmann strongly advocates making decisions on the basis of the best objective data available: "Install comprehensive metrics that not only concentrate on technological efficiency but also convey convincing evidence of managerial effectiveness"[124] (page 391).

Arguably, Strassmann could in the interest of simplicity be considered either a subtype within the Information Economics school of valuation or a disciple of the Measurement Systems school. Given the sheer bulk of his work and its prominence in the domain of information technology valuation, a separate category for "The Strassmann Approach" is the more appropriate categorization.

Valuation Method 6: The Japanese Approach

As a counterpoint to the schools of thought mandating explicit justification of IT, Bensaou and Earl offer a contrasting view framed from the viewpoint of the Japanese manager.[221] They observe that the IT management traditions that have evolved in Western businesses over the last 40 years are flawed in their demands for specialized, technocratic management. The Japanese view of IT contrasts with the Western approach in several respects:

- Japanese business, which invests half as much in IT as Western companies, rarely subscribes to the "technology for technology's sake" approach common in the United States.
- The Japanese business is much more likely to let the basic way it competes and its operational goals drive IT investments ("strategic instinct") rather than developing an IT strategy that aligns with business strategy ("strategic alignment").
- Japanese firms gauge their IT investments on the basis of operational performance improvements instead of relying on the financial metrics of traditional capital budgeting processes.
- The Japanese emphasis is on appropriate technology, selecting the right technology to meet a specific performance goal and to support the people doing the work. Neither technology *per se* nor the newest, fastest technology are assumed to be better.

- Lastly, the Japanese cultural emphasis on themes such as consensus, teambuilding, continuous improvement, job rotation and shared decisionmaking shapes the role of IT in Japanese business.

Other authors confirm the unique Japanese mindset. Yoshimura points out the relatively greater reliance placed on qualitative analysis by Japanese managers. Decisions are often made on the basis of "what seems to be the right thing to do", relying upon "faith that competitive advantage stems from making one's choices work, not in making the right choices."[222] This difference is particularly evident in projections where the Japanese demonstrate a distrust of detailed quantitative forecasts as contrasted with a strong emphasis on detailed quantitative information as an indicator of past performance. The Japanese *sarariiman* [salaryman] exhibits a distrust of financial projections, holding the view that given the right assumptions, one can manipulate financial projections to arrive at any desired outcome. Such a perspective is not uniquely Japanese, but the Japanese manager's hesitancy to embrace financial projections is much less common in Western businesses. Contrasting with Western (and particularly American) goal-orientation, Japanese businessmen place greater emphasis on attitude and doing business the right way than upon simply achieving objectives; correct process is more important than results. Other authors examining Japanese business in general[223-225] and IT in particular[226] confirm the significantly different perspective of the Japanese firm relative to its Western counterpart.

From the standpoint of valuing information systems, this unique Japanese perspective translates into an avoidance of the rigid Western cost justification strategies such as cost effectiveness analysis or cost benefit analysis in favor of qualitative prospective justification of IT augmented by a retrospective emphasis upon outcomes as assessed by both quantitative and qualitative performance improvement.

Valuation Method 7: Strategic Value

In any consideration of the value, information technology should be appreciated as more than simply computers. IT embraces a far broader concept, extending its domain to encompass the interlinked technologies that process information as well as the information itself which businesses produce and use. Porter has identified three ways that IT is affecting competition:

1. Advances in technology are changing industry structure and altering the rules of competition.
2. IT is an increasingly important lever to create competitive advantage by providing new ways for firms to outperform their rivals.
3. The information revolution is spawning entire new businesses.[13]

These three modes of IT impact upon the firm represent pathways to value creation.[122]

Scott notes that evaluating a firm's information technology strategy entails more than a superficial examination of the level of IT spending relative to revenue. The larger question is how effectively is IT being deployed to increase productivity and to shape the firm's response to the market.[20] Use of the communication capabilities of IT has wide-ranging implications for the operation of the organization. Similarly, IT presents opportunities to integrate the firm's value chain both internally and externally. Answers to questions such as these will better assess how well a firm is utilizing the potential of IT.

The strategic value approach to valuation centers around the crucial position of information within both firms and industries. Evans and Wurster observe that information represents a large portion of the cost structure of many businesses not traditionally considered "information businesses." Within the United States health care industry, the costs related to capturing, storing and processing information account for around $300 million – approximately one third of the total expenditure for health care.[16] They additionally note that information and the mechanisms for manipulating it act to stabilize corporate structures and underlie competitive advantage. In this thrust to employ information as a strategic tool, it is not enough to simply throw technology such as information systems at the problem. The right technology must be employed at the right time and place and in the right fashion to achieve desired results. The three conditions that allow companies to successfully exploit technology have been described by Frohman:

1. Top management possesses a familiarity and fluency in technical issues.
2. Managers employ specific criteria to allocate funds among projects that will support and maintain technological leadership in specific areas.
3. The company's decision making systems and structure reinforce the priority of technical matters by maintaining a strong link between business and technological decision making and by employing systems and structure for technological decision making consistent with the firm's other systems.[227]

The essence of the strategic value approach to valuing information systems is the assertion that IT is of critical and strategic importance to the operations of the firm. As such, the rationale is that IT earns a special position in the organization's cost structure, insulated from the requirements for rigid cost justification as contrasted with the procurement of more routine capital expenditures such as buildings and equipment. The argument often employed is that IT is essential infrastructure, often termed "the cost of doing business", implying that it is unnecessary and impossible to insist on the same cost justification required for other investments.

Overview of Valuation Methods

These different approaches to establishing the value of information systems (and specifically health information systems) occupy different positions across a spectrum. At one end of this spectrum lies the point of view that information systems are no different than any other business assets and must therefore be subjected to a rigid analysis of the return generated from investment to justify the enterprise's investment of capital in such systems; this is the explicit justification end of the scale. At the opposite end of the spectrum lies the contrasting point of view that information systems represent strategically important investments which are a fundamental requirement to compete in the current health care delivery marketplace, and as such they should be exempt from formal cost justification; this is the implicit justification end of the scale. Between these two extremes lie intermediate positions where both implicit and explicit justification coexist in a balance. Within this intermediate zone lie valuation approaches which allow for some areas of IT to be explicitly justified, while others may be held to more implicit standards of justification.

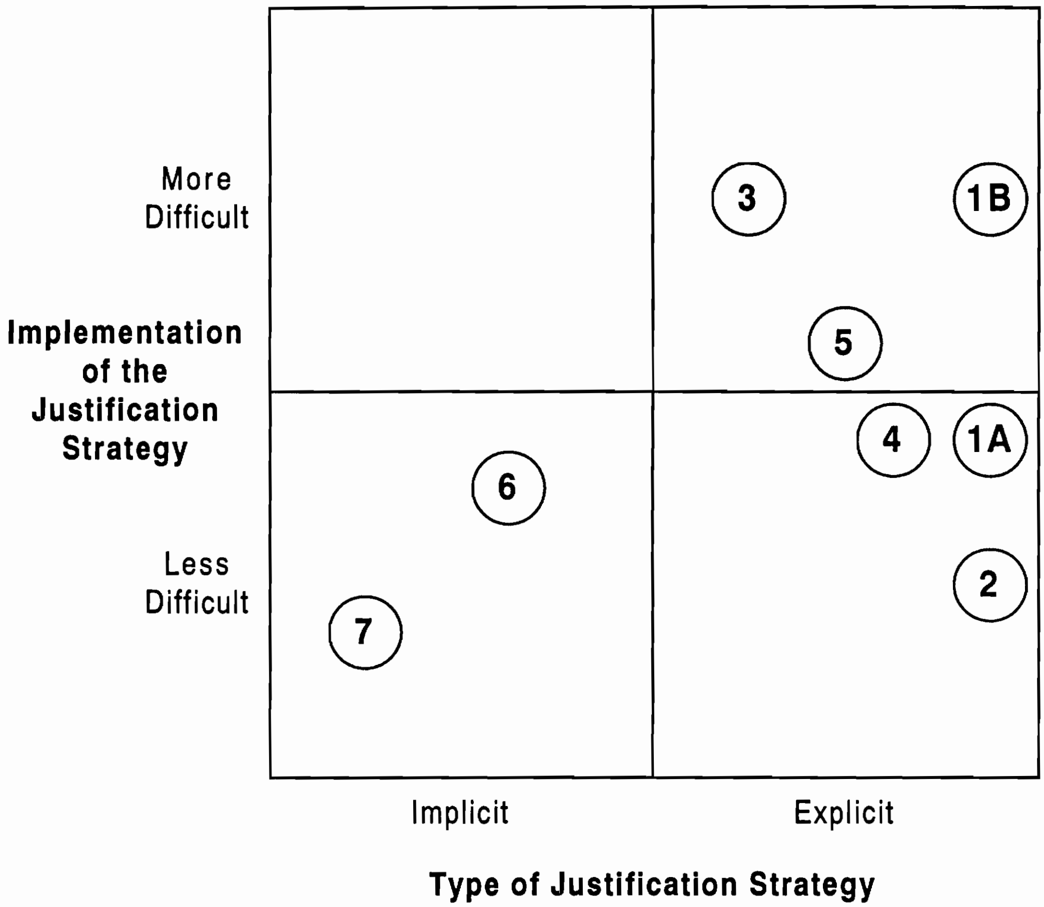
Coexisting with this spectrum of explicit/implicit justification strategies for health information systems are differences in the ease with which these particular strategies may be implemented. None of these approaches is genuinely easy to implement, but some are more difficult than others. Cost-benefit analysis, for example, is judged more difficult to implement than its counterpart cost-effectiveness due to the inherent difficulties involved with assigning specific dollar values to the impacts of health information systems. The strategic value approach, by contrast, demands little formal financial justification and is therefore considered the least difficult of the valuation strategies. The relationships between these competing strategies are represented graphically in the Health Information System Valuation Strategy Matrix in Figure 14.

Survey Results

Two surveys have been published which provide real-world evidence as to which valuation methods are actually employed in operating health care enterprises.

CPRI Survey

The Computer-based Patient Record Institute, a nonprofit organization committed to advancing improvements in health care quality, cost and access through the routine use of information technology[228] in September 1996 undertook a survey to assess current CPR value assessment practices.[87] The study population was



Valuation Strategies:

1. Cost-effectiveness analysis / cost-benefit analysis
   1A. Cost-effectiveness analysis
   1B. Cost-benefit analysis
2. Return on Investment
3. Information Economics
4. Measurement Systems
5. The Strassmann Approach
6. The Japanese Approach
7. Strategic Value Approach

Figure 14
Health Information System Valuation Strategy Matrix

comprised of chief information officers (CIOs) and vice presidents of information systems who were members of the College of Healthcare Information Management Executives (CHIME), a nonprofit professional organization created to serve the professional needs of healthcare Chief Information Officers.[229] A total of 67 responses was received. The important survey findings include:

- The major value expected from CPR systems was improved service (70 percent or respondents), followed by improved outcomes (58 percent) and reduced costs (52 percent) (Figure 15).
- Valuation was assessed across two dimensions: types of assessments and categories of CPR system investments:

Assessments	Prediction of system costs
	Prediction of benefits
	Predictions of improvements in key indicators
	Formal cost-benefit analysis
	No formal assessment
CPR system investments	Strategic systems
	Nonstrategic systems
	Infrastructure products
	System upgrades
	System replacements

- Prospective value assessment practices varied depending upon the type of investment (Figure 16).

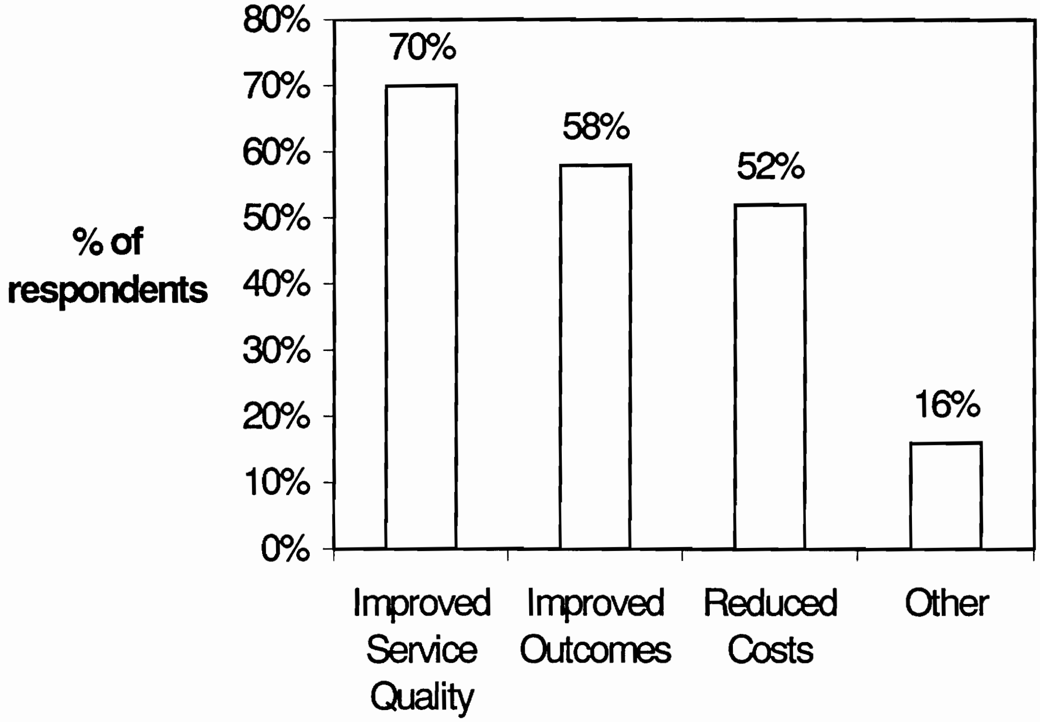


Figure 15
CPRI Survey: Major Value Expected from CPR System

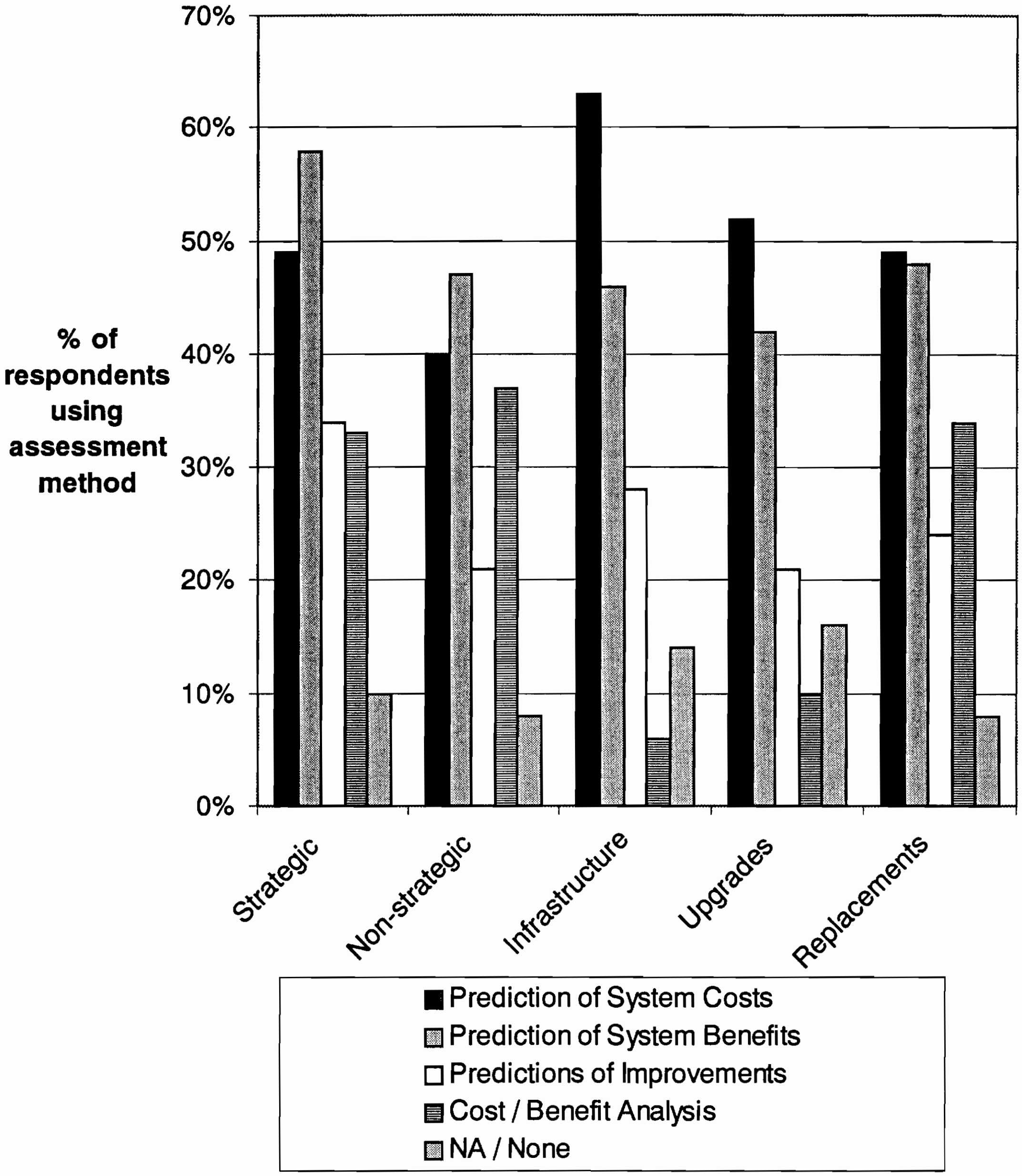


Figure 16
CPRI Survey: Types of Assessments Utilized for CPR Investments

- Cost alone was the most common method of assessing CPR value, used from 63 percent for infrastructure projects to 40 percent of the time for nonstrategic systems.
- Prediction of benefits was also a common method, used from 58 percent strategic systems to 42 percent of the time for system upgrades.
- Formal cost-benefit analysis was used less commonly, from 37 percent for nonstrategic systems to 6 percent of the time for infrastructure projects.
- Prediction of improvements in key performance areas was used from 34 percent to 21 percent of the time, most frequently for strategic systems.
- Significantly, no formal value assessments were made from 13 percent to 6 percent of the time. System upgrades were the least likely category to undergo assessment.

- Information systems department personnel were most often involved in value assessments (87 percent of the time), although users were heavily involved as well (63 percent).
- Management was the major audience for value assessments (93 percent of the time), with boards (33 percent) and clinicians (21 percent) much less frequently involved.
- Postimplementation value assessments were uncommon (25 percent of implementations

- Narrative comments from those polled confirmed the challenge posed by predicting and measuring information system value as well as the desire for a more formal method to make such assessments.

HIMSS Survey

The Healthcare Information and Management Systems Society (HIMSS) has, in association with IBM Global Healthcare Industry, also performed surveys of its membership to assess the opinions of senior executives and managers from healthcare provider organizations regarding the use of information technology.[230, 231] The survey was performed both on-site at the February 1998 HIMSS Annual Conference and Exhibition in Orlando, Florida as well as via the Web. Respondents were 1,754 senior operations and financial managers, IT managers, clinical managers, and other provider organization professionals, IT consultants and IT vendors. Eighty eight percent were HIMSS members; 79 percent represented healthcare provider organizations and 21 percent were IT consultants or vendors.

While the survey's results broadly covered the healthcare informatics domain, a portion of the information obtained relates to the question of valuing information systems.

- "Proving IT quantifiable benefits" was tied for the third most common response by 9 percent of respondents asked "What are the most significant barriers to successfully implementing IT in your organization today?" (Figure 17).

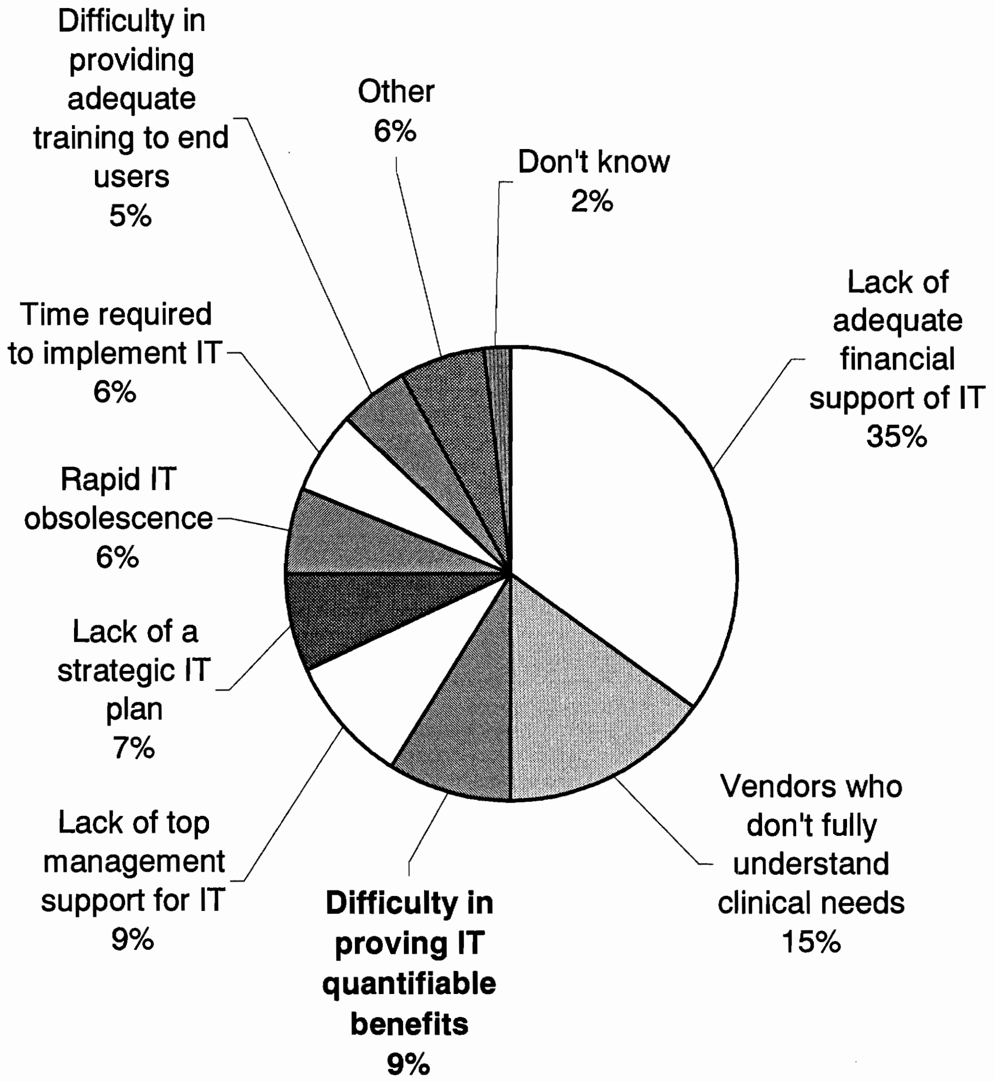


Figure 17
1998 HIMSS Survey Responses:
What Are the Most Significant Barriers to Successfully Implementing Information Technology in Your Organization Today?

- "Deriving more value from data" was the top response by 42 percent of respondents asked "Which …business challenges are driving the increased reliance on information technology in your organization?" (Figure 18).Those who predicted an *increase* in their organization's IT budget cited their ability to prove IT return-on-investment as the second most common reason at 21 percent.
- Those who predicted a *decrease* in their organization's IT budget cited their inability to prove IT return-on-investment as the reason 3 percent of the time (the 5th most frequent response, dwarfed by overall budget decreases which were cited by 72 percent of respondents). "Inability to demonstrate cost-effectiveness" was identified by 9 percent of respondents as 5th on a list of 13 obstacles to full implementation of a CPR system in their organizations.

Thus, the senior healthcare IT executives and managers perceive valuation as a significant issue in organizations intimately involved in the application of information technology to healthcare delivery.

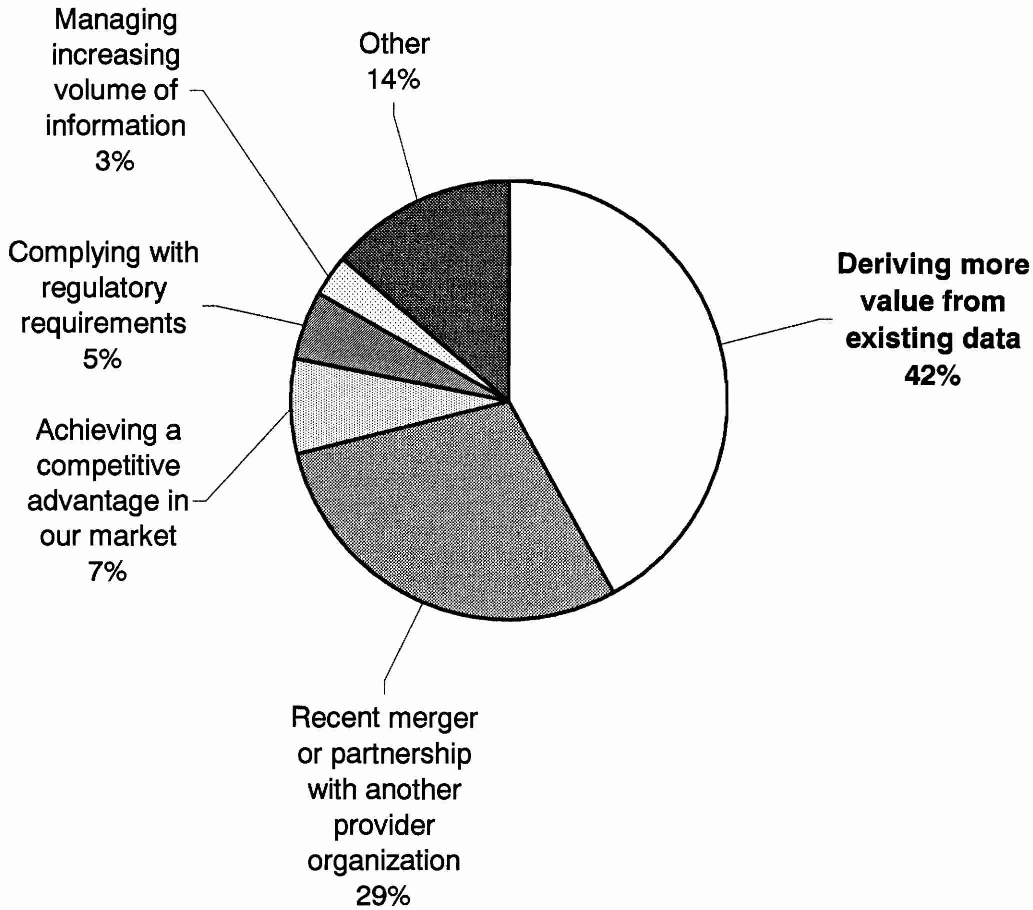


Figure 18
1998 HIMSS Survey:
Which of the Following Business Challenges Are Driving the Increased Reliance on Information Technology in Your Organization?

INTERMOUNTAIN HEALTH CARE

It is our intent to be a model health care system.

Intermountain Health Care Mission Statement[232]

Background

Intermountain Health Care

Intermountain Health Care (IHC) is a not-for-profit full-service health care organization operating in the intermountain west. Based in Salt Lake City, UT, IHC operates a network of hospitals and health centers throughout Utah as well as in Idaho and Wyoming. IHC was the first and, until the advent of the University of Utah Health Network (UUHN) in 1998, the only integrated delivery system (IDS) in the region with its blending of hospitals, physicians, and health plans. IHC is the dominant Health Maintenance Organization (HMO) in its region.

IHC began as a health care system created by The Church of Jesus Christ of Latter-Day Saints. Its flagship LDS Hospital was established in 1905. Primary Children's Hospital was founded as a ward of LDS Hospital in 1911 and transformed into a stand-alone facility in 1922. In 1975 the LDS Church decided to leave the business of providing health care which had proven peripheral to its religious mission and which had become prohibitively expensive. The church donated the 15 hospitals in its system to the communities they served. A charitable, nonprofit, non-denominational organization called Intermountain Health Care was created to operate the 15 hospitals as a system on behalf of the communities. Community leaders were asked to govern the organization as unpaid, volunteer trustees. Over the subsequent years, IHC has grown substantially and expanded the range of its services as well as its geographic extent. Important characteristics of the organization include:

- 24 hospitals (2 in Idaho, 2 in Wyoming, and 20 in Utah) with a total of 2,701 licensed beds and 2,083 staffed beds;
- 24 Health Centers plus another 40 clinics located in 8 Utah counties;
- 14 InstaCare urgent care centers;
- 6 WorkMed occupational health centers;
- Over 20,000 employees;
- Over 400 physicians employed by IHC Physician's Group;
- Over 2,500 affiliated physicians;
- Annual revenue of $2.01 billion in fiscal 1997; and
- Charitable care exceeding $134 million has been provided in over 272,000 cases over the last six years; $26 million in charitable care was provided in 1998 alone.[233, 234]

Financial statements and operating statistics for IHC are tabulated in Appendices A and B.

The organizational structure of Intermountain Health Care is shown in Figure 19. IHC is comprised of three main divisions: IHC Health Services, which includes the

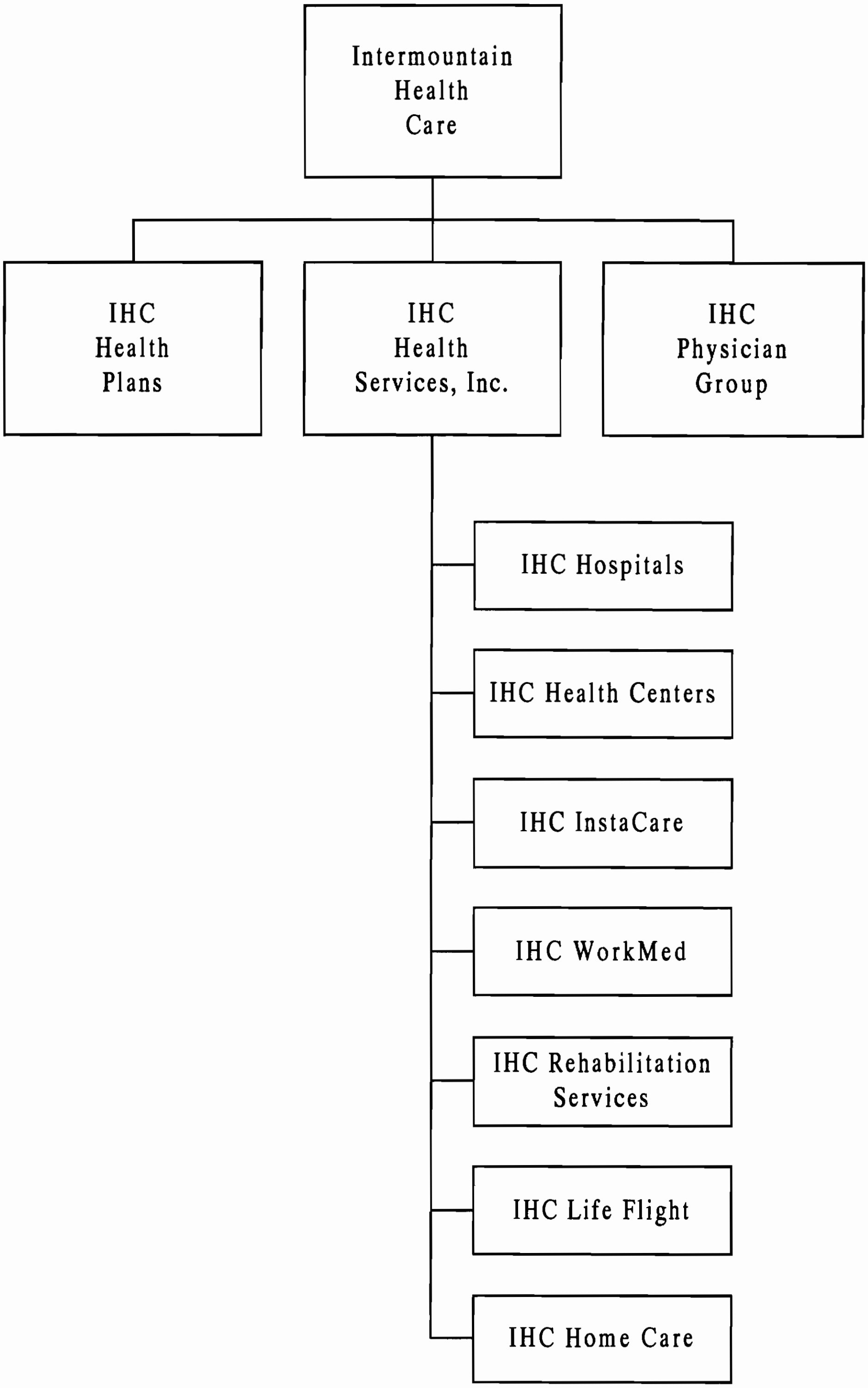


Figure 19
Intermountain Health Care Organizational Diagram

corporation's hospitals and other health care facilities; IHC Physician group, incorporating the employed physicians in the enterprise; and IHC Health Plans, which is concerned with the marketing of various health insurance plans within its market.

Intermountain Health Care's stated mission is "Excellence in the provision of health care services to communities in the Intermountain region." The corporation lists a number of commitments to satisfy this mission:

1. "**Excellent service** to our patients, health plans members, customers, and physicians is our most important consideration. We will provide our services with **integrity**. Our actions will enhance our reputation and reflect the trust placed in us by those we serve.
2. **Our employees are our most important resource.** We will attract exceptional individuals at all levels of the organization and provide fair compensation and opportunities for personal and professional growth. We will recognize and reward employees who achieve excellence in their work.
3. We are committed to **serving diverse needs** of the young and old, the rich and poor, and those living in urban and rural communities.
4. We will reflect the **caring and noble** nature of our mission in all that we do. Our services must be high quality, cost-effective, and accessible, achieving a balance between community needs and available resources.
5. It is our intent to be a **model health care system**. We will strive to be a national leader in nonprofit health care delivery.

6. We will maintain the **financial strength** necessary to fulfill our mission." [235, 326]

The sixth of these statements is especially germane to IHC's use of technology and to the value of information systems to the corporation.

Competitive Context

Intermountain Health Care is positioned in a competitive environment populated with a variety of other health care providers of different capabilities. Any consideration of the importance of technology in general and of health information systems in particular requires that IHC be considered not as a solitary entity in a vacuum but instead as a dynamic entity located amidst a context of competitive forces. It is this interplay of competitive pressures which gives value to technology such as health information systems. In the absence of an environment necessitating that IHC differentiate itself from its competition, technology assumes a diminished importance.

IHC's basic strategy is simply stated: to be the strongest integrated delivery system (IDS) in its region by providing high quality, low cost health care services.[236] It was the first and until recently the only vertically integrated health care system in Utah,[237] incorporating three major components: hospitals, physicians, and health plans (Figure 20). The first two of these are commonplace among those organizations participating in the delivery of health care. What has made IHC unique has been its integration of health plans into its operations to enable it to market a unified health care product.

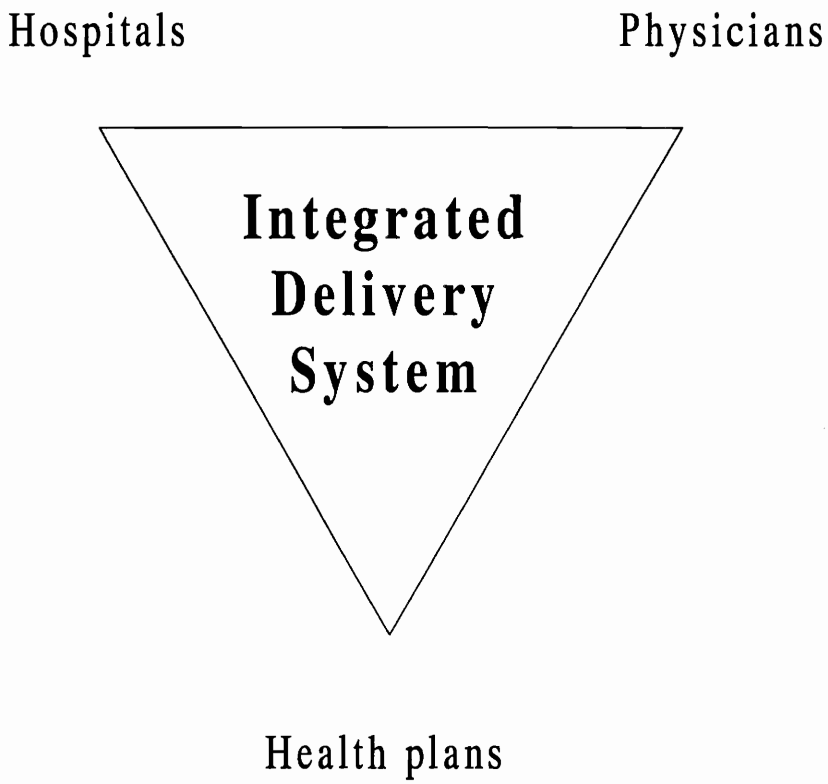


Figure 20
Components of an Integrated Delivery System

IHC entered into the market for health plans in 1983, prior to the advent of managed care and contrary to the conventional wisdom of the era of fee-for-service medicine. In retrospect, IHC's decision to provide health plans has proven visionary. IHC currently offers several distinct health plans which allow balancing premium options with choice of physicians to satisfy different customer needs. The basic health plans are:

1. **SelectMed** is a small panel Health Maintenance Organization (HMO) offering maximum cost savings by working with a select group of over 1,100 primary care physicians and specialists. **SelectMed Plus** is a point-of-service version of this plan, providing the same basic benefits plus the opportunity to use non-SelectMed providers at somewhat higher cost
2. **IHC Direct Care** is a large panel HMO whose members retain direct access to over 2,500 primary care and specialty physicians who are members of the plan's panel. A modified version of this plan, **IHC Direct Care Plus,** offers the same coverage as the basic plan while allowing members to use non-participating providers at a lower level of benefit.
3. **IHC Care** is a large panel gatekeeper HMO with over 2,500 participating physicians. Primary care physicians provide the first level of care and coordinate care with specialists as necessary. As with the other Plus options, **IHC Care Plus** allows members to use nonparticipating providers at a lower level of benefit.
4. **IHC Access** is a Medicaid HMO with a defined group of providers and facilities.[238-240]

This selection of health plan products is not fixed, but has been changed by IHC in response to shifts in the conditions of the marketplace. Two former health plans, **Health Choice** (a point-of-service plan) and **IHC Senior Care** (a plan designed for Medicare beneficiaries) are no longer marketed.[241]

IHC Health Plans now directly cover more than 475,000 enrollees plus another 475,000 through affiliations offered by other insurance plans that use IHC's facilities for delivery of health care services.[242] Utah is a small state with a population of only 1,770,000 in the 1990 census.[243] The majority of the state's population concentrates along the 175-mile stretch of land known as the Wasatch Front, running along the western face of the Wasatch Mountains from Ogden in the north to Provo in the south. The 1990 census identified this area as the 38th largest urban area in the United States, with over 80 percent of Utah's residents.[244] Thus, IHC provides health care services for over half of all Utahns.[236]

By all accounts, it does a good job: IHC Health Plans, Inc. was rated the Salt Lake City HMO with the greatest overall member satisfaction by the National Research Corporation, earning its "1997 Quality Leader Award." IHC also had the highest satisfaction (87 percent) and lowest dissatisfaction (2 percent) figures in a survey of patients of five Utah HMOs conducted by the State of Utah.[245] IHC Health Plans is the first managed care organization in Utah to earn Full Accreditation status from the National Committee for Quality Assurance (NCQA), and received its second three-year Full Accreditation status effective June 1996 through June 1999.[246]

IHC finds itself positioned within a tumultuous health care market,[247] facing a range of competitors in each of the three domains of its operations (Table 10). In the hospital arena, competition breaks down as follows:[248]

- **Columbia/HCA** is the largest hospital company in the United States, operating 500 hospitals and surgery centers nationwide in addition to overseas facilities. The Nashville-based corporation reported sales of $18.9 billion in 1997, but presently is undergoing significant restructuring in the wake of an ongoing multistate Medicare fraud investigation. Formerly poised in an aggressive acquisition mode, Columbia has undergone a fundamental change evidenced by its recent sale of 34 surgery centers as well as 22 Southern hospitals.[249] Columbia's Utah Division operates 9 acute care hospitals and 14 medical clinics; no sales of any of these facilities have been announced.
- **HealthSouth**, the nation's largest provider of rehabilitative health care and outpatient surgical services (1800 facilities in all 50 states), operates a rehabilitation hospital and an outpatient surgical center in the Salt Lake City area. The $3 billion Birmingham, AL-based corporation does not publicize specific figures for its Utah operations.
- **Paracelsus Healthcare Corporation**, a Houston-based firm with $659 million in sales in 1997 operates a total of 31 healthcare facilities in 9 states, including four hospitals in the Salt Lake area. Paracelsus also owns a fifth strategically located hospital in Salt Lake City which has been closed for over 2 years. Paracelsus has announced plans to exit the Utah market by selling all five of its Utah medical facilities for $280 million to IASIS Healthcare, a private

Table 10

Intermountain Health Care Competitors

Hospitals	Physicians	Health Plans
Columbia/HCA	UU FPO	Altius
HealthSouth	Various practitioners in solo and group practice	CIGNA
Paracelsus (IASIS)		HealthWise (BC/BS)
University of Utah		Intergroup (Altius)
Veterans Administration		United
		UUHN

hospital management company based in Nashville, Tennessee.[250] The transaction must be approved by the Federal Trade Commission and is expected to close late in 1999.

- The **University of Utah Health Science Center**, which operates the 358-bed University Hospital, the Neuropsychiatric Institute, and the Schools of Medicine, Pharmacy, Nursing and Health, pursues patient care, educational and research initiatives across a multitude of health disciplines. Total revenues for the Health Sciences Center for the 1997-1998 fiscal year were $612 million, of which slightly less than half ($301 million) came from University Hospital. Excluding research and education figures for a more valid comparison with those competitors participating only in the patient care realm, the University of Utah Health Sciences Center generated $437 million in clinical revenue.[251] The University in 1998 entered the managed care marketplace of integrated delivery systems with the creation of the University of Utah Health Network (UUHN).
- The **Veterans Administration Medical Center** in Salt Lake City is a 351 bed facility providing health care to military veterans throughout the intermountain region. The Veterans Health Administration represents the nation's largest managed care organization, operating 171 medical centers, 340 outpatient clinics and numerous other facilities across the country. The Salt Lake Veterans Administration Medical Center (SLVAMC) is experiencing the same financial problems which have recently confronted VA medical centers nationwide as budgets have been tightly controlled by Congress. Because of

budget constraints, the SLVAMC has curtailed many services and since April 1999 been operating with only 111 active beds. Further budget cuts (projected decrease for the SLVAMC from $110 million for FY 1999 to $100 million for FY 2000) are expected to require additional cuts in active beds to as few as 90.[252]

Physician competition is largely fragmented into a disconnected array of single practitioners and small groups. Unlike the Midwest, few large multispecialty physician groups have been established in Utah. The largest such group in Salt Lake City was the Talbert Medical Group, part of a large multispecialty practice operating in Utah, New Mexico, Arizona, Nevada, and California. The practice had seven medical facilities in the Salt Lake valley, employing a total of 56 physicians as well as a heterogeneous assortment of other nonphysician health care providers. No other Utah medical groups approached the Talbert Clinic's size. The University of Utah in 1998 acquired Talbert for $16 million and created the **University of Utah Health Network** (UUHN).[253] This move was noteworthy in that it signified the University's vertical integration of its health care operations, thereby challenging IHC's status as the only vertically integrated health care enterprise in Utah. The University of Utah's **Faculty Practice Organization (FPO)** occupies an intermediate position between IHC's and Talbert's directly employed physician groups at one extreme and totally independent private practitioners on the other. Composed of over 400 medical faculty members, the FPO is intended to operate as a unified managed care contracting entity. Individual physicians or departments within the University retain billing and compensation autonomy. The magnitude of IHC's penetration of the physician marketplace is noteworthy: with approximately 7000 physicians holding Utah licenses, of whom two-thirds (around 4700) reside in the state, the 400-odd MDs directly employed by IHC's Physician Group represent only about 8.5 percent of Utah physicians. Another 2500 physicians are affiliated with IHC – approximately 53 percent of all in-state Utah physicians (omitting consideration of Wyoming and Idaho physicians as 96 percent of IHC's operations are at its Utah facilities).[254]

Competition on the HMO level within the health plan arena breaks down as follows:[248]

- **Altius Health Plans** is Utah's newest HMO, created in 1998 as the culmination of a cascade of acquisitions of predecessors Pacificare, FHP Health Care, Utah Group Health Plan, and Neighborhood Health Center with origins dating back to 1971.[255] Nationally, PacifiCare had operated the nation's largest Medicare HMO chain and serviced 3.8 million patients in 11 states. Sales for the Santa Ana, California firm in 1997 were reported at $8.99 billion. Facing substantial losses and citing the difficulties of competing against the dominant presence of IHC in the Utah market, PacifiCare in 1997 had announced its intent to sell its Utah HMO operations,[256] and actually sold its HMO operations to Altius in 1998. Altius is presently Utah's third largest HMO with 96,000 members. Altius is not yet in the black, having reported losses of $24 million in 1998, although improved from the results of its immediate precursor Pacificare's losses of $77 million in the previous year.[255]

- **CIGNA**, a Philadelphia-based multiline insurance and financial services company has its major presence in health care. Its CIGNA HealthCare unit has 5.4 million HMO members in 30 states. The firm's medical indemnity insurance covers another 6.6 million people. CIGNA reported annual sales just over $20 billion in 1997, while its Utah operation reported losses of $2 million.
- **HealthWise**, an HMO product of long-established Regence Blue Cross and Blue Shield of Utah, reported a profit of $1.8 million in 1997.[257] Less than 10 percent of Blue Cross's 625,000 Utah members are enrolled in this plan, which reflects only one choice from an extensive portfolio of health insurance options.[257]
- **Intergroup**, a successful Arizona-based HMO, has competed aggressively on price in Utah, offering rates below the cost of providing care in the opinion of its competitors. Its attempts to generate market share have fallen short, and the plan reported losses of $6 million in 1997 in Utah. The smallest of Utah's HMOs, Intergroup recently announced plans to sell its Utah operations to Altius Health Plans, the successor to the former FHP and Pacificare HMOs.[255]
- **United HealthCare Corporation** is the nation's third largest managed care company (Aetna and Kaiser are first and second), owning or operating 25 HMOs plus a number of preferred provider organizations in all 50 states. Based in Minnetonka, MN, it services over 13 million patients and reported sales of $11.6 billion in 1997. Its Utah operation reported losses of $2 million in 1997. United promises to become even larger, having just announced plans to buy Humana for $5.38 billion to create the largest managed care company in

the United States ($27 billion in annual revenue; 55,000 employees; coverage of 10.4 million people).[258]

- The **University of Utah Health Network** was created in 1998 with the $16 million purchase of the Talbert Medical Group from its parent corporation MedPartners and with the $19 million purchase of five Wasatch Front outpatient medical centers from PacifiCare Health Systems.[253]

Against these largely negative health plan experiences, IHC reported the largest profit of any HMO in Utah, $5.5 million in 1997. The firm is criticized by its competitors for employing aggressive tactics to undercut its rivals and gain a larger share of the market. IHC denies tactics such as predatory pricing or hiding financial losses, but acknowledges exclusive contracting policies. An approximate indication of market share may be derived from published enrollments in HMO plans (Table 11). This table demonstrates significant shifts of patients between HMOs within a fluid market which is changing in character as different firms enter and exit but which has remained approximately fixed in overall size over these two years. The increasingly dominant position of IHC within the Utah HMO market is apparent. Another indicator of market share is 1996 hospital discharge data maintained by the State of Utah (Table 12), also demonstrating IHC's commanding position.

With the advent of managed care, more and more health care is being delivered on an outpatient basis (especially so among those organizations more successful in controlling costs), making hospital admission figures an incomplete method of assessing the relative sizes of competing institutions or health plans. Additionally,

Table 11
Utah HMO Market, 1997 and 1998

HMO	1997 Enrollment (%)	1998 Enrollment (%)
Altius	NA	89,800 (11.4%)
CIGNA	31,000 (3.9%)	30,000 (3.8%)
HealthWise	26,500 (3.4%)	73,000 (9.3%)
IHC	400,000 (50.8%)	450,000 (57.0%)
Intergroup	10,300 (1.3%)	6,200 (0.8%)
PacifiCare	200,000 (25.4%)	NA
United	119,000 (15.1%)	140,000 (17.8%)
Totals	786,800 (99.9%)	789,000 (100.1%)

NA = Not applicable

Sources: Wagner and Utah Department of Health[255, 259]

Table 12
Hospital System Market Share by Discharge, 1996

Hospital System	Percentage of Discharges
IHC	52.2%
HCA/HealthTrust	24.9%
University of Utah	8.5%
VA, Psychiatric, Other	5.6%
Salt Lake Regional	3.4%
FHP	2.9%
Local/Government/Community	2.5%
Total	100.0%

Source: Utah Department of Health[259]

these hospital discharge figures are limited to Utah and do not reflect the contributions of IHC's four Idaho and Wyoming facilities which total 198 beds (7.3 percent of IHC's total 2701 licensed beds among its 23 hospitals). By any measure, however, it is apparent that IHC is quite successful in its region despite the presence of competitors many times its size and resources when considered on a national scale. Within its chosen domain of operations, IHC is successfully competing against all comers, to the point that its market dominance causes the firm's employees to be very punctilious about emphasizing the virtues of competition while simultaneously minimizing questions of antitrust or monopoly. IHC's large financial reserves are indicative of its success in the medical marketplace.

LDS Hospital and the HELP System

At 520 beds, LDS Hospital is the flagship tertiary medical center in the IHC system and the largest hospital in the intermountain west between Denver and the West Coast. LDS Hospital is intimately involved in the use of technology to deliver modern health care in areas such as LifeFlight (IHC's emergency/ critical care air transport service), cardiovascular surgery, organ transplantation, and hyperbaric medicine. Information systems have also been an area of core competence for IHC and LDS Hospital.

LDS Hospital was the site of development of the first hospital information system implemented to collect patient data needed for clinical decision-making and at the same time incorporate a medical knowledge base and inference engine to assist the clinician in making decisions.[66, 260] Known as the HELP System (for Health

Evaluation through Logical Processing), the original system was developed at LDS Hospital by a team headed by Homer R. Warner, Reed M. Gardner and T. Allan Pryor.[261] They were assisted in their efforts by additional faculty members and by graduate students from the Department of Biophysics and Bioengineering (now known as the Department of Medical Informatics) at the University of Utah, as well as by programmers, engineers, and practicing physicians. Unlike typical hospital information systems which were designed only to assist in the *business* domain with administrative and financial hospital functions, the HELP system differentiates itself by virtue of its additional functionality in the storage of a wide variety of clinical patient data. This clinical information is employed to assist in a range of hospital functions in the *clinical* domain, including results review, order communication, the preparation of clinical reports, and computer-assisted decision making.

The HELP system did not spring forth *de novo*, designed from the start as an integrated system and complete in all respects. The information system instead evolved incrementally over many years as the net result of sequential building upon prior accomplishments and lessons learned from mistakes. HELP's development may be considered to have taken place in three overlapping phases (Figure 21).

The first phase of information system development dates back to the 1950s. Initial efforts directed at using analog computers to process analog signals in the LDS Hospital Cardiovascular Laboratory in 1956 led to applications using the digital computer to diagnose congenital heart disease. After automating much of the data collection, analysis and reporting for the heart catheterization laboratory, these digital computer functions were extended into the operating rooms (ORs) and the intensive

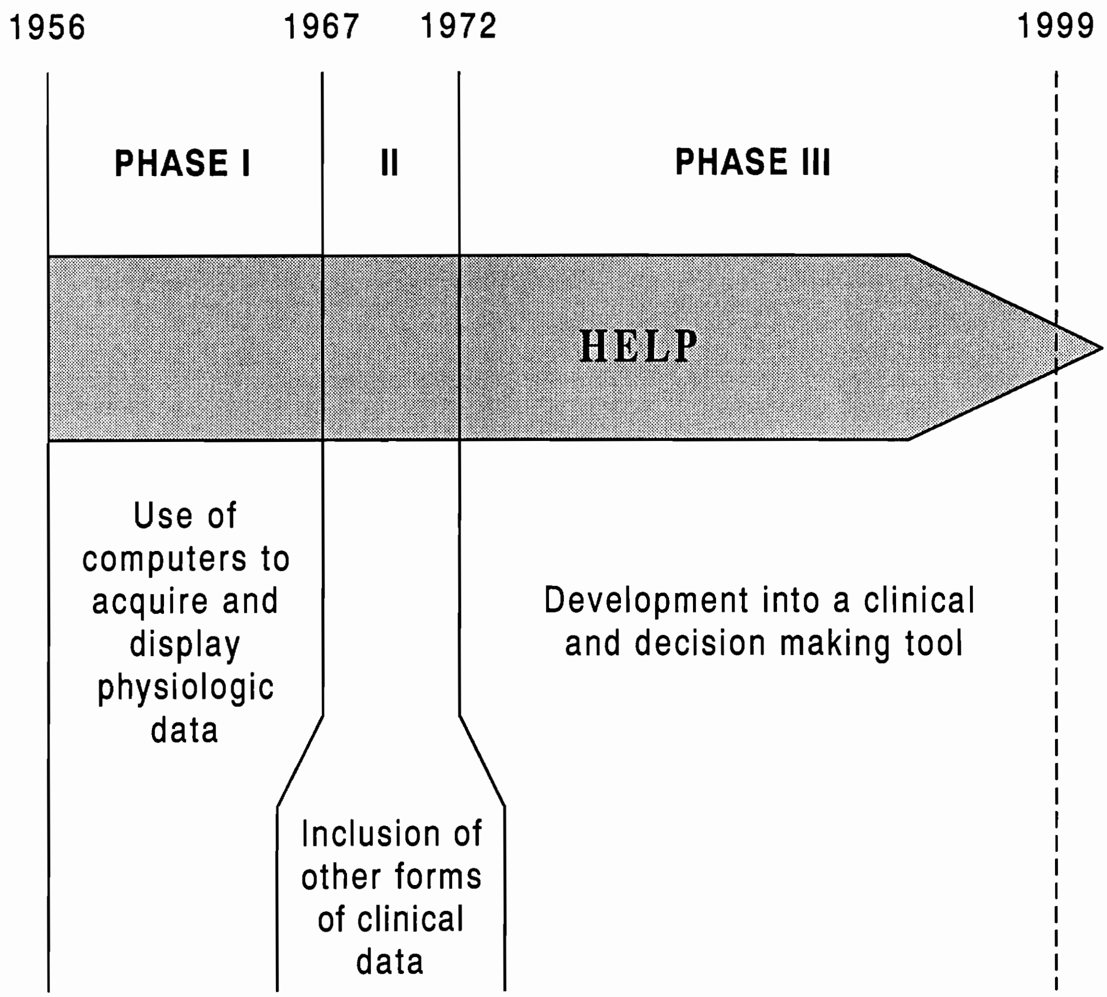


Figure 21
Evolution of the HELP System

care units (ICUs). A variety of physiologic signals were acquired and processed by computer, giving rise to techniques which developed into modern patient monitoring. The second phase of development occurred between 1967 and 1972 when other forms of clinical data beyond physiologic factors and vital signs were incorporated into the clinical database. This additional data included coded medical diagnoses; admission, discharge and transfer (ADT) data; clinical laboratory data; and automated interpretations of electrocardiographic (ECG) data.

As data collection became automated, it became apparent that using this information to assist in medical decision-making would be desirable, thus leading to the third phase, the development of the data-driven clinical decision-making system that became known in 1972 as HELP. The information system was seen to have potential not just to acquire and display data but also to interpret that information to assist in clinical decision making. Initial decision making applications were ECG and blood gas interpretations were followed by others including medication ordering, medication monitoring, and computerized nurse charting. Additional computerized clinical applications including antibiotic selection, blood ordering, ventilator management protocols for ICU patients, and clinical laboratory alerting were developed in the 1980s. The existence of the extensive database of clinical information has allowed the establishment of concurrent real-time quality assurance amidst a pervasive continuous quality improvement (CQI) culture. Over 1200 specific applications have been created for the HELP system, extending its functionality into a wide range of inpatient and outpatient care and allowing the HELP system to become a routine part of the daily operations of LDS Hospital.

The seminal role of grant support in the development of the HELP system is noteworthy. Beginning in 1967 during the second phase of HELP development, the Intermountain Regional Medical Program administered by the Department of Health and Human Services provided grant funds for information system development. Additional grant support was provided to Dr. Homer Warner by the Heart, Lung and Blood Institute (a National Institute of Health program) and to Dr. Reed Gardner by the National Center for Health Services Research (now known as the Agency for Health Care Policy Research).

Just as HELP's functionality has evolved over the years, so too has the system has gone through a similar evolution of its underlying hardware and architecture. By the late 1970s the demands to have the system operating and available on a continuous basis led to the migration of the system from its original dual Control Data Corporation (CDC) computers to a Tandem machine noted for its reliability due to redundant hardware and software. System uptime for 1997 averaged better than 99.85 percent. Pentium PCs networked with asynchronous transfer mode (ATM) or Ethernet networks have replaced the original older and slower terminals, and 1,418 PCs (2.7 terminals/inpatient bed) are now present throughout LDS Hospital as well as at nearly every bedside. Consideration is now being turned to HELP's next platform, a client-server architecture expected to be phased in over approximately the next 5 years. HELP is not the only information system in the IHC armamentarium, but rather it exists in parallel and integrated with a number of other application-specific information systems to comprise a complex network of systems governing the entirety of the IHC information enterprise (Figure 22).

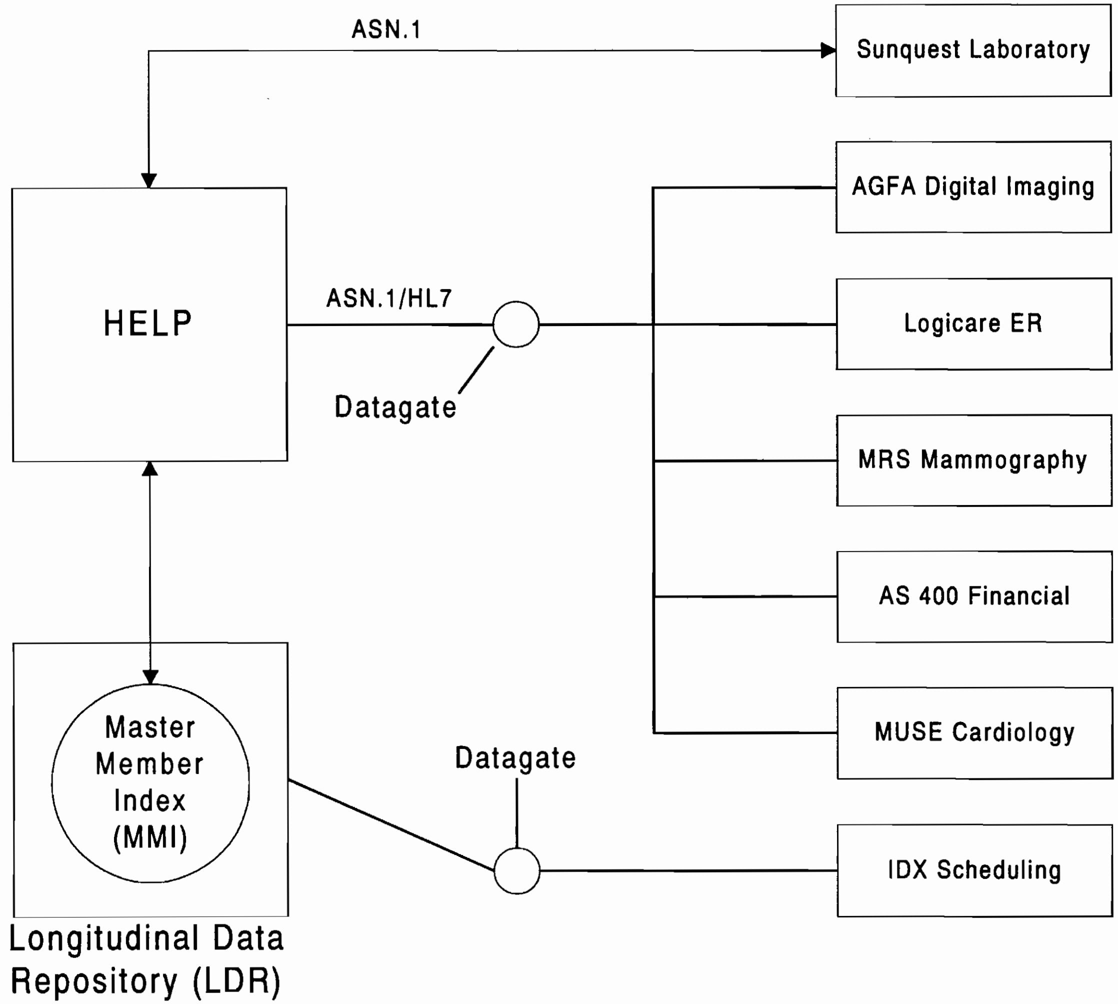


Figure 22: HELP and Related Information Systems

Having demonstrated its utility at LDS Hospital, the HELP system has been implemented at eight other hospitals in IHC's network. Having been installed at different times at different institutions with different cultures, each of these supplemental implementations is in a different state of completeness with only limited HELP functionality thusfar available at several sites as of June 1998 (Table 13).

Notwithstanding the pivotal role played by HELP at LDS Hospital and increasingly at other IHC hospitals, a comprehensive assessment of the value of this information system to IHC has never been made. There exists an implicit general acceptance among IHC employees that the system has been beneficial, although there is also an appreciation that the development and operation of the system comes at a substantial cost and obligates considerable resources. The costs to develop and to operate the system have never been rigorously examined. Benefits have been addressed in a fragmentary fashion in several publications dealing with the impacts of specific applications,[66, 69, 110, 262-264] but the entirety of benefits derived from the system has not been examined. Unmistakable indicators of the substantial penetration of computing into the fabric of IHC's operations are the 12,000 to 13,000 PCs maintained corporate-wide and the approximately 3.5 percent of IHC's total budget (approximately $35 million annually) devoted to information systems.[236] Given this major presence of computers, their value merits closer scrutiny.

Table 13

IHC HELP Site Locations and Implementation (June 1998)

	Hospitals								
	LDS	McKay-Dee	PCMC	CW	UVRMC	American Fork	Alta View	Orem	Dixie
HELP Installed	1/72	11/89	11/91	11/92	8/93	12/93	4/95	2/98	4/98
# Beds	520	380	232	227	395	72	70	20	106
1997 Admissions	20333	12719	9505	10538	17964	4622	4723	1489	8479
Terminals	1418	749	742	423	742	245	140	131	114
Printers	321	151	184	161	117	66	53	20	39
ADT	+	+	+	+	+	+	+	+	+
Medical records	+	+	+	+	+	+	+	+	-
Results review	+	+	+	+	+	+	+	-	-
Order entry	+	+	+	+	+	+	+	-	-
Pharmacy	+	+	+	+	+	+	+	-	-
radiology	+	+	+	+	+	+	+	-	-
Nursing documentat ion	+	+	+/-	+	+	+	-	-	-
Micro-biology	+	+	+	+	+	+	-	-	-
Alerts	+	+	+	+	+	+	-	-	-
Flow sheets	+	+	-	-	-	+	+	+	+
ICU	+	+	+	+	+	-	-	-	-
Nursing protocols	+	+	-	+	+	+	-	-	-
Respiratory care	+	+	+	+	+	-	-	-	-
Surgery scheduling	+	-	-	+	+	-	+	-	-
Infectious disease	+	-	-	+	+	-	-	-	-
Functions	15	13	10	14	14	11	8	4	2

Adapted from Gardner.[260] Used with permission.

Previous IHC Work to Establish HIS Value

Published Reports

Although there are no published reports considering the global value of the HELP system, a number of reports addressing specific aspects of the value of the system have appeared in the scientific literature over the years.

1. Halford et al discussed measuring the impact of bedside terminals used with the HELP system in a 1987 report.[262] Nurses expressed a strong preference for bedside terminals and felt their charting was more accurate. Bedside terminal charting was more timely than other approaches. Patients were accepting of the use of bedside terminals.
2. Kuperman in 1991 discussed Continuous Quality Improvement at LDS Hospital utilizing the HELP system as well as an obstetrical information system for data collection.[265] The results were limited to collecting and displaying individual physician data against a context of benchmarks provided by similar practitioners at LDS Hospital. The clinical and financial outcomes of such comparisons were not presented.
3. Willson in 1994 reported on nurse perceptions of the clinical usefulness of bedside computers providing access to the HELP system.[266] The survey established that nurses valued bedside computers and during the day shift used them 82 percent of the time to record vital signs, 78 percent of the time for input and output recording, and 60 percent of the time to document therapies or treatments. Use of bedside computers declined only slightly during the night shift.

4. Gardner and Lundsgaarde in 1994 reported on user acceptance of the HELP system.[110] Personnel using the HELP system at LDS Hospital were surveyed: 246 of 360 surveyed physicians responded (68 percent) as did 374 of 960 nurses (39 percent). Responses were generally favorable; satisfaction correlated with both duration and frequency of use of the system. Users rated highly access to various forms of patient data and clinical alerts. Common complaints included slow response time, system downtime, need for more functionality, need for more education, and need for more terminals.
5. IHC's accomplishments with its health information system were honored at the First Annual Nicholas E. Davies CPR Recognition Symposium in 1995.[158] Impacts on quality of care, health status of the population served, education, research, and cost were detailed in this report. Three examples of cost impacts were provided:
    - The cost benefits of computerized adverse drug event (ADE) monitoring were substantial. Evans identified 569 ADEs accounting for $1.1 million in costs at LDS Hospital in 1992.[267] Classen employed an automated method to track ADEs, yielding 731 verified episodes over an 18-month period as contrasted with only 9 episodes identified by traditional reporting methods (an 81-fold difference).[268]
    - A computerized concurrent utilization review system offered potential cost savings estimated at $500,000 to $1,000,000 annually

by identifying patients potentially inappropriately hospitalized via automated means using the HELP system rather than through manual chart review.[269]

- The LDS Hospital computerized pharmacy system generated alerts to identify potential medication reactions. A total of 86 alert types generated cost savings of $339,752 vs. a cost of $86,282 for a benefit to cost ratio of 3.94 to 1.[270]

6. Pestotnik detailed the clinical and financial outcomes with infectious diseases applications, HELP-based computerized decision support programs created to assist physicians in the use of antiinfective agents and to improve the quality of care.[264] During a period of increasing frequency of antibiotic use and increasing severity of illness, antibiotic use decreased by 22.8 percent overall and antibiotic costs per treated patient (adjusted for inflation) decreased from $122.66 per patient in 1988 to $51.90 in 1994. The percentage of patients having surgery who received appropriately timed antibiotics[263] increased from 40 percent in 1988 to 99.1 percent in 1994, while the average number of doses of prophylactic antibiotics decreased from 19 to 5.3. Antibiotic–associated adverse drug events decreased by 30 percent. Antibiotic resistance patterns were stable during the period of the study, length of stay was unchanged, and mortality rates for patients treated with antibiotics decreased from 3.65 percent to 2.65 percent ($P<0.001$).

7. Nursing aspects of the HELP system were reviewed by Peck et al in 1997.[271] Nursing-related applications impacting patient care include physician-dictated history and physical examination, vital signs, radiology records, laboratory test results, patient-care plans, pharmacy scheduling and medication charting, order entry, procedures performed, discharge summaries, and other pertinent data. Real-time patient data entry, nursing comments reports, and shift reports make information available to all who are caring for the patient and allow use of a broad range of care protocols. Information is stored as coded data and is employed in a range of different care protocols such as the Antibiotic Assistant as discussed above. The techniques developed at LDS Hospital are being extended to handle communication and standardization of care across all IHC sites. Specific HELP applications in the Quality Resource Management program, the Emergency Department, in the documentation of patient problem/event records, and in the pressure ulcer prevention and treatment protocols are discussed. Although the article refers to pressure ulcers costing IHC $1.5 million annually and documents process improvements in preventing such complications, no attempt was made to quantitate IHC's cost savings from such process improvements.
8. In a subsequent report on the same infectious disease programs discussed by Pestotnik in 1996, Evans et al. demonstrated the value of the program by several measures:[69]

- Significant reductions in orders for drugs to which patients had allergies (35 vs. 146 during the preintervention period; P<0.01);
- Significant reductions in excess drug dosages (87 vs. 405, P<0.01);
- Significant reductions in antibiotic-susceptibility mismatches (12 vs. 206, P<0.01);
- Reductions in the mean number of days of excessive drug dosages (2.7 vs. 5.9, P<0.002);
- Reductions in adverse events caused by antiinfective agents (4 vs. 28, P<0.02);
- Significant reductions in the cost of antiinfective agents between those patients who always received the computer program recommended regimens, those who did not always receive the computer program recommended regimens, and those in the preintervention period (adjusted mean, $102 vs. $427 and $340, respectively; P<0.001);
- Significant reductions in total hospital costs (adjusted mean, $26,315 vs. $44,865 vs. $35,283; P<0.001); and
- Significant reductions in length of hospital stay (adjusted mean, 10.0 vs. 16.7 vs. 12.9 days; P<0.001).

Internal Studies

Aside from the above referenced literature reports, additional work has been done internally within IHC to describe the impacts of information systems.

1. The most exhaustive internal report examining the impact of a nursing information system (NIS) at McKay-Dee Medical Center was prepared in 1993 by Paul Allen, an IHC systems engineer.[272, 273] The findings of this report may be briefly summarized:

    - The computerized NIS:
        - Increased time spent by nurses in direct patient care;
        - Reduced time spent completing paperwork;
        - Provided patient data for review easier, faster and with greater accuracy;
        - Provided patient data in an easily understandable and readily available format.
    - The anticipated benefit of added time spent with the patient attributable to locating computer terminals in patient rooms did not materialize.
    - The cost savings of the NIS were difficult to trace. Potential cost savings of $76,000 annually for increased time with direct patient care on the 4th South nursing unit extrapolated to a total of $850,000 if successfully extended to the entire hospital. The reduction in time spent completing forms suggested a potential savings of $250,000 annually. The specific staffing changes necessary to realize these potential cost savings were not examined.
    - It was concluded that the greatest potential benefits of improved patient outcomes and quality of care could be achieved only with

integration with an electronic medical record. These potential benefits were not estimated.

2. In a 1998 presentation for the Medical Information Systems Physicians' Association (MISPA), Gardner estimated the annual cost savings for several existing HELP applications at LDS Hospital:[217]

Adverse drug events	$900,000
Surgical wound infections	$750,000
Nosocomial infections	$150,000
Pharmacy drug alerts	$1,100,000
Prophylactic antibiotics	$100,000
Therapeutic antibiotics	$300,000
Urinary catheter monitor	$100,000
Total	$3,400,000

3. A summary of the benefits attributable to the Clinical Workstation (CW), the health information system working environment under continued development synthesizing a variety of clinical computing applications, has been prepared by IHC staff.[274, 275] A total of 53 potential benefits derivable from the CW has been identified, but these remain incompletely quantified. A quantifiable subset of these potential benefits has been combined into projected financial savings over a hypothetical five-year period as shown in Table 14, ranging from $2.1 million in Year 1 to $5.3

Table 14
Intermountain Health Care
Estimated Clinical Workstation Benefits

Clinical Workstation Benefits	Year 1	Year 2	Year 3	Year4	Year 5
Reduced transcription costs	$ 540,000	$ 594,000	$ 653,400	$ 718,740	$ 790,614
Decreased chart pulls	$ 187,000	$ 205,700	$ 226,270	$ 248,897	$ 273,787
Decreased chart storage costs	$ 5,130	$ 10,260	$ 15,390	$ 20,520	$ 25,650
Decreased supply costs					
Decreased long distance charges	$ 1,061	$ 1,274	$ 1,528	$ 1,834	$ 2,201
Decreased duplication charges	$ 1,733	$ 1,906	$ 2,096	$ 2,306	$ 2,537
Decreased office supplies charges	$ 21,000	$ 23,100	$ 25,410	$ 27,951	$ 30,746
Decreased forms and printing charges	$ 9,000	$ 9,900	$ 10,890	$ 11,979	$ 13,177
Improved charge capture	$ 61,875	$ 68,063	$ 74,869	$ 82,356	$ 90,591
Decreased undercoding	$ 150,000	$ 165,000	$ 181,500	$ 199,650	$ 219,615
Reduced malpractice premiums	$ 75,000	$ 82,500	$ 90,750	$ 99,825	$ 109,808
Decreased referral letters	$ 38,680	$ 42,548	$ 46,803	$ 51,483	$ 56,631
Decreased NCQA/HEDIS audit costs	$ 21,000	$ 42,000	$ 63,000	$ 84,000	$ 105,000
Decreased JCAHO audit costs	$ 3,750	$ 4,125	$ 4,538	$ 4,991	$ 5,490
Increased internal referrals	$ 200,000	$ 300,000	$ 400,000	$ 500,000	$ 500,000
Facilitate formulary use	$ 134,400	$ 268,800	$ 403,200	$ 537,600	$ 672,000
Reduced office costs by preventing ADEs	$ 408,713	$ 817,425	$ 1,226,138	$ 1,634,850	$ 2,043,563
Reduced office visit costs from Self Care	$ 216,000	$ 237,600	$ 261,360	$ 287,496	$ 316,246
Totals	$ 2,074,342	$ 2,874,201	$ 3,687,142	$ 4,514,478	$ 5,257,656

million in Year 5. This projection simplistically assumes implementation of the clinical workstation with full functionality across the entire IHC computing application development and implementation. The details of each individual estimate calculation are not reproduced here. The potential financial impacts of several other clinical computing applications under current development but not yet implemented for the Clinical Workstation by IHC have additionally been estimated (Table 15).[276] When and if development and implementation of these additional applications is completed remains uncertain. It is probable that this full list of supplemental applications will not reach fruition as development problems are encountered amidst a continuously changing clinical, competitive and regulatory environment. Additional applications are also likely to emerge over time.

Collaborative Groups

Intermountain Health Care is a participant in a recently formed consortium addressing the benefits of ambulatory clinical information systems.[220] Founded in 1998 and named the Scottsdale Institute (SI), this group is an elite invitation-only membership organization populated by a select group of large Integrated Delivery Systems (IDSs) with experience in the area of health information systems.[277] The goal of the Scottsdale Institute is to promote better healthcare and improve organizational performance through information management and technology. One of the collaborative studies undertaken by SI involves finding ways to evaluate

Table 15
Intermountain Health Care
Potential Additional Clinical Workstation Benefits

Internal standardization	
Common laboratory codes and keyboard standards	$40,000
Standard nursing documentation frames in HELP	$40,000
Single case mix/ data warehouse system	$40,000
Enforcement of standard interface requirements for purchased systems	$80,000
Stricter control over IS projects re compliance with IHC IS architecture	$40,000
Single vendor for all department systems	$80,000
Better utilization of existing IS technology	
Reduced transcription costs from CW and voice recognition technology	$1,000,000 clinic use/ $4,000,000 hospital use
Full CW functionality	$500,000
Extend proven cost-saving applications to all major IHC hospitals	$1,000,000
Implement CW applications under current development	
Implement formulary control in Medication Management application	$500,000
Medication alerting logic in Medication Management application	$500,000
Lab ordering profiles consistent with HCFA rules	$240,000 in FTE costs/ $250,000 savings in potential fines
Online billing interface between CW and IDX	$400,000
Implement disease management protocols	?
Implement preventive medicine/ wellness package into CW	?

ambulatory care information systems. Six member IDSs have participated in a collaboration to investigate the impact of such information systems and how to measure effectiveness:

- BJC Health System (St. Louis)
- Central Maine Healthcare Corporation (Lewiston, Maine)
- Integris Health (Oklahoma City)
- Partners HealthCare System (Boston)
- The University of Pennsylvania Medical Center and Health System (Philadelphia)
- Intermountain Health Care

The group generated 6 "objectives" which actually constituted domains of IS impact within which key indicators were targeted for measurement:

- Quality improvement and increasing clinical decision support
- Financial improvement
- Productivity
- User satisfaction
- Strategy
- Research

Sharing and refining their experiences within their own institutions, the 6 member IDSs developed a framework for evaluating the impacts of information systems. Each measurement frame consisted of five components (Table 16):

- A measurable concept within a given domain,
- Expected benefits,

Table 16
The Scottsdale Institute
Computerized Patient Record Impact Measurement Frame

Metric:				
Measurable concept	**Expected benefits**	**Measurement tool**	**Feasibility**	**Timing**

- Measurement tools to collect the necessary data,
- The feasibility of utilizing the metric, and
- The timing of each metric.

Sample metric frames are shown in Table 17. The efforts by SI to evaluate ambulatory computer-based patient record systems are an ongoing project with a goal of extracting a common basis for assessing the impacts of these complex and costly systems.

Taken together, published reports and internal studies provide a partial but incomplete picture of the value of health information systems at Intermountain Health Care.

Table 17
The Scottsdale Institute
Sample Computerized Patient Record Impact Measurement Frames

Metric: Clinical communication				
Measurable concept	**Expected benefits**	**Measurement tool**	**Feasibility**	**Timing**
Staff perception of communication effectiveness within clinical site.	Anticipate improved communications within clinic site.	Provider and staff questionnaires.	Fairly easy, once questionnaire is available.	Interval: every 6 months.

Metric: Financial improvement				
Measurable concept	**Expected benefits**	**Measurement tool**	**Feasibility**	**Timing**
Calculation of under and over billing	More accurate billing	Chart review and existing reports	Moderate/ easy	To be determined

Metric: Reduced transcription costs				
Measurable concept	**Expected benefits**	**Measurement tool**	**Feasibility**	**Timing**
Total transaction costs per physician per period	Reduction in transcription services as physician become proficient with system documentation tools	Data gathering: count of dictated documents per provider per month divided by totla number of patients seen	Moderate	One month before pilot launch, again 6 months after pilot launch

Sources: Latimer and The Scottsdale Institute.[220, 278]

METHODS

We ought, in every instance, to submit our reasoning to the test of experiment, and never to search for truth but by the natural road of experiment and observation.

Lavoisier[279] (page585)

Hypothesis

The hypothesis of the present thesis is that health information systems do deliver value, and that although this value can be elusive, it is identifiable and to an extent quantifiable.

Research Design

Confronted with the *fait accompli* of a pre-existing implemented information system of many years duration, selection of an appropriate research design to allow examination of the hypothesis is problematic. Despite this difficulty, the choice of a valid study design remains crucially important. A basic typology of epidemiologic research classifies studies into three categories based upon their handling of the study factor and the randomization of study subjects (Table 18).[280] In the present case, the study factor would be the presence or absence of a hospital information system, and study subjects would be health care institutions, or more specifically, hospitals.

Table 18
Typology of Epidemiologic Studies

Study type	Manipulation of study factor	Randomization of study subjects
Experimental	Yes	Yes
Quasi-experimental	Yes	No
Observational	No	No

Thus, study options would include:

- An **experimental study** would require that the study subjects (i.e., hospitals) be randomized to exposure to the study factor (i.e., health information systems) which are themselves not under the control of the subjects. Such a study would require that the subject hospitals be comparable in most respects (number of beds, clinical services available, severity of admissions, length of stay [LOS],demographics of patients, mortality rates, infection rates, etc.) to minimize the influence of confounding factors. Matching hospitals in this fashion would be quite difficult if not impossible given the small population of potential study subjects. Additionally, it is unlikely that any hospital would agree to participate in a study where a major strategic and operational decision such as acquiring an HIS would be left to the chance inherent in randomization. Finally, such an experimental study has a prospective point of view that is ill-suited to examining the LDS Hospital experience over the last 30+ years with the HELP system.
- A **quasi-experimental study** would require that the study subjects not be selected randomly but that the study factor (i.e., health information systems) be manipulable by the investigator. Again, it is unlikely that any hospital would agree to participate in a study where the important particulars underlying the implementation of an HIS would be left to the choices of outside parties. Additionally, a quasi-experimental study also has a prospective point of view which is ill-suited to the present situation.

- An **observational study** is better suited to the LDS Hospital situation since it does not require that either the study factor or study subjects be manipulated. This type of study additionally allows for either a prospective or retrospective point of view, the latter being ideally suited to the LDS Hospital situation. Were we considering the impacts of an HIS in a "virgin" hospital with no prior experience with information systems, a prospective before-after assessment would be a viable study design (Figure 23A). Such is not the case at LDS Hospital where the HELP system originated and evolved, but this approach could have been taken at any one of the eight other IHC hospitals that have implemented HELP over the last 9 years. This observational study design acknowledges that a scientific experiment is certainly impractical and probably unethical. While one approach to assessing the impacts of the HELP system on LDS Hospital operations could be an on-off study in which the system is alternately activated and de-activated (Figure 23B), such a strategy is clearly not only imprudent but also potentially hazardous in an environment where information systems have become an ingrained part of day-to-day clinical practice to care for seriously ill patients. This is a high-risk situation and clearly *not* the proper climate for such a scientific experiment, as rigorous as it might be.

Observational studies are those in which the investigator measures but does not intervene.[281] The observer is restricted from controlling the study population; observational studies are the most common and traditional type of epidemiologic research.[282] Observational studies are categorized as

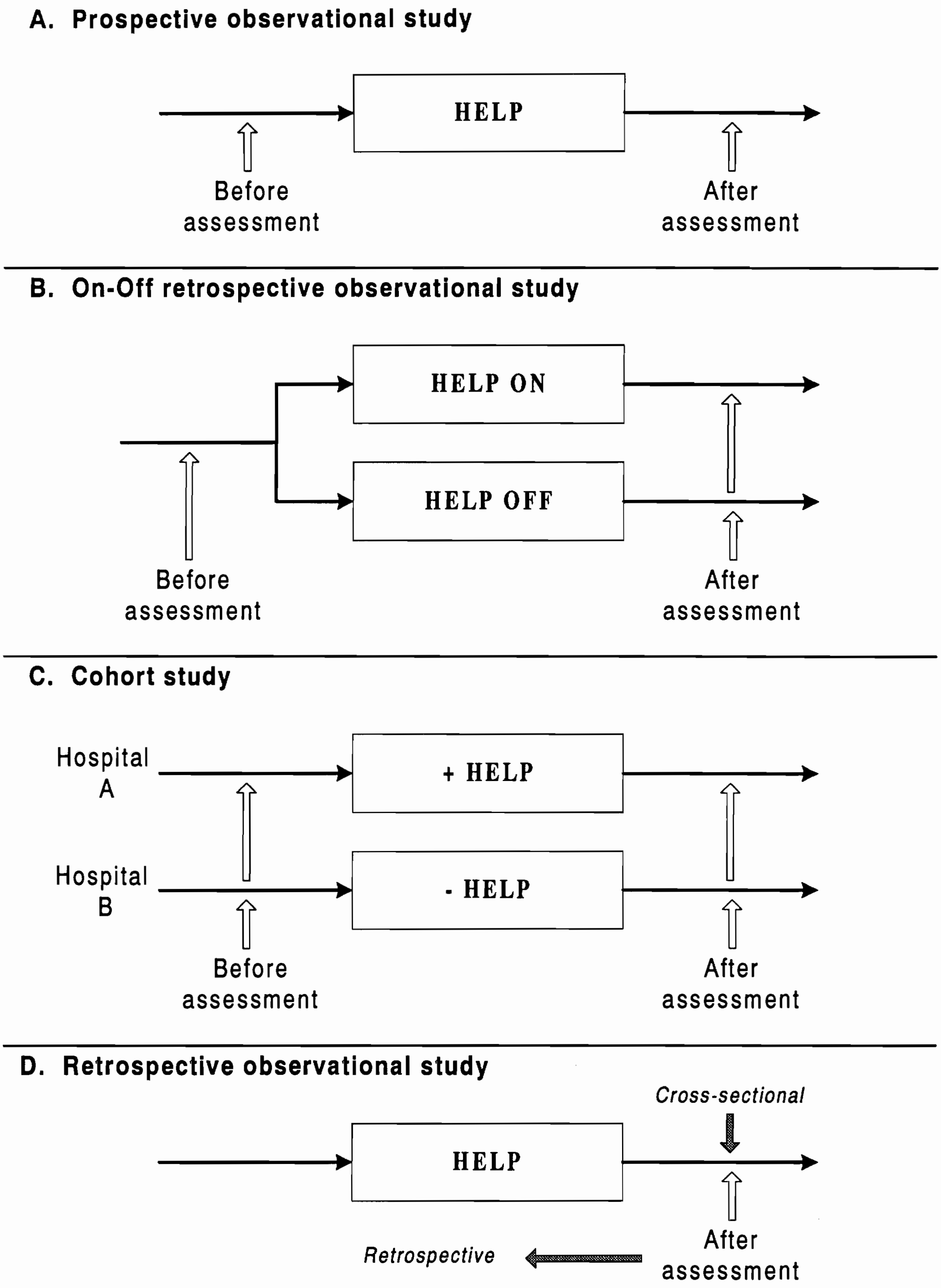


Figure 23
Summary of Possible HELP Study Designs

descriptive studies and analytical studies. In the present HIS context, the former would be represented by a simple description of an HIS and its relationship with the enterprise and the individuals who use it. An analytic study is more concerned with cause and effect relationships and would require an ecologic, case-control, or cohort study design. The ecologic study design examines populations rather than individuals, a point of view poorly suited to the present study given the limited number of hospitals with implemented information systems, and the even smaller number with health information systems similar to HELP. The case-control study design would require that from the population of hospitals, institutions operating effectively versus ineffectively (by measures yet to be defined) be examined retrospectively to assess the role of health information systems in creating this difference. The cohort study design would take hospitals without information systems and "expose" some to health information systems while excluding others while assessing the impacts over time (Figure 23C). As discussed above, such a study design is ill-suited to the present situation at LDS Hospital. We are therefore left with a retrospective observational study as the preferred choice for the present thesis (Figure 23D).

The present study is conceived as a descriptive observational study of existing operational and financial data. The study includes both longitudinal and cross-sectional aspects. The longitudinal portion of the study addresses the cumulative investment in developing and operating the HELP system at LDS Hospital, to the extent those data still exist from the approximately 30+ years of the system's development. The cross-sectional portion of the study will address the operational costs and benefits of the HELP system at LDS Hospital for a defined period of time.

RESULTS

Technology....is a queer thing. It brings great gifts with one hand,

and it stabs you in the back with the other.

C.P.Snow[283]

Interviews

A number of current and former employees of Intermountain Health Care were interviewed to establish the current state of the HELP system at LDS Hospital as well as at the other hospitals in the IHC system. Additionally, these interviews provided perspective on the historical development of the HELP system and on previous evaluation efforts. Other interviews were also conducted with personnel from different health care organizations to provide alternative viewpoints. These interviews are detailed in Table 19.

The information obtained from these interviews may be broadly summarized as follows:

1. IHC's present information system architecture is the result of a lengthy evolutionary process with origins dating back to the 1950s. As previously noted by Kuperman and illustrated in Figure 21 (page 139), information systems originated as computer applications to collect and analyze

Table 19
Interviews Regarding Valuing Health Information Systems

Interviewee	Date	Interviewee Name	Title	Topic
1	4/27/98	Blake Jensen, M.B.A.	Assistant Vice President for Information Systems, Intermountain Health Care	IHC information systems operations and strategy
2	5/7/98	David Olson	Director of Sales, IHC Health Plans	IHC Health Plans products and marketing
3	10/28/98	David Larsen, M.B.A.	Chief Financial Officer, Urban Central Region	HELP system development, IHC investment in information systems, thesis proposal
4	11/4/98	Matthew H. Samore, M.D.	Associate Professor of Medicine, Hospital Epidemiologist, University of Utah	Approaches to quantify value of the UU clinical data repository
5	11/20/98 and multiple other dates	Ron Jensen, M.B.A.	Budget Manager, LDS Hospital	LDS Hospital investments in the HELP system, operating and capital budgets, other LDS Hospital and IHC contacts

Table 19 continued

Interviewee	Date	Interviewee Name	Title	Topic
6	12/9/98	Jill Hoggard Green, R.N., Ph.D.	Assistant Vice President, Intermountain Health Care	Case management and disease management from information systems perspective
7	12/9/98	Paul O. Allen, P.E.	Senior Management Engineer, Information Systems, Intermountain Health Care	Clinical workstation evaluation studies, McKay-Dee evaluations
8	1/5/99	Watson A. Bowes III, M.D.	Medical Informatics, Information Systems, Intermountain Health Care	Clinical workstation, evaluation studies
9	1/7/99	T. Allan Pryor, Ph.D.	Assistant Vice President, Medical Informatics, Intermountain Health Care; Professor, Department of Medical Informatics, University of Utah	HELP system evolution, system-wide HELP implementation, HELP system costs
10	1/8/99	Richard McGuire	Systems engineer, LDS Hospital (Retired)	HELP system history, benefits, cost reduction
11	1/27/99	David Baird	Information Systems Director, IHC Urban Central Region	HELP system costs; confounding factors from other IT expenditures

Table 19 continued

Interviewee	Date	Interviewee Name	Title	Topic
12	2/3/99	Reed M. Gardner, Ph.D.	Professor and Chairman, Department of Medical Informatics, University of Utah; Co-Director of Medical Informatics, LDS Hospital	HELP system evolution, IHC management perspective on HELP, IHC evaluation studies of HELP
13	2/16/99	Larry D. Grandia	Vice President and Chief Information Officer, Intermountain Health Care	HELP system evolution, IHC management perspective on HELP, value of health information systems
14	2/18/99	Lynnette Pacheco	Director of Health Information, St. Mark's Hospital	Medical records, electronic storage of health information
15	2/24/99	Peter J. Haug, M.D.	Associate Professor, Department of Medical Informatics, University of Utah; Co-Director of Medical Informatics, LDS Hospital	HELP system development and structure; relationship of other LDS/IHC information systems, system financing
16	3/2/99	Stanley M. Huff, M.D.	Senior Medical Informaticist, IHC; Professor, Department of Medical Informatics, University of Utah	HELP system development, 3M relationship, methods of evaluation HELP system value

Table 19 continued

Interviewee	Date	Interviewee Name	Title	Topic
17	3/3/99	Nancy Nelson, B.S.N., R.N.	Clinical Information Systems Coordinator, LDS Hospital	HELP system nursing applications, nursing acceptance, downtime procedures
18	3/15/99	Paul D. Clayton, Ph.D.	Medical Informaticist, IHC; Professor of Medical Informatics, Columbia University	Establishing HIS value, published studies, IHC IT investment
19	3/15/99	Homer R. Warner, Sr., M.D., Ph.D.	Former Chairman of Department of Medical Informatics, University of Utah	Historical perspective on HELP system development
20	3/17/99	Julie Jacobsen, R.N.	Director, Quality Resources, LDS Hospital	Quality Resources perspective on HIS value, methods of assessing IS applications
21	3/22/99	Mo Mulligan, R.N., J.D.	Director of Performance Monitoring and Improvement, University of Utah Health Sciences Center	Quality assessment, quality improvement, benchmarking, role of information systems

Table 19 continued

Interviewee	Date	Interviewee Name	Title	Topic
22	3/24/99	Tammy Smith	Director, Installation and Support, Central Office Information Systems, IHC	HELP system and other IHC information systems, network design, benefits of IS including regulatory compliance
23	3/31/99	Craig Malcolm	Chief Operating Officer, Utah Radiology Associates; formerly Administrative Director of Radiology, LDS Hospital	HELP impacts in radiology, benefits of IS in radiology
24	4/5/99	Pierre S. Pincetl, M.D.	Chief Information Officer, University Hospital; Associate Professor, Department of Medical Informatics, University of Utah	IS investments at UU; benchmarking IS investments
25	4/7/99 and 6/28/99-6/30/99	Brent C. James, M.D., M.Stat.	Executive Director, Institute for Health Care Delivery Research; Vice President for Medical Research, Intermountain Health Care	Quality aspects of IS, economics of IS, suboptimization effects of IS

Table 19 continued

Interviewee	Date	Interviewee Name	Title	Topic
26	4/7/99	David S. Memel, M.D.	Vice President of Healthcare Improvement and Informatics, Peacehealth	IS value, levels of IS budgeting within Peacehealth, justification of IS to management
27	4/16/99	Marjorie Peck, Ph.D., R.N.	Former Nurse Executive and Operating Officer for IHC Urban Central Region; Associate Professor and Director of Graduate Studies, University of Utah School of Nursing	HELP system in nursing care, IHC management perspective on information systems, IHC strategic planning
28	6/30/99	Larry Staker, M.D.	Former Director of Clinical Practice Improvement and Clinical Integration, Intermountain Health Care	Clinical practice improvement, quality improvement
29	7/8/99	Jeremy Meacham	Budget Manager, IHC Information Systems	Information systems capital and operating budgets
30	7/12/99	Mike Gunderson	Programmer/ analyst, Department of Medical Informatics, LDS Hospital	LDS Hospital information systems network

Table 19 continued

Interviewee	Date	Interviewee Name	Title	Topic
31	8/24/99	R. Scott Evans, Ph.D.	Director of Research, Department of Epidemiology, LDS Hospital; Associate Research Professor, Department of Internal Medicine and Adjunct Associate Professor, Department of Medical Informatics, University of Utah	Benefits to patient care from computer applications; IHC management relationships; disease management
32	8/24/99	Stanley L. Pestotnik, M.S., R. Ph.	Director of Drug Services Program, LDS Hospital	Re-engineering, disease management and the role of information systems

physiologic data.[66] After the inclusion of other forms of clinical data, attention was directed to transforming the HELP system into a decision support tool to facilitate improved clinical practice. IHC's information systems currently embrace not just HELP but also several other application-specific systems networked together into a complex web This IS web requires the ongoing support of a large cadre of information. workers spread across the full range of IHC sites.

2. The magnitude of IHC's IS network has outstripped the ability of any individual to manage. No one person is knowledgeable about the entirety of the IHC IS network. It is only through the cooperative efforts of the large cohort of IS support staff that IHC is able to provide and continue to extend the breadth and depth of its information systems capabilities.
3. IHC is engaged in a gradual migration from the HELP system to its successor the clinical workstation (CW). The underlying premise of the CW is to implement standardized protocols and care plans adapted to specific patients by presenting the clinician with critical information at the time it is necessary to make a management decision. The CW initiative ties into disease management and clinical integration, concepts which will be discussed later in this thesis.
4. IHC has been consistently willing to design new applications in search of additional benefit from its IS investment. This persistent pursuit of value has distinguished the enterprise from its counterparts in the health care

domain, most of whom have been content to not exploit the potential for process change inherently present in IS.

5. IHC management has possessed the vision that IS offers significant prospects for competitive advantage in the marketplace. For this reason, management has supported and continues to support IS with substantial funding and staffing. The intimate involvement of IHC management in information technology fits into arm A of the IT decisionmaking model described by Keen in which IT leadership may be abdicated to technical specialists unless management appreciates the importance of IT and drives IT planning itself (Figure 24).[284]
6. The impetus behind IHC's incorporation of computers into medical care has been a shared vision of the possibilities to improve the quality of health care.
7. IHC has demonstrated the connection between quality of care and cost.
8. Recognizing that there are currently no generally accepted metrics to gauge IS value, IHC has recently engaged in the Scottsdale Institute, a consortium devise a framework for the evaluation of IS benefits in a consistent fashion.

Value

To consider value, the components that comprise value must be recognized and understood. The most commonly encountered definition of value is cast in terms of outcome and cost:[115, 285]

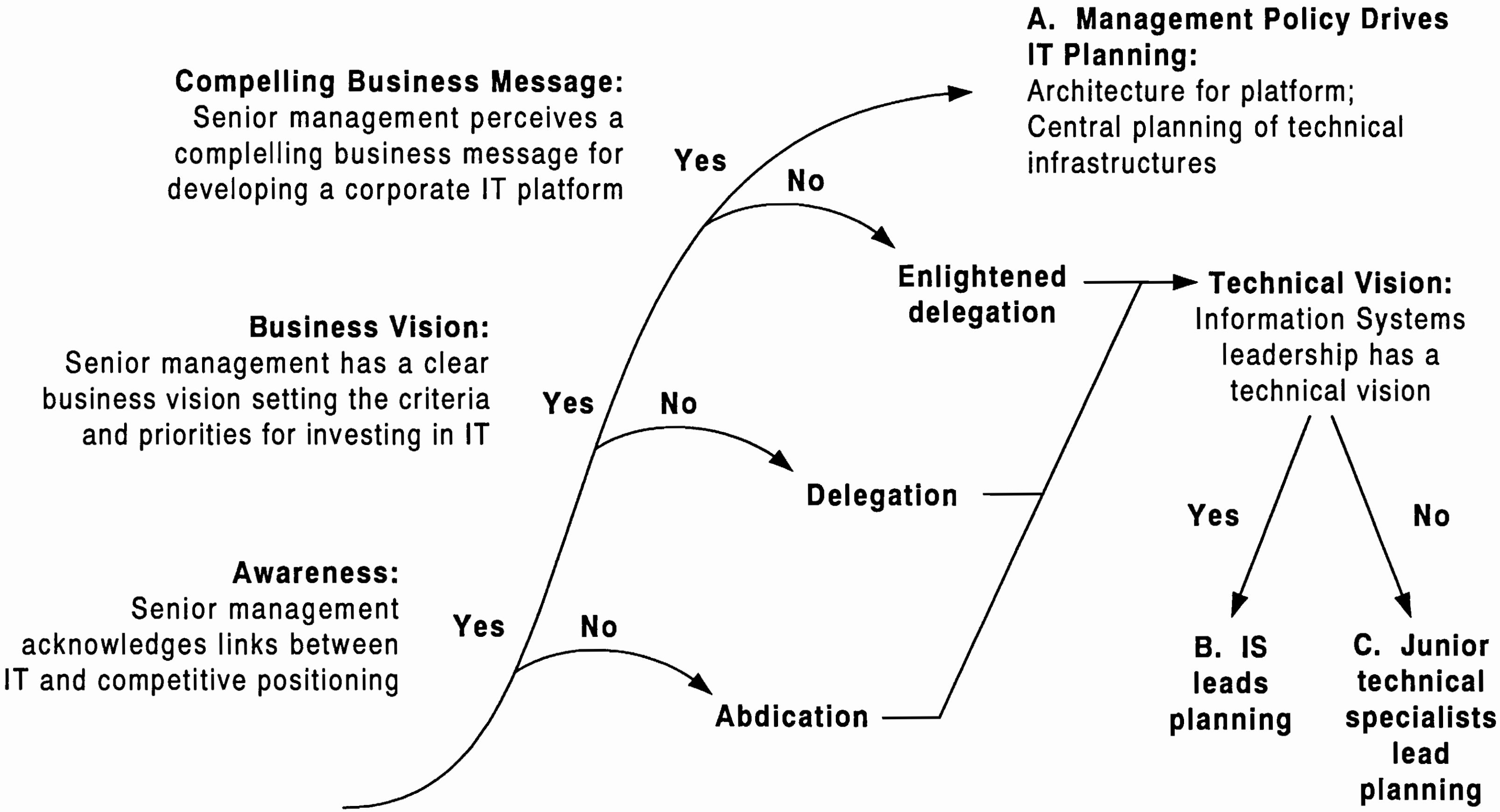


Figure 24
The Information Technology Decision Making Process

$$\text{Value} = \frac{\text{Outcome}}{\text{Cost (\$)}} \qquad [6]$$

Another approach to the value equation is that of James who characterizes value in terms of three classes of outcomes:[218]

- Physical outcomes, incorporating measures of medical outcomes, complications, therapeutic goals, and functional status;
- Service outcomes, incorporating measures of satisfaction across multiple customer domains; and
- Cost outcomes.

Utilizing these concepts, the value equation for a health care enterprise may be rewritten:

$$\text{Value} = \frac{\text{Medical outcomes} + \text{Service outcomes}}{\text{Cost outcomes (\$)}} \qquad [7]$$

An alternative interpretation of the value equation is structured around outcome. Outcome is a global term embracing the full range of impacts, both positive and negative; outcome will typically be comprised of multiple components rather than a solitary item. Outcomes of health information systems may be considered in terms of benefits and their converse dis-benefits (a term coined by Remenyi to label those adverse impacts resulting from information systems[154]). Outcome can then be expressed as the net of the respective summations of benefits and dis-benefits:

$$\text{Value} = \frac{(\sum \text{Benefits}) - (\sum \text{Dis-benefits})}{\text{Costs (\$)}} \qquad [8]$$

The basic question underlying each of these alternative value formulae is straightforward: given its sizable financial investment in information technology in general and health information systems in particular, what is the evidence that IHC receives its money's worth?

Costs

LDS Hospital Information Technology Investments

From a retrospective standpoint, the ideal situation would allow a detailed year-by-year tabulation of the capital and operating investments in developing and operating the HELP system at LDS Hospital from its inception until the present. Such a detailed accounting is not possible for a number of reasons:

1. The HELP system did not spring forth *de novo*, but rather had a diffuse origin, developing incrementally over many years. As discussed previously, HELP's earliest origins date back to 1954 when Dr. Homer R. Warner established the LDS Hospital Cardiovascular Laboratory.[66] Computer applications were gradually developed and extended into other areas within LDS Hospital. The first publication discussing HELP as an information system appeared in 1972.[261] Multiple other innovations and associated publications have appeared over the intervening 27 years as detailed elsewhere in this thesis.
2. Even if 1972 is accepted as the official starting point for the application of cost accounting to HELP, a period of 27 years has elapsed over which time

much of the cost-related data has been discarded since its maintenance in perpetuity was not required.[286]

3. Within the last decade or so for which partial IHC cost information still exists, differing levels of importance have been assigned different cost data. Capital cost information, which retains long-term financial importance to the enterprise, is more readily retrievable than operating cost information.
4. Further complicating the accounting picture, even during those years for which financial information still exists, the accounting systems in use by LDS Hospital and IHC have not remained static but have themselves changed to meet shifting managerial needs. As departments have appeared, disappeared, merged, or split, the accounting trail been obscured.
5. Complicating the picture even further, around 1986 the IHC corporate budget began to play a role in hospital information system budgeting, further complicating what had previously been relatively straightforward accounting for the information system of an individual hospital.
6. Even if the cost information for these early years of HELP was still available, the true cost of the development of the HELP system would be seriously underestimated. The recurring pattern for HELP development was to conceptualize a potentially useful medical computing application, to apply for and be awarded a grant for this task, to develop the application, to publish a paper about the new application, and finally (as the grant funding neared exhaustion) to induce LDS Hospital to take over the funding for

maintaining the new computer application as another component in its developing hospital information system.[287] Many of the hardware, software and personnel costs of system development are thus hidden within the grant fundings about which detailed information no longer exists.

7. The budgetary channels that provide funding for information technology in general and HELP in particular are complex. All funding does not stem from a single source to be applied to a single use. The budgetary relationships between IHC, LDSH and its information systems development and operations are shown in Figure 25.[70, 71, 286, 288-294] In this context of tangled budgetary relationships, it is important to appreciate that in addition to obvious support from the Medical Informatics Department, LDS Hospital information system development and support also arises from a number of clinical departments (e.g., Cardiology, Pulmonary, and Infectious Disease) which maintain their own clinical computing resources including hardware, software such as databases, and programmers independent of those resources provided by their corporate IT budgets.

8. To view HELP as a single, monolithic information system governing the entirety of LDS Hospital's clinical information systems represents a major oversimplification. The reality is that HELP is one of several independent information system modules which have arisen over the span of many years and have gradually been woven together into a complex tapestry to serve the clinical, administrative and business needs of the hospital against

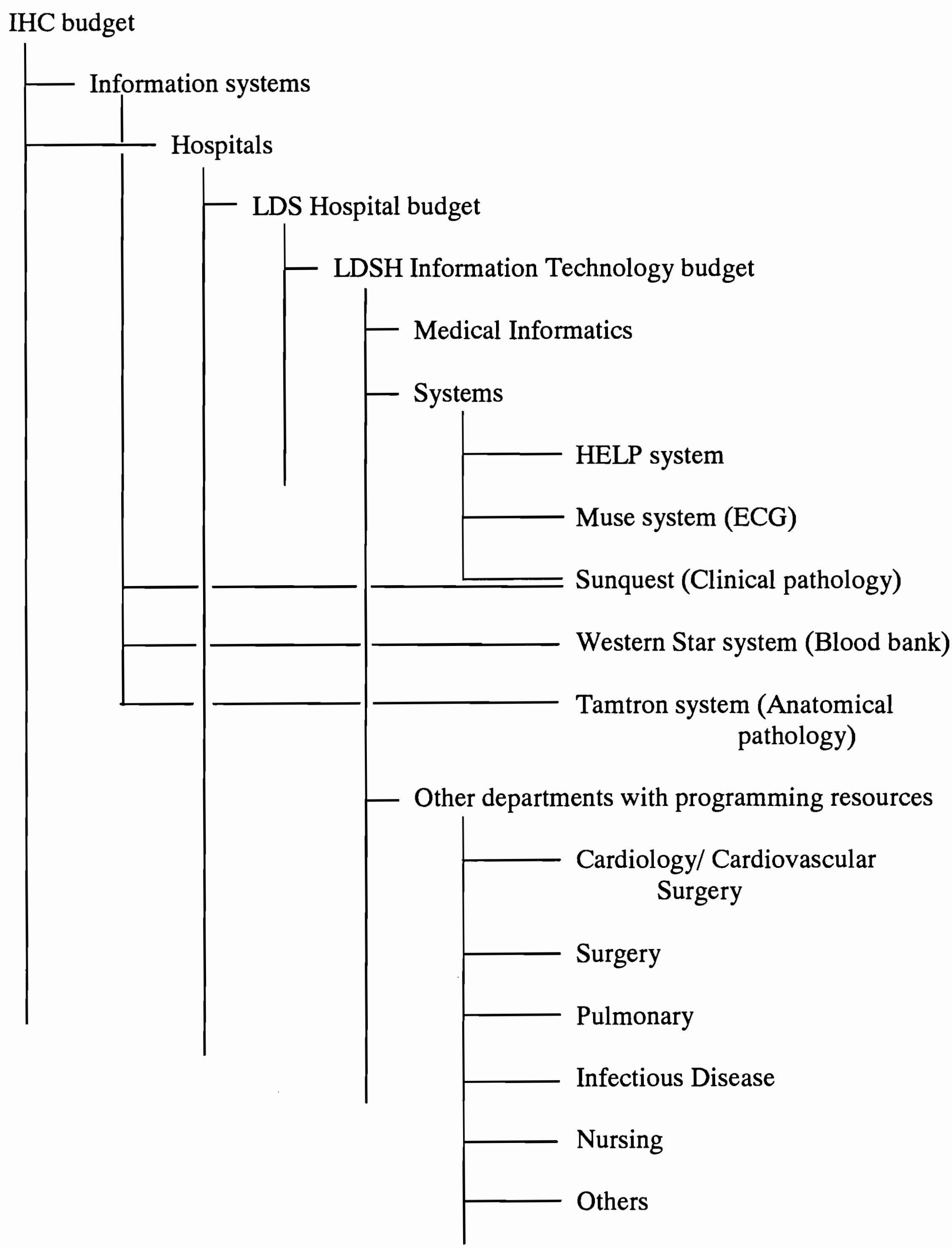


Figure 25
IHC/LDSH Information Systems Budget Hierarchy

the context of an increasingly IT-intensive health care delivery enterprise. The IS network has grown so large and is so pervasive that there exists no one person who is knowledgeable in the entire system and who is responsible for its development and operation. HELP and its companion information systems exist due to the ongoing efforts of legions of support and development personnel who focus on specific parts of the IS whole.

9. Notwithstanding considerable cooperation from IHC employees at various levels, the picture of information system costs remains incomplete as much of the detailed financial information necessary for a full picture has been either not located or judged proprietary and made unavailable.

For these reasons, a definitive cost accounting of the development of the HELP system does not exist nor can it be reliably reconstructed. Such financial information, even were it complete and available, would be of primarily historical interest but could provide valuable insight into the role and fiscal realities of clinical computing. This financial information would, however, be of relatively limited usefulness for current management of the enterprise. The rapid evolution of information technology in general and health information systems in particular places current IT investments in an altogether different context than existed 20 to 40 years ago when the HELP system had its origins. These past investments are most appropriately viewed as *sunk costs*, costs which have already been incurred and cannot be reversed by some future action.[295] That financial information which is presently of value to IHC or any other health care delivery organization is relatively contemporary information which may impact current decisions being made by the enterprise.

Accordingly, the present report considers cost information for IHC's three most recent fiscal years, i.e., calendar years 1996, 1997 and 1998. This three-year window was chosen instead of a single year to smooth out the inevitable variations in funding from year to year as capital equipment has been acquired and operating expenses have undergone changes.

Table 20 illustrates LDS Hospital IT costs incurred within these three most recent fiscal years.[286, 288, 294] Analyzed by department, this tabulation considers the four major support departments which comprise the overwhelming majority (>99.7 percent) of IT expense at LDS Hospital: Medical Informatics, Computer Support Service, Systems Analysis Service, and LAN Operations. Those seven clinical departments having the greatest IT involvement are also included, although in the aggregate they comprise <0.3 percent of total LDSH IT expenditures. The small amount of departmental funding reflects an idiosyncrasy of the accounting system: account 4154 for computer and software support collects a variety of small ancillary computing charges for each department such as printer supplies or software but not the more substantial costs such as hardware or personnel which are aggregated in the lump sums in Departments 726, 725, 724, and 711.

The costs which are tabulated include operating expenses, capital expenses (listed as "Depreciation/ Amortization"), and in the case of the Systems Analysis Service only, a corporate data processing charge. This latter charge reflects the assessment applied to all IHC hospitals from the corporate information systems department to cover its services. Although the entirety of IHC's corporate IS budget is allocated among the hospitals according to a weighted average, none of those

Table 20
LDS Hospital Information Technology Expenditures, 1996-1998

Department	1996	1997	1998
726 Medical Informatics			
Expense	$ 592,435	$ 728,808	$ 657,336
Depreciation/ Amortization	$ 5,492	$ 6,264	$ 10,039
Total	$ 597,927	$ 735,072	$ 667,375
725 Computer Support Service			
Expense	$ 862,626	$ 1,052,407	$ 831,050
Depreciation/ Amortization	$ 832,978	$ 659,105	$ 552,122
Total	$ 1,695,604	$ 1,711,512	$ 1,383,172
724 Systems Analysis Service			
Expense	$ 427,134	$ 463,536	$ 486,557
Depreciation/ Amortization	$ 83,053	$ 229,592	$ 312,243
Corporate data processing charge	$ 1,645,439	$ 2,711,010	$ 3,601,853
Total	$ 2,155,626	$ 3,404,138	$ 4,400,653
711 LAN Operations			
Expense			$ 155,362
Depreciation/ Amortization			$ 8,144
Total			$ 163,506
448 Cardiology			
4154 Computer software and support	$ 5,156	$ 13,262	$ 5,887
Departmental computer personnel	NA	NA	NA
759 Pulmonary			
4154 Computer software and support	$ -	$ 2,984	$ 2,881
Departmental computer personnel	NA	NA	NA
505 Infectious disease			
4154 Computer software and support	$ 1,645	$ 1,999	$ 1,868
Departmental computer personnel	NA	NA	NA
250 Coronary ICU			
4154 Computer software and support	$ 737	$ 2,134	$ 1,188
251 Medical/ Surgical ICU			
4154 Computer software and support	$ 239	$ 2,174	$ 1,523
252 Thoracic ICU			
4154 Computer software and support	$ 266	$ 922	$ 925
253 Shock/ Trauma/ Respiratory ICU			
4154 Computer software and support	$ 550	$ 1,401	$ 864
Totals	$ 4,457,750	$ 5,875,598	$ 6,629,842

interviewed were familiar with the exact method by which this allocation was calculated. Missing from these numbers is the amount of supplemental financial support provided by the Cardiology, Pulmonary and Infectious Disease departments for computing including hardware, software and/or personnel. Department 711, LAN Operations, illustrates the problem alluded to in item #4 on page 179. This department did not have a separate budgetary existence in 1996 or 1997, but was created for 1998 accounting purposes. Table 20 illustrates that substantial and increasing sums are being invested annually in information technology at LDS Hospital, from $4.5 million in 1996 to $6.6 million in 1998 with increases of 31.8 percent and 12.8 percent between 1996-1997 and 1997-1998, respectively.

The above data must be considered in proper context. These numbers reflect the totality of LDS Hospital's IT investments of all types and are not constrained solely to health information systems nor to the HELP system alone. As HISs have become increasingly ingrained within the fabric of IHC's operations, separating out a given HIS as an entity distinct from the totality of LDS Hospital's information technology has become increasingly difficult. A crude but inadequate attempt to make such a distinction between HIS costs as a proportion of IS costs is reflected in Table 21 which examines HELP's Tandem system operating and capital expenses for FY 1998. Operating expenses totaled $467,821 for this system alone. Although total IS operating expenses for FY 1998 are not available, substituting the FY 1997 value of $6.26 million suggests that the Tandem system comprises only 7.5 percent of the total. This first estimate is considered quite low, but represents the best approximation that can be made at the present time in the face of a typical accounting system which is

Table 21
Intermountain Health Care
LDS Hospital HELP System Information Technology Costs, 1996-1998

	Fiscal years 1996	1997	1998
HELP (Tandem) System			
Operating expenses			
System software licensing			$51,840
System hardware maintenance			$85,488
Personnel			
HELP desk support resources			$59,033
Clinical services technical support			$96,048
Clinical information systems specialists education/support			$100,244
Peripherals hardware support			$75,168
Subtotal, Operating expenses	NA	NA	$467,821
Capital expenses			$192,650
Total Tandem expenses	NA	NA	$660,471

NA = Not available

department-centric rather than oriented to specific information systems. The implication is that either substantial HELP system operating expenses have been overlooked or the remaining non-HELP information systems at LDS Hospital consume the majority of the IS operating budget.

Budget numbers from LDS Hospital offer some perspective regarding the level of IT investment as compared to overall expenditures. The LDS Hospital budget for fiscal years 1995-1997 is detailed in Table 22.[296] Several individual departmental budgets within laboratories, radiology, InstaCares and Home Health have been combined into global departmental categories at the request of IHC management. Information technology operating expenses for each department have been broken out separately, averaging a total of $5.3 million annually for all LDSH departments together during this 1995-1997 period. This level of funding represents approximately 1.81 percent of total operating expenses for LDS Hospital during these three years. As discussed above relative to Table 20, the amounts attributed to each department are artificially low given the substantial corporate funding flowing through those three departments providing information systems throughout the hospital (the fourth IS department shown in Table 20, LAN Operations, was not created until 1998). This artificially low average amount of 1.81 percent of budget applied to IT operating expense from each department thus represents a minimum estimate. This overall LDS Hospital funding for IT operations averaging $5.3 million per year from Table 22 compares closely with the values derived from Table 20 for a slightly different time period.

Table 22
Intermountain Health Care: LDS Hospital Budget, 1995-1997

Department	Departmental Operating Expenses			Information Technology Operating Expenses			IT Total by Dept	Annual Average IT	IT as % of Dept
	1997	1996	1995	1997	1996	1995	1995-1997	Expense	Expenses
Nursing support	$ 465,135	$ 437,294	$ 363,008	$ 916	$ 1,485	$ 1,545	$ 3,946	$ 1,315	0.31%
Central processing	$ 20,932,988	$ 18,150,978	$ 16,179,119	$ 1,742	$ 825	$ 339	$ 2,906	$ 969	0.01%
Labor and delivery	$ 2,221,772	$ 1,941,579	$ 1,780,673	$ 3,632	$ 2,366	$ 11,015	$ 17,013	$ 5,671	0.29%
Midwifery	$ 830,065	$ 643,955	$ 516,593	$ 309	$ 958	$ 672	$ 1,939	$ 646	0.10%
Emergency room	$ 4,214,685	$ 3,619,202	$ 2,913,521	$ 3,583	$ 3,089	$ 5,137	$ 11,809	$ 3,936	0.11%
Life Flight	$ 5,695,145	$ 5,407,308	$ 5,251,073	$ 1,906	$ 3,002	$ 2,014	$ 6,922	$ 2,307	0.04%
Intravenous therapy	$ 789,943	$ 1,334,255	$ 1,083,590	$ 400	$ 514	$ 683	$ 1,597	$ 532	0.05%
Operating rooms	$ 6,821,201	$ 5,958,399	$ 5,355,408	$ 5,527	$ 7,383	$ 4,221	$ 17,131	$ 5,710	0.09%
Short stay surgery	$ 1,220,280	$ 1,124,212	$ 904,215	$ 452	$ 119	$ 1,116	$ 1,687	$ 562	0.05%
PACU	$ 599,303	$ 527,137	$ 469,105	$ 92	$ 122	$ -	$ 214	$ 71	0.01%
Anesthesiology	$ 1,333,896	$ 1,204,811	$ 965,237	$ -	$ 48	$ -	$ 48	$ 16	0.00%
ICUs	$ 9,427,785	$ 8,283,773	$ 8,471,585	$ 6,631	$ 1,792	$ 4,578	$ 13,001	$ 4,334	0.05%
Newborn intensive care	$ 2,543,763	$ 2,406,570	$ 1,990,827	$ 1,372	$ 553	$ 372	$ 2,297	$ 766	0.03%
Maternity - west 4	$ 1,671,962	$ 1,469,678	$ 1,270,763	$ 636	$ 456	$ 1,022	$ 2,114	$ 705	0.05%
West 3 - Orthopedics	$ 2,195,802	$ 1,863,959	$ 1,647,416	$ 970	$ 1,078	$ 1,082	$ 3,130	$ 1,043	0.05%
Intermountain surgical center	$ 4,074,461	$ 25,284	$ 3,820,050	$ 1,576	$ -	$ 705	$ 2,281	$ 760	0.03%
Thoracic/medicine - west 7	$ 3,316,215	$ 2,731,435	$ 2,339,675	$ 5,251	$ 1,343	$ 1,609	$ 8,203	$ 2,734	0.10%
E-8 oncology/general surgery	$ 2,340,846	$ 2,368,975	$ 2,013,891	$ 2,761	$ 869	$ 1,865	$ 5,495	$ 1,832	0.08%
Medical - West 8	$ 3,055,314	$ 2,503,708	$ 2,317,229	$ 2,171	$ 608	$ 2,529	$ 5,308	$ 1,769	0.07%
West 6 surgical	$ 3,433,949	$ 2,782,941	$ 2,432,472	$ 2,346	$ 1,735	$ 1,318	$ 5,399	$ 1,800	0.06%
Rehabilitation center	$ 1,782,857	$ 1,650,788	$ 1,460,303	$ 1,508	$ 1,180	$ 791	$ 3,479	$ 1,160	0.07%
Dayspring	$ 790,030	$ 714,401	$ 168,222	$ 382	$ 672	$ 19	$ 1,073	$ 358	0.06%
Psychiatry	$ 2,068,032	$ 1,802,435	$ 2,735,964	$ 2,109	$ 1,416	$ 1,057	$ 4,582	$ 1,527	0.08%
Instacares	$ 5,577,851	$ 6,224,493	$ 3,394,423	$ 8,073	$ 11,495	$ 508	$ 20,076	$ 6,692	0.14%
Clinic	$ 433,838	$ 429,892	$ 400,759	$ 333	$ 92	$ 527	$ 952	$ 317	0.08%
Salt Lake Workmed	$ 1,298,229	$ 1,210,267	$ 1,115,263	$ 358	$ 562	$ 178	$ 1,098	$ 366	0.03%
Wendover midwifery clinic	$ 111,995	$ 36,079	$ 38,896	$ 225	$ 145	$ -	$ 370	$ 123	0.20%
St. Joseph's clinic	$ 612,776	$ 414,427	$ 240,440	$ 2,193	$ 1,551	$ 520	$ 4,264	$ 1,421	0.34%
Community clinics	$ 6,319,128	$ 3,671,551	$ 643,284	$ 1,446	$ 2,913	$ -	$ 4,359	$ 1,453	0.43%
Nutritional support	$ 456,433	$ 372,822	$ 319,037	$ 473	$ 9	$ 407	$ 889	$ 296	0.08%
Cardiology	$ 1,372,729	$ 1,038,418	$ 860,955	$ 13,262	$ 5,156	$ 7,428	$ 25,846	$ 8,615	0.79%
Peripheral vascular lab	$ 343,686	$ 339,703	$ 347,545	$ 442	$ 4,791	$ -	$ 5,233	$ 1,744	0.51%
Electroencephalography	$ 678,859	$ 668,460	$ 622,336	$ 196	$ 392	$ 320	$ 908	$ 303	0.05%
Hospice	$ 341,878	$ 294,153	$ 270,003						
Cardiovascular lab	$ 5,837,408	$ 5,527,842	$ 4,336,766	$ 5,998	$ 668	$ 2,739	$ 9,405	$ 3,135	0.06%
CV Monitoring	$ -	$ 2,143	$ 30,218						
Home IV therapy	$ 293,022	$ 226,563	$ 215,806	$ -	$ 237	$ -	$ 237	$ 79	0.03%
Blood bank	$ 4,512,932	$ 3,992,920	$ 1,825,856	$ 1,231	$ 1,433	$ 1,655	$ 4,319	$ 1,440	0.04%
Apheresis therapy	$ 497,876	$ 2,039	$ 3,627,242	$ 74	$ -	$ 4,688	$ 4,762	$ 1,587	0.12%
Laboratory	$ 9,861,422	$ 9,141,502	$ 8,074,510	$ 32,032	$ 38,909	$ 18,794	$ 89,735	$ 29,912	0.33%
Infectious disease	$ 673,323	$ 639,581	$ 694,697	$ 1,999	$ 1,645	$ 1,266	$ 4,910	$ 1,637	0.24%
Radioisotope	$ 880,905	$ 747,312	$ 703,980	$ 4,258	$ 2,151	$ 959	$ 7,368	$ 2,456	0.32%
Occupational therapy	$ 605,666	$ 540,650	$ 448,876	$ -	$ -	$ 40	$ 40	$ 13	0.00%
Home health	$ 5,773,594	$ 5,418,789	$ 4,828,442	$ 6,106	$ 5,523	$ 6,295	$ 17,924	$ 5,975	0.07%
Pharmacy	$ 13,559,289	$ 12,472,145	$ 10,729,549	$ 8,395	$ 3,696	$ 1,333	$ 13,424	$ 4,475	0.04%
St. Joseph's pharmacy	$ 538,280	$ 407,262	$ 179,803	$ 4,544	$ 182	$ -	$ 4,726	$ 1,575	0.42%
Rehab ancillary services	$ 824,140	$ 718,158	$ 738,879	$ 3,362	$ 4,428	$ 1,768	$ 9,558	$ 3,186	0.42%
Physical therapy - rehab	$ 435,790	$ 388,720	$ 376,721	$ 27	$ -	$ -	$ 27	$ 9	0.00%
The Fitness Institute	$ 622,506	$ 511,291	$ 503,662	$ 1,366	$ 472	$ 753	$ 2,591	$ 864	0.16%
Physical therapy	$ 1,351,793	$ 1,280,530	$ 1,310,680	$ 437	$ 348	$ 385	$ 1,170	$ 390	0.03%
Pulmonary function	$ -	$ 1,041,151	$ 939,890	$ -	$ 2,351	$ 2,987	$ 5,338	$ 1,779	0.27%
Sleep lab	$ 427,551	$ 368,017	$ 392,643	$ 3,106	$ 3,714	$ 14,330	$ 21,150	$ 7,050	1.78%
Endoscopy lab	$ 916,407	$ 849,492	$ 756,502	$ 1,092	$ 615	$ 438	$ 2,145	$ 715	0.09%
Radiology	$ 6,963,532	$ 6,417,560	$ 5,779,809	$ 30,610	$ 15,731	$ 5,979	$ 52,320	$ 17,440	0.22%
ET therapy	$ 54,646	$ 46,142	$ 44,709						
Respiratory therapy	$ 3,623,914	$ 3,055,874	$ 2,676,054	$ 5,028	$ 2,029	$ 3,669	$ 10,726	$ 3,575	0.11%
Barometric medicine	$ 369,639	$ 401,467	$ 359,090	$ 1,410	$ 1,679	$ 602	$ 3,691	$ 1,230	0.33%

Table 22 continued

Department	Departmental Operating Expenses 1997	Departmental Operating Expenses 1996	Departmental Operating Expenses 1995	Information Technology Operating Expenses 1997	Information Technology Operating Expenses 1996	Information Technology Operating Expenses 1995	IT Total by Dept 1995-1997	Annual Average IT Expense	IT as % of Dept Expenses
Speech therapy	$ 660,311	$ 588,126	$ 471,754						
Ultrasound	$ 322,402	$ 339,757	$ 339,420	$ 165	$ -	$ -	$ 165	$ 55	0.02%
Bone marrow transplant	$ 921,498	$ 567,907	$ 224,707	$ 1,435	$ 2,255	$ -	$ 3,690	$ 1,230	0.22%
Dialysis	$ 4,221,161	$ 3,883,739	$ 3,519,663	$ 2,137	$ 1,014	$ 61	$ 3,212	$ 1,071	0.03%
Transplant	$ 2,411,280	$ 2,532,503	$ 2,609,998	$ 5,851	$ 4,607	$ 2,511	$ 12,969	$ 4,323	0.17%
Social services	$ 673,172	$ 597,718	$ 564,339	$ 995	$ 424	$ 796	$ 2,215	$ 738	0.12%
Dept of Internal Medicine	$ 2,610	$ 11,466	$ 341,985	$ -	$ -	$ 1,346	$ 1,346	$ 449	0.38%
Perinatology	$ 1,119,634	$ 944,780	$ 805,972	$ 3,281	$ 1,910	$ 1,649	$ 6,840	$ 2,280	0.24%
ER physicians	$ 2,516,545	$ 2,191,096	$ 2,034,960						
Continuing medical education	$ 456,114	$ 409,079	$ 264,245	$ 911	$ 966	$ 933	$ 2,810	$ 937	0.25%
Housestaff	$ 3,766,540	$ 3,599,361	$ 3,495,597	$ 875	$ 216	$ 1,248	$ 2,339	$ 780	0.02%
Depreciation & amortization	$ 8,959,761	$ 8,950,877	$ 11,263,771						
Dietary	$ 3,002,104	$ 2,770,687	$ 2,439,731	$ 2,325	$ 2,545	$ 5,358	$ 10,228	$ 3,409	0.12%
Security	$ 559,010	$ 532,817	$ 462,891	$ 2,542	$ 164	$ 2,577	$ 5,283	$ 1,761	0.34%
Environmental services	$ 2,622,616	$ 2,250,148	$ 2,009,315	$ 1,993	$ 200	$ 858	$ 3,051	$ 1,017	0.04%
Clinical engineering	$ 640,387	$ 599,442	$ 581,400	$ 171	$ 2,348	$ -	$ 2,519	$ 840	0.14%
Risk management	$ 206,897	$ 181,085	$ 161,293	$ 2,028	$ 530	$ 813	$ 3,371	$ 1,124	0.61%
Plant operation	$ 4,349,682	$ 4,444,026	$ 4,346,352	$ 8,039	$ 2,163	$ 3,036	$ 13,238	$ 4,413	0.10%
Printing	$ (1,225)	$ 150,709	$ 127,514						
Facilities	$ 123,854	$ -	$ -	$ 5,334	$ 14,053	$ 768	$ 20,155	$ 6,718	0.35%
Accounting	$ 1,345,223	$ 1,025,881	$ 886,205	$ 10,618	$ 10,542	$ 6,989	$ 28,149	$ 9,383	0.86%
Patient account services	$ 2,891,347	$ 2,676,142	$ 2,414,403	$ 15,880	$ 13,527	$ 23,757	$ 53,164	$ 17,721	0.67%
Deductions from revenue	$ 879,454	$ 831,713	$ 712,950						
Federal grant administration	$ (120,171)	$ (168,469)	$ (121,250)						
Statistical data center	$ 136,249	$ 108,532	$ 90,384	$ 4,814	$ 1,301	$ 9,637	$ 15,752	$ 5,251	4.70%
Communications	$ 1,243,351	$ 1,263,006	$ 1,199,553	$ 37,104	$ 5,835	$ 28,130	$ 71,069	$ 23,690	1.92%
Systems analysis service	$ 3,408,980	$ 2,159,020	$ 1,932,934	$ 3,408,980	$ 2,159,020	$ 1,932,934	$ 7,500,934	$ 2,500,311	100.00%
Computer support service	$ 1,723,176	$ 1,701,695	$ 1,858,031	$ 1,723,176	$ 1,701,695	$ 1,858,031	$ 5,282,902	$ 1,760,967	100.00%
Medical informatics	$ 744,918	$ 605,658	$ 460,779	$ 744,918	$ 605,658	$ 460,779	$ 1,811,355	$ 603,785	100.00%
Health information services	$ 1,926,620	$ 1,691,027	$ 1,568,848	$ 21,258	$ 9,792	$ 9,819	$ 40,869	$ 13,623	0.79%
UCR administration	$ 557,173	$ 3,108	$ -	$ 5,166	$ 122	$ -	$ 5,288	$ 1,763	0.94%
Dept of critical care medicine	$ 543,614	$ 488,955	$ 434,186	$ 877	$ 393	$ 936	$ 2,206	$ 735	0.15%
Physician relations	$ 410,313	$ 379,746	$ 617,088	$ 691	$ 364	$ 519	$ 1,574	$ 525	0.11%
Administrative office	$ 15,019,024	$ 13,640,157	$ 12,378,983	$ 10,334	$ (8,428)	$ 36,551	$ 38,457	$ 12,819	0.09%
Administrative nurses	$ 1,396,449	$ 1,716,442	$ 1,546,211	$ 6,865	$ 6,421	$ 8,018	$ 21,304	$ 7,101	0.46%
Women's center admin	$ 121,966	$ 110,023	$ 106,128	$ 74	$ 28	$ 610	$ 712	$ 237	0.21%
Department of OB/GYN	$ 343,827	$ 365,953	$ 380,820	$ 258	$ 468	$ 622	$ 1,348	$ 449	0.12%
Department of surgery	$ 300,072	$ 196,582	$ 162,268	$ 347	$ 2,400	$ 654	$ 3,401	$ 1,134	0.52%
Department of medicine	$ 268,302	$ 270,655	$ 179,763	$ 1,515	$ 702	$ 1,396	$ 3,613	$ 1,204	0.50%
Department of neonatology	$ 885,348	$ 832,813	$ 831,180	$ 74	$ 289	$ 407	$ 770	$ 257	0.03%
Senior services	$ 829,192	$ 648,775	$ 652,995	$ 1,817	$ 1,484	$ 255	$ 3,556	$ 1,185	0.17%
Pulmonary division	$ 807,846	$ -	$ -	$ 2,984	$ -	$ -	$ 2,984	$ 995	0.37%
Fund development	$ 4,802	$ 5,333	$ 43,969						
Medical ethics	$ 95,016	$ 47,842	$ (55,270)	$ 461	$ 1,238	$ 854	$ 2,553	$ 851	2.91%
Employee fitness center	$ 44,074	$ 43,256	$ 37,874						
Day care center	$ 845,770	$ 870,692	$ 811,114	$ 178	$ 458	$ 48	$ 684	$ 228	0.03%
Human resources	$ 1,220,523	$ 957,306	$ 695,287	$ 7,365	$ 1,641	$ 1,274	$ 10,280	$ 3,427	0.36%
Materials management	$ 1,803,704	$ 1,653,115	$ 1,438,054	$ 3,456	$ 6,500	$ 3,407	$ 13,363	$ 4,454	0.27%
Inservice education	$ 618,247	$ 666,104	$ 602,424	$ 3,669	$ 7,976	$ 15,499	$ 27,144	$ 9,048	1.44%
Medical staff	$ 44,347	$ 54,421	$ 44,379	$ 245	$ 292	$ 1,097	$ 1,634	$ 545	1.14%
Public relations	$ 324,765	$ 284,284	$ 229,419	$ 3,112	$ 13,163	$ 6,501	$ 22,776	$ 7,592	2.72%
Work redesign	$ 419,610	$ 636,867	$ -	$ 267	$ 692	$ -	$ 959	$ 320	0.09%
Volunteer service	$ 186,814	$ 208,910	$ 159,583	$ 2,201	$ 869	$ 137	$ 3,207	$ 1,069	0.58%
Quality management	$ 841,697	$ 706,280	$ 740,757	$ 16,924	$ 9,430	$ 14,549	$ 40,903	$ 13,634	1.79%
Administrative general	$ (117,586)	$ 168,498	$ 49,308						
Medical informatics	$ 40	$ 201	$ 36	$ 40	$ 201	$ 36	$ 277	$ 92	100.00%
Revenue offsets	$ (272,124)	$ (364,987)	$ (229,271)						
Totals	$ 259,558,782	$ 232,035,884	$ 222,263,449	$ 6,360,333	$ 4,832,453	$ 4,610,222	$ 15,803,008	$ 5,267,669	1.81%

Intermountain Health Care Information Technology Investments

Considered from the more global perspective of the entire health care enterprise, Intermountain Health care's overall information technology investment has been quite substantial and is projected to remain so for the foreseeable future. Table 23 displays IHC IT investments totaling approximately $157 million over approximately the decade ending with fiscal year (FY) 1998.[290] The various components of IT at IHC are in different stages of development, with approximately 63 percent of the $249.4 million total projected for IT having been invested though FY 1998. The major portion of the investment to date ($108.5 million, or 69.1 percent) has been committed to infrastructure, the IS foundation upon which specific applications must be built. Administrative applications comprise the next largest portion of IT investment to date ($39.1 million, or 24.9 percent), with only a minority of IT investment ($9.5 million, or 6 percent) having been thusfar devoted to clinical applications (Figure 26). Remarkably, capital budget numbers for IT were available only in the aggregate, not stratified into specific fiscal years.

Table 24 details current projections for IT operating expenses and capital investments for the 1999-2004 fiscal years.[290] Projected operating expenses range from $27.5 million in FY 1999 to $41.0 million in FY 2004, representing an annual increase of approximately 7.6 percent. Capital expenditure projections for FY 1999-2004 range from $19.1 million to $27.97 million per year. The trends in these IT operational and capital expenses are shown graphically in Figure 27. Capital investments are projected to peak in FY 2000 and then decline as IHC will have

Table 23
Intermountain Health Care Information Technology Costs Incurred Through Fiscal Year 1998

	Cost per node/user	Number of users	Capital cost	Current deployment	Investment to date
Infrastructure					
Network	$ 1,200	18000	$ 21,600,000	90%	$ 19,440,000
Phones (cable plant and switch)	$ 900	35000	$ 31,500,000	90%	$ 28,350,000
Security, including firewalls			$ 5,000,000	50%	$ 2,500,000
Directories, access privileges			$ 1,000,000	10%	$ 100,000
Desktop PCs	$ 2,500	18000	$ 45,000,000	75%	$ 33,750,000
Desktop management			$ 300,000	80%	$ 240,000
Hardware			$ 12,500,000	100%	$ 12,500,000
System and database software			$ 2,000,000	100%	$ 2,000,000
Master Member Index			$ 2,000,000	90%	$ 1,800,000
Clinical repository			$ 5,000,000	50%	$ 2,500,000
Data warehouse			$ 1,000,000	20%	$ 200,000
Dictionary			$ 1,000,000	70%	$ 700,000
Up-time, disaster recovery			$ 1,300,000	50%	$ 650,000
E-mail	$ 225	18000	$ 4,050,000	60%	$ 2,430,000
Interfaces			$ 4,500,000	30%	$ 1,350,000
Subtotal			$ 137,750,000		$ 108,510,000
Administrative applications					
Patient registration			$ 4,500,000	90%	$ 4,050,000
Billing and scheduling (Ambulatory)			$ 8,500,000	95%	$ 8,075,000
Billing (Hospital)			$ 3,000,000	100%	$ 3,000,000
Time and attendance			$ 750,000	90%	$ 675,000
Payroll/ personnel			$ 7,500,000	50%	$ 3,750,000
Medical records			$ 2,000,000	100%	$ 2,000,000
Accounts payable			$ 1,000,000	100%	$ 1,000,000
Health plans			$ 15,000,000	90%	$ 13,500,000
Case mix management			$ 1,000,000	100%	$ 1,000,000
General ledger			$ 1,000,000	100%	$ 1,000,000
Materials management			$ 1,000,000	100%	$ 1,000,000
Subtotal			$ 45,250,000		$ 39,050,000
Clinical applications					
Results review			$ 2,000,000	30%	$ 600,000
Store HELP data in HEMS			$ 1,000,000	30%	$ 300,000
Order communication			$ 4,000,000		
Order entry			$ 4,000,000	0%	$ -
Laboratory			$ 3,000,000	80%	$ 2,400,000
Pharmacy robot			$ 1,500,000	50%	$ 750,000
Pharmacy robot			$ 2,000,000		
Radiology			$ 2,000,000		
Ambulatory practice			$ 4,000,000	20%	$ 800,000
PACS			$ 6,000,000	0%	$ -
Library, medline, micromedix			$ 300,000	10%	$ 30,000
Alerts, reminders, suggestions			$ 1,000,000	30%	$ 300,000
ICU	$ 10,000	150	$ 1,500,000		
Disease management			$ 5,000,000		
Blood bank			$ 500,000		
Radiation therapy					
Social work service					
Neurology			$ 25,000		
Intraoperative/ anesthesiology			$ 2,000,000		
Surgery scheduling/ reporting			$ 1,500,000	10%	$ 150,000
Nurse staffing			$ 300,000	50%	$ 150,000
Nurse charting			$ 2,000,000		
Home care			$ 1,500,000	90%	$ 1,350,000
Anatomic pathology			$ 3,000,000	40%	$ 1,200,000
Cardiology tests			$ 500,000		$ 100,000
Cath lab			$ 500,000	20%	$ 100,000
Labor and delivery			$ 500,000	30%	$ 150,000
Patient access			$ 3,000,000		
Physical therapy/ rehabilitation			$ 25,000		
Dietary			$ 500,000	20%	$ 100,000
Tumor registry			$ 300,000	100%	$ 300,000
Respiratory therapy/ pulmonary function			$ 200,000		
Text management/ speech recognition			$ 1,000,000		
Report generation tool			$ 200,000		
Enterprise scheduling			$ 3,000,000	20%	$ 600,000
Quality assurance			$ 200,000	75%	$ 150,000
Subtotal			$ 58,050,000		$ 9,530,000
Contingency/ Mandated needs			$ 8,396,000		
Total			$ 249,446,000		$ 157,090,000

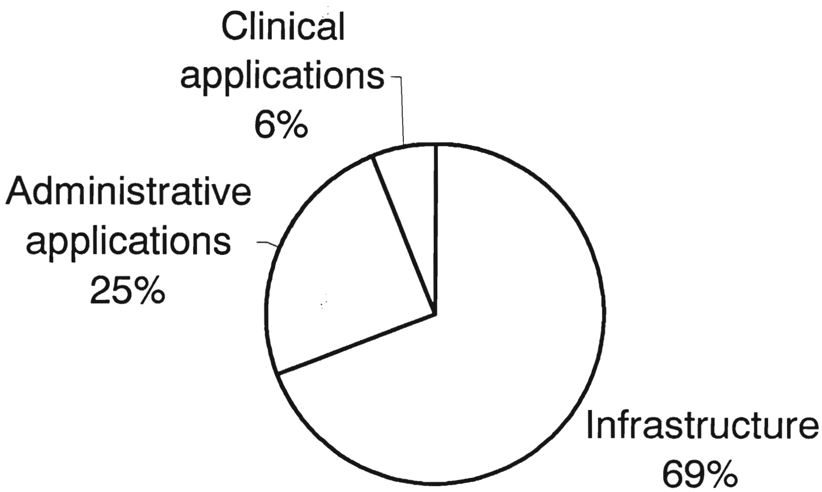


Figure 26
Intermountain Health Care
Distribution of Information Technology Investments through FY 1998

Table 24
Intermountain Health Care
Projected Information Technology Costs

	1999		2000		2001	
	Operating expenses	Capital expenditures	Operating expenses	Capital expenditures	Operating expenses	Capital expenditures
Infrastructure						
Network	$ 3,304,800	$ 1,000,000	$ 3,474,800	$ 1,000,000	$ 3,672,000	$ 1,000,000
Phones (cable plant and switch)	$ 4,819,500	$ 200,000	$ 4,853,500	$ 200,000	$ 4,887,500	$ 200,000
Security, including firewalls	$ 425,000	$ 750,000	$ 552,500	$ 750,000	$ 680,000	$ 750,000
Directories, access privileges	$ 17,000	$ 100,000	$ 34,000	$ 500,000	$ 119,000	$ 100,000
Desktop PCs	$ 5,737,500	$ 5,000,000	$ 5,737,500	$ 7,500,000	$ 7,650,000	$ 7,500,000
Desktop management	$ 40,800	$ 50,000	$ 49,300	$ 10,000	$ 51,000	
Hardware	$ 2,125,000	$ 2,000,000	$ 2,125,000	$ 2,000,000	$ 2,125,000	$ 2,000,000
System and database software	$ 340,000		$ 340,000		$ 340,000	$ 100,000
Master Member Index	$ 306,000	$ 150,000	$ 331,500	$ 150,000	$ 357,000	
Clinical repository	$ 425,000	$ 500,000	$ 510,000	$ 1,000,000	$ 680,000	$ 500,000
Data warehouse	$ 34,000	$ 300,000	$ 85,000	$ 150,000	$ 110,500	$ 50,000
Dictionary	$ 119,000	$ 300,000	$ 170,000	$ 150,000	$ 195,500	$ 50,000
Up-time, disaster recovery	$ 110,500	$ 200,000	$ 144,500	$ 200,000	$ 178,500	$ 200,000
E-mail	$ 413,100	$ 225,000	$ 451,350	$ 225,000	$ 489,600	$ 225,000
Interfaces	$ 229,500	$ 500,000	$ 314,500	$ 1,000,000	$ 484,500	$ 1,000,000
Subtotal	$ 18,446,700	$ 11,275,000	$ 19,173,450	$ 14,835,000	$ 22,020,100	$ 13,675,000
Administrative applications						
Patient registration	$ 688,500	$ 100,000	$ 705,500	$ 200,000	$ 739,500	$ 50,000
Billing and scheduling (Ambulatory)	$ 1,372,750	$ 100,000	$ 1,389,750	$ 100,000	$ 1,406,750	$ 100,000
Billing (Hospital)	$ 510,000		$ 510,000		$ 510,000	
Time and attendance	$ 114,750	$ 50,000	$ 123,250	$ 25,000	$ 127,500	
Payroll/ personnel	$ 637,500	$ 2,000,000	$ 977,500	$ 1,500,000	$ 1,232,500	$ 20,000
Medical records	$ 340,000		$ 340,000		$ 340,000	
Accounts payable	$ 170,000		$ 170,000		$ 170,000	
Health plans	$ 2,295,000	$ 300,000	$ 2,346,000	$ 300,000	$ 2,397,000	$ 200,000
Case mix management	$ 170,000		$ 170,000		$ 170,000	
General ledger	$ 170,000		$ 170,000		$ 170,000	
Materials management	$ 170,000		$ 170,000		$ 170,000	
Subtotal	$ 6,638,500	$ 2,550,000	$ 7,072,000	$ 2,125,000	$ 7,433,250	$ 370,000
Clinical applications						
Results review	$ 102,000	$ 200,000	$ 136,000	$ 700,000	$ 255,000	$ 400,000
Store HELP data in HEMS	$ 51,000	$ 300,000	$ 102,000	$ 400,000	$ 170,000	
Order communication	$ 240,000		$ 240,000	$ 500,000	$ 85,000	$ 1,500,000
Order entry	$ -	$ 100,000	$ 17,000	$ 500,000	$ 102,000	$ 1,500,000
Laboratory	$ 408,000		$ 408,000		$ 408,000	
Pharmacy robot	$ 127,500	$ 750,000	$ 255,000		$ 255,000	
Pharmacy robot	$ 144,000		$ 144,000	$ 500,000	$ 85,000	$ 1,000,000
Radiology	$ 96,000		$ 96,000		$ 96,000	$ 500,000
Ambulatory practice	$ 136,000	$ 200,000	$ 170,000	$ 1,000,000	$ 340,000	$ 1,000,000
PACS	$ -		$ -		$ -	
Library, medline, micromedix	$ 5,100	$ 50,000	$ 13,600	$ 200,000	$ 47,600	$ 50,000
Alerts, reminders, suggestions	$ 51,000	$ 100,000	$ 68,000	$ 200,000	$ 102,000	$ 200,000
ICU	$ 108,000		$ 108,000		$ 108,000	
Disease management	$ -	$ 200,000	$ 34,000	$ 1,000,000	$ 204,000	$ 1,000,000
Blood bank	$ 40,000		$ 40,000	$ 250,000	$ 42,500	$ 250,000
Radiation therapy	$ -		$ -		$ -	
Social work service	$ -		$ -		$ -	
Neurology	$ 2,000		$ 2,000		$ 2,000	
Intraoperative/ anesthesiology	$ 48,000		$ 48,000		$ 48,000	$ 500,000
Surgery scheduling/ reporting	$ 25,500	$ 300,000	$ 76,500	$ 800,000	$ 212,500	$ 200,000
Nurse staffing	$ 25,500		$ 25,500		$ 25,500	
Nurse charting	$ 80,000		$ 80,000	$ 500,000	$ 165,000	$ 1,000,000
Home care	$ 229,500		$ 229,500		$ 229,500	
Anatomic pathology	$ 204,000	$ 1,000,000	$ 374,000	$ 800,000	$ 510,000	
Cardiology tests	$ 17,000		$ 17,000		$ 17,000	$ 200,000
Cath lab	$ 17,000		$ 17,000		$ 17,000	
Labor and delivery	$ 25,500	$ 200,000	$ 59,500	$ 200,000	$ 93,500	$ 100,000
Patient access	$ -	$ 100,000	$ 17,000	$ 300,000	$ 68,000	$ 500,000
Physical therapy/ rehabilitation	$ 1,000		$ 1,000		$ 1,000	
Dietary	$ 17,000	$ 100,000	$ 34,000	$ 200,000	$ 68,000	$ 100,000
Tumor registry	$ 51,000		$ 51,000		$ 51,000	
Respiratory therapy/ pulmonary function	$ 8,000		$ 8,000		$ 8,000	
Text management/ speech recognition		$ 100,000	$ 17,000	$ 300,000	$ 68,000	$ 200,000
Report generation tool	$ 9,600	$ 100,000	$ 17,000	$ 100,000	$ 34,000	
Enterprise scheduling	$ 102,000		$ 102,000		$ 102,000	
Quality assurance	$ 25,500	$ 30,000	$ 30,600	$ 20,000	$ 34,000	
Subtotal	$ 2,396,700	$ 3,830,000	$ 3,038,200	$ 8,470,000	$ 4,054,100	$ 10,200,000
Contingency/ Mandated needs		$ 1,765,500	$ 300,135	$ 2,543,000	$ 732,445	$ 2,424,500
Totals	$ 27,481,900	$ 19,420,500	$ 29,583,785	$ 27,973,000	$ 34,239,895	$ 26,669,500
Year total	$	46,902,400	$	57,556,785		$ 60,909,395

Table 24 continued

	2002		2003		2004	
	Operating expenses	Capital expenditures	Operating expenses	Capital expenditures	Operating expenses	Capital expenditures
Infrastructure						
Network	$ 3,672,000	$ 1,000,000	$ 3,672,000	$ 1,000,000	$ 3,672,000	$ 1,000,000
Phones (cable plant and switch)	$ 4,921,500	$ 200,000	$ 4,955,500	$ 200,000	$ 4,989,500	$ 200,000
Security, including firewalls	$ 807,500	$ 250,000	$ 850,000	$ 100,000	$ 867,000	$ 100,000
Directories, access privileges	$ 136,000	$ 100,000	$ 153,000	$ 100,000	$ 170,000	$ 100,000
Desktop PCs	$ 7,650,000	$ 7,500,000	$ 7,650,000	$ 7,500,000	$ 7,650,000	$ 7,500,000
Desktop management	$ 51,000		$ 51,000		$ 51,000	
Hardware	$ 2,125,000	$ 2,000,000	$ 2,125,000	$ 2,000,000	$ 2,125,000	$ 2,000,000
System and database software	$ 357,000		$ 357,000	$ 100,000	$ 374,000	
Master Member Index	$ 357,000		$ 357,000		$ 357,000	
Clinical repository	$ 765,000	$ 500,000	$ 850,000		$ 850,000	
Data warehouse	$ 119,000		$ 119,000		$ 119,000	
Dictionary	$ 204,000	$ 50,000	$ 212,500	$ 50,000	$ 221,000	$ 50,000
Up-time, disaster recovery	$ 212,500	$ 50,000	$ 221,000		$ 221,000	
E-mail	$ 527,850	$ 225,000	$ 566,100	$ 225,000	$ 604,350	$ 225,000
Interfaces	$ 654,500	$ 250,000	$ 697,000	$ 200,000	$ 731,000	$ 200,000
Subtotal	$ 22,559,850	$ 12,125,000	$ 22,836,100	$ 11,475,000	$ 23,001,850	$ 11,175,000
Administrative applications						
Patient registration	$ 748,000	$ 50,000	$ 756,500	$ 50,000	$ 765,000	$ 2,000,000
Billing and scheduling (Ambulatory)	$ 1,423,750	$ 100,000	$ 1,440,750	$ 25,000	$ 1,445,000	
Billing (Hospital)	$ 510,000		$ 510,000		$ 510,000	
Time and attendance	$ 127,500		$ 127,500		$ 127,500	
Payroll/ personnel	$ 1,235,900	$ 50,000	$ 1,244,400		$ 1,244,400	
Medical records	$ 340,000		$ 340,000		$ 340,000	
Accounts payable	$ 170,000		$ 170,000		$ 170,000	
Health plans	$ 2,431,000	$ 200,000	$ 2,465,000	$ 200,000	$ 2,499,000	$ 200,000
Case mix management	$ 170,000		$ 170,000		$ 170,000	
General ledger	$ 170,000		$ 170,000		$ 170,000	
Materials management	$ 170,000		$ 170,000		$ 170,000	
Subtotal	$ 7,496,150	$ 400,000	$ 7,564,150	$ 275,000	$ 7,610,900	$ 2,200,000
Clinical applications						
Results review	$ 323,000	$ 100,000	$ 340,000		$ 340,000	
Store HELP data in HEMS	$ 170,000		$ 170,000		$ 170,000	
Order communication	$ 340,000	$ 1,500,000	$ 595,000	$ 500,000	$ 680,000	
Order entry	$ 357,000	$ 1,000,000	$ 527,000	$ 900,000	$ 680,000	
Laboratory	$ 408,000		$ 408,000		$ 408,000	
Pharmacy robot	$ 255,000		$ 255,000		$ 255,000	
Pharmacy robot	$ 255,000	$ 500,000	$ 340,000		$ 340,000	
Radiology	$ 85,000	$ 1,000,000	$ 255,000	$ 500,000	$ 340,000	
Ambulatory practice	$ 510,000	$ 500,000	$ 595,000	$ 400,000	$ 663,000	$ 100,000
PACS	$ -	$ 1,000,000	$ 170,000	$ 2,000,000	$ 510,000	$ 200,000
Library, medline, micromedix	$ 56,100		$ 56,100		$ 56,100	
Alerts, reminders, suggestions	$ 136,000	$ 200,000	$ 170,000		$ 170,000	
ICU	$ 108,000		$ 108,000	$ 500,000	$ 85,000	$ 1,000,000
Disease management	$ 374,000	$ 1,000,000	$ 544,000	$ 1,000,000	$ 714,000	$ 800,000
Blood bank	$ 85,000		$ 85,000		$ 85,000	
Radiation therapy	$ -		$ -		$ -	
Social work service	$ -		$ -		$ -	
Neurology	$ 2,000		$ 2,000		$ 2,000	
Intraoperative/ anesthesiology	$ 133,000	$ 1,000,000	$ 303,000	$ 500,000	$ 388,000	
Surgery scheduling/ reporting	$ 246,500	$ 50,000	$ 255,000		$ 255,000	
Nurse staffing	$ 25,500		$ 25,500		$ 51,000	
Nurse charting	$ 335,000	$ 500,000	$ 420,000	$ 150,000	$ 420,000	
Home care	$ 229,500		$ 229,500		$ 229,500	
Anatomic pathology	$ 510,000		$ 510,000		$ 510,000	
Cardiology tests	$ 51,000	$ 200,000	$ 85,000	$ 100,000	$ 102,000	
Cath lab	$ 17,000	$ 250,000	$ 59,500	$ 150,000	$ 85,000	
Labor and delivery	$ 110,500		$ 110,500		$ 110,500	
Patient access	$ 153,000	$ 500,000	$ 238,000	$ 500,000	$ 323,000	$ 500,000
Physical therapy/ rehabilitation	$ 1,000		$ 1,000		$ 1,000	
Dietary	$ 85,000		$ 85,000		$ 85,000	
Tumor registry	$ 51,000		$ 51,000		$ 51,000	
Respiratory therapy/ pulmonary function	$ 8,000		$ 8,000	$ 100,000	$ 25,000	$ 100,000
Text management/ speech recognition	$ 102,000	$ 200,000	$ 136,000	$ 100,000	$ 153,000	$ 100,000
Report generation tool	$ 34,000		$ 34,000		$ 34,000	
Enterprise scheduling	$ 102,000		$ 102,000	$ 500,000	$ 187,000	$ 1,000,000
Quality assurance	$ 34,000		$ 34,000		$ 34,000	
Subtotal	$ 5,692,100	$ 9,500,000	$ 7,307,100	$ 7,900,000	$ 8,542,100	$ 3,800,000
Contingency/ Mandated needs	$ 1,144,610	$ 2,202,500	$ 1,519,035	$ 1,965,000	$ 1,853,085	$ 1,737,500
Totals	$ 36,892,710	$ 24,227,500	$ 39,226,385	$ 21,615,000	$ 41,007,935	$ 18,912,500
Year total		$ 61,120,210		$ 60,841,385		$ 59,920,435

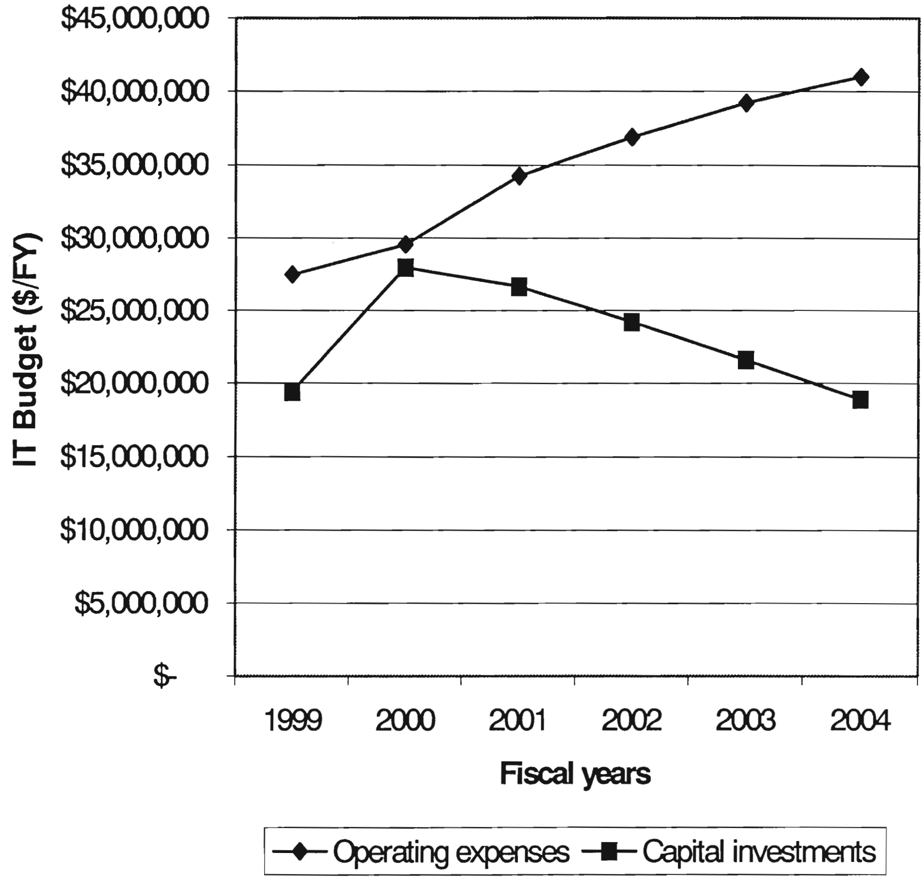


Figure 27
Intermountain Health Care Information Technology Budget Projections

constructed much of the infrastructure and specific applications necessary to support its information systems initiatives in both the clinical and administrative spheres. Operating expenses, by contrast, are projected to steadily increase throughout the 1999-2004 time period as IS becomes more completely ingrained into the fabric of IHC's operations. The distribution of the total projected capital investment for FY 1999-2004 is represented in Figure 28. Compared to the IT investment through FY 1998 (Figure 26, page 192), proportional future investments in clinical applications are projected to increase fivefold while those in infrastructure will decrease modestly and those in administrative applications will decrease substantially. These shifts reflect changes in funding emphasis as IHC's IT platforms exit the developmental phase and become an established component of health care operations. Clinical applications are projected to consume between $6.2 million and $15.2 million annually through 2004.

The relationship IHC's capital investment in information technology and overall corporate revenue is shown in Figure 29. The corporate revenue data reflect actual experience from 1995 through 1998, while the IT capital investment data are projections from 1999 through 2004. Directly comparable data for the same fiscal years are not available. The actual experience of IT capital investment prior to the current year would better illustrate the relationship (if any) between the two sets of data. It is not certain that any such connection exists, and the work of Strassman suggests the contrary.[119, 124, 138, 139]

As noted previously in regard to LDS Hospital's IT investments, the above IHC corporate data must be also considered in proper context. These numbers reflect

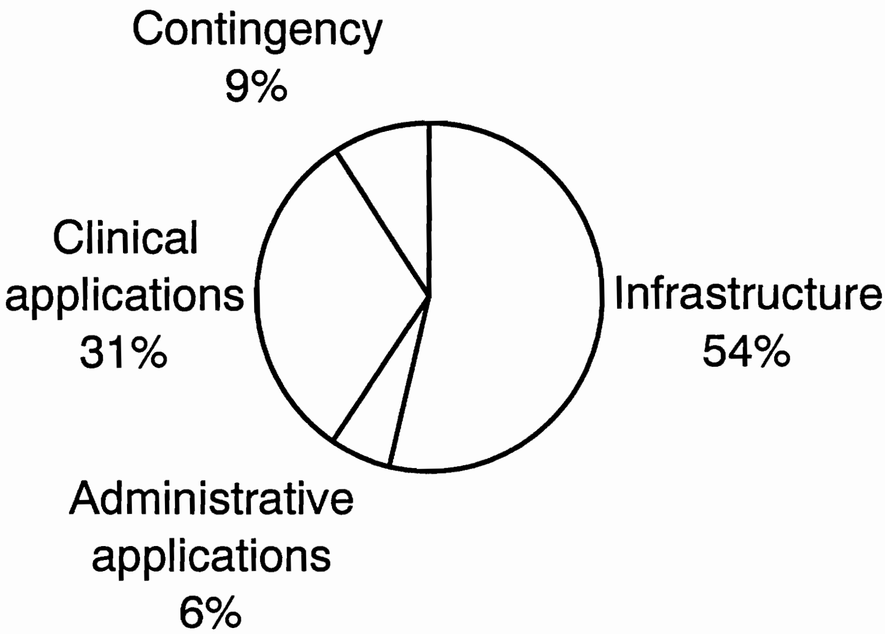


Figure 28
Intermountain Health Care
Projected Distribution of IT Investments, FY 1999-2004

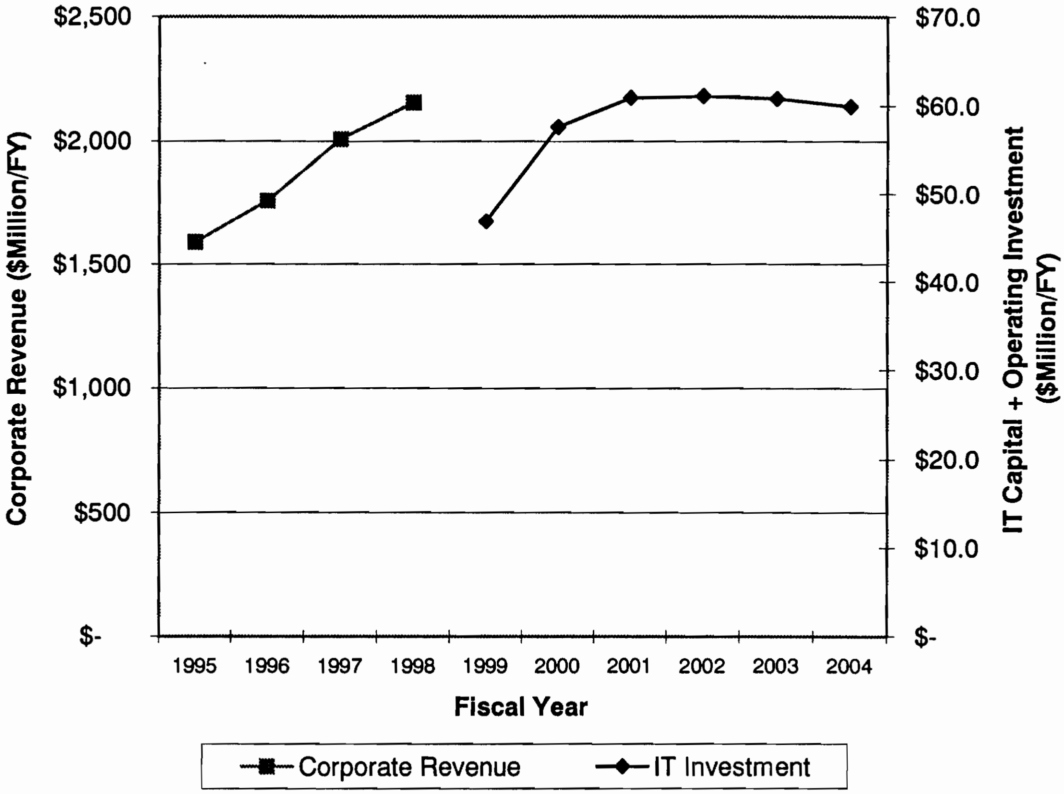


Figure 29
Intermountain Health Care
Revenue and Information Technology Capital Investments

the totality of IHC's IT investments of all types and are not constrained solely to health information systems. As already noted, separating out a given HIS as a distinct accounting entity amidst the totality of IHC's information technology expenditures is not readily supported by the existing accounting system.

Benchmarks

Caveat. Benchmark data from the IT and healthcare industries allow the above IHC numbers to be placed in some perspective. Benchmarks, however, must be employed judiciously and with an appreciation of their shortcomings. Comparing IT operating expenses and capital investment between institutions can be highly misleading given the implicit assumption that the different institutions in question are comparable. In reality, rarely are any two health care enterprises truly comparable. Differences in patient demographics, severity of illness, clinical services, staffing, areas of expertise, marketing, and other factors contribute to the difficulty in making simplistic financial comparisons between institutions. Even were such sources of variation controlled for, any head-to-head comparison of IT funding between institutions requires an appreciation of the inevitable differences in information system functionality. Two institutions spending comparable amounts on IT are not at all likely to achieve identical or even similar IS functionality given the multiple developmental and implementation pathways inherent in any such complex system.

External. Comparison figures for capital and operational expenditures for the University of Utah Health Sciences Center (UUHSC) are shown in Table 25. Considered on the basis of the level of total IT funding (operating expenditures plus

Table 25
University of Utah Health Sciences Center
Information Technology Capital and Operating Expenditures
FY 1996-2000

Fiscal Year	Capital Expenditures	Operating Expenditures
1996	NA	$6.5 million
1997	$2 million	$6.8 million
1998	$2 million	$8.9 million
1999	$4.5 million	NA
2000	$4.5 million	NA

NA = Not available

Source: Pincetl.[297]

capital investment) as a proportion of overall health sciences center revenues of $612 million, UUHSC spent 1.9 percent of revenue on IT in the 1997-98 fiscal year. (This ratio increases to 2.7 percent if only clinical revenues of $437 million are considered, but the smaller percentage is considered more directly comparable to IHC's value which is calculated on the basis of overall net revenue, not clinical revenue only.) These UUHSC values contrast with IHC which has budgeted $46.9 million ($27.5 million operating expenses plus $19.4 million capital investment) for FY 1999. Assuming that net revenues hold flat at $1.68 billion from the reported figures for FY 1998 (Appendix A), IHC is projected to spend 2.8 percent of revenues on IT. The comparison of different fiscal years introduces possible error but is unavoidable given the incomplete data; the greater level of IT funding by IHC is noteworthy. These numbers should be considered in the context of the Rubin benchmark data indicating an average IT expenditure for health care organizations of 2.77 percent of revenue: At 2.8 percent, IHC is near this average value and exceeds UUHSC's IT funding of 1.9 percent by nearly 50 percent. The relative levels of IS functionality at the two institutions are quite different in keeping with the substantially different levels of IT funding. The META Group data relative to its six levels of IT development consider only operating expenditures, not capital investments. The operating expenditure ratios for both UUHSC and IHC are low on the META Group scale (1.45 percent and 1.64 percent, respectively), suggesting either problems with the model or inaccuracies in the component numbers from which the UUHSC and IHC ratios are derived.

Internal. Internal benchmarks would be available if data regarding the level of IT investment at the other IHC hospitals which have installed the HELP system were available for comparison to those from LDS Hospital. Although hospital IT funding is now more obscure since it is derived from the corporate rather than the individual hospital budgets, the "corporate data processing charge" noted in Table 20 (page 184) offers a method to track the level of IT funding at different IHC hospitals. This individual IHC hospital IT financial information was requested but was not provided secondary to IHC management confidentiality concerns.

Outcomes

Framework

The numerator of the value equation [6] is outcome. As discussed above, outcome may be considered in terms of benefits and dis-benefits. The former term is often used colloquially to encompass the net summation of these two concepts.

Benefits are less well characterized as compared to their more quantifiable counterparts costs, which as discussed above are themselves less well characterized than might be expected. IHC has not expended a great deal of effort to identify or to quantitate the benefits of its health information systems. In any consideration of HIS benefits, the question of how much effort to expend quantifying the impacts must be addressed either explicitly or implicitly. A decision to quantify requires additional choices on how to measure and to what level of precision.

Assessing benefits from a functional standpoint, to the extent that clinical computing and health information systems confer benefits, they may be categorized into four types:

1. **Strategic benefits:** those benefits improving the enterprise's competitive position *vis-à-vis* its competitors;
2. **Productivity benefits**: those benefits improving the enterprise's productivity, allowing the same work to be accomplished with fewer resources or more work to be accomplished with the same resources;
3. **Quality benefits:** those benefits allowing the enterprise to perform its work with fewer errors or unnecessary steps; and
4. **Innovation benefits:** those benefits allowing the enterprise to perform tasks of which it would otherwise be incapable without the assistance of information systems.

The interrelationship of these four types of benefits is shown diagrammatically in Figure 30. A given beneficial effect may have characteristics allowing it to be classified in more than one of the above categories.

Identification of IHC Health Information Systems Benefits

The initial step in establishing outcomes from health information systems lies in identifying those benefits which arise from the use of these systems. Utilizing the above categorization and building from the potential benefits of the IHC Clinical Workstation as detailed by Bowes,[275] a representative framework of clinical information system benefits is listed in Table 26.

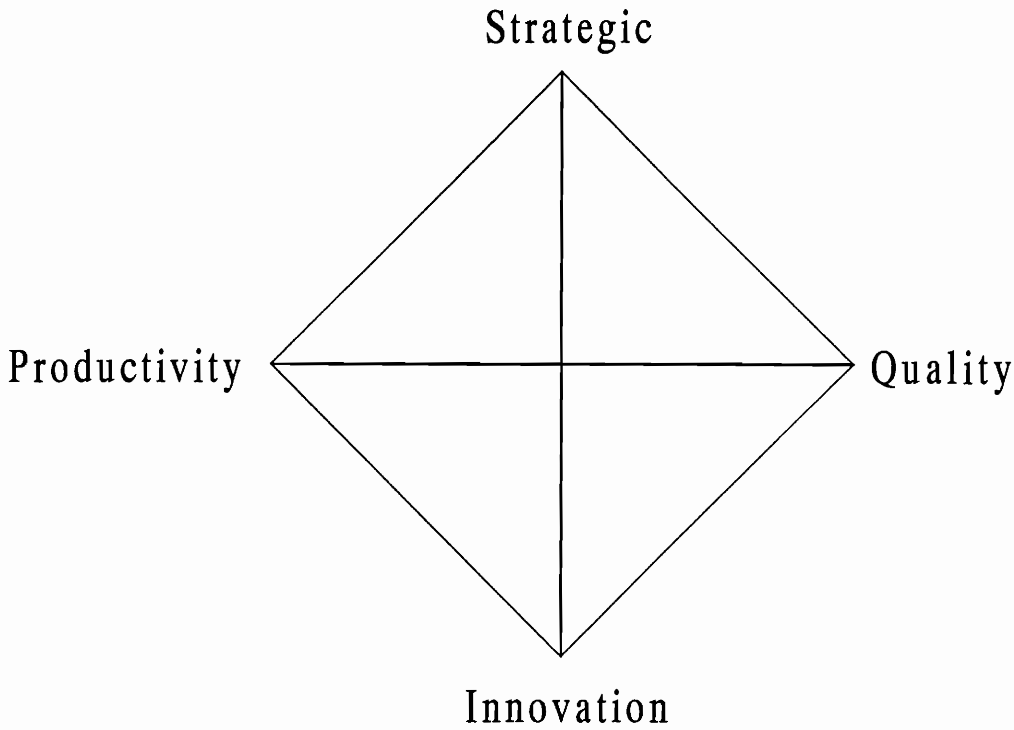


Figure 30
Types of Benefits from Health Information Systems

Table 26
Intermountain Health Care
Health Information System Benefits

Benefit type	Benefit
Strategic	S1: Increased market share S2: Staff recruitment S3: Data availability for multiple uses S4: Improved population health
Productivity	P 1: Improved chart efficiency P1.1: Decreased transcription costs P1.2: Decreased documentation costs P1.3: Decreased chart pulls P1.4: Decreased chart storage costs P1.5: Improved access to patient information P2: Increased internal referrals P3: Improved profiling of providers/ patients P3.1: Improved disease profiling P3.2: Improved drug profiling P3.3: Improved procedure monitoring P3.4: Improved practice pattern monitoring P4: Facilitated formulary use P5: Backup for IDX downtime P6: Improved billing efficiency P6.1: Improved charge capture P6.2: Improved billing staff productivity P6.3: Improved billing accuracy

Table 26 continued

Benefit type	Benefit
Quality	Q1: Improved clinical outcomes
	Q2: Improved patient documentation Q2.1: Improved organization of medical record Q2.2: Increased standardization of dictation Q2.3: Improved medication management Q2.4: Improved chart access
	Q3: Improved decision support Q3.1: Improved medication alerts and support Q3.2: Improved preventive care reminders and tracking Q3.3: Improved guideline compliance
	Q4: Improved decision making
	Q5: Improved communication
	Q6: Reduced duplication of diagnostic tests
	Q7: Decreased time on phone with patients
	Q8: Improved tracking of referred patients
	Q9: Improved tracking of system manipulators
	Q10: Improved regulatory compliance Q10.1: Fraud prevention Q10.2: Regulatory compliance Q10.3: Mandated reports (JCAHO, HCFA, HEDIS)
	Q11: Reduced malpractice premiums
	Q12: Improved patient satisfaction
	Q13: Provider perception of improved care
Innovation	I1: Reduced time to market new products

Adapted from [275]. Used with permission.

Quantification of IHC Health Information Systems Benefits

The second step in establishing outcomes from health information systems lies in quantifying those benefits which arise from the use of these systems. This constitutes the more difficult task. Benefits may be grouped into those that may be quantified directly or indirectly and those that do not appear to be readily quantifiable; many benefits clearly exist but are difficult to measure. This approach gives rise to a benefit hierarchy:

- Benefits
  - Quantifiable benefits
    - Directly quantifiable
    - Indirectly quantifiable
  - Unquantifiable benefits

No specific benefit measures have been undertaken for the present thesis.

Dis-benefits

The impacts of information systems are not exclusively positive; every such intervention has costs (both financial and otherwise) as well as benefits. The latter tend to receive much greater attention than the former, but both unquestionably exist in differing degrees. A brief listing of the obvious dis-benefits of health information systems includes the following.

1. The most obvious dis-benefit of health information systems is cost. These systems are notoriously expensive in absolute dollars, typically much more

so than initially projected. The basic price tag for a HIS is theoretically incorporated within the cost variable residing in the denominator of the value equation. This quantity is actually the direct cost of the HIS, typically incorporating costs for hardware acquisition, software acquisition, installation and a degree of employee training. Omitted from this direct cost are various indirect costs related to employee training expenses (such as time lost from their usual activities while employees are otherwise involved in training) and costs attendant with ongoing system support, upgrades and maintenance. “Total Cost of Ownership” (TCO) is a concept that attempts to incorporate these other considerations by combining both direct and indirect costs together to arrive at a global information system cost.[298, 299]

2. While information systems produce cost savings in certain areas, it has been observed that these cost savings are typically consumed by the costs involved in developing, implementing and maintaining the information systems themselves. Expressed formulaically,

$$\text{Costs}_{\textit{AFTER}\ \text{HIS}} \cong \left(\text{Costs}_{\text{BEFORE HIS}} - \text{Cost savings}\right) + \text{HIS costs} \qquad [9]$$

This observation is anecdotal and without evidence, but does offer a plausible explanation for the observation that those organizations implementing HIS do not find themselves with large amounts of excess funds at the end of the fiscal year.[71, 300]

3. The introduction of health information systems clearly changes the organization, resulting in a type of cultural ingraining which fundamentally alters the organization itself as well as its response to challenges.[301, 302] The incorporation of computing into daily patient care operations is a one way transition with no easy return along the same path to the *status quo ante*. This phenomenon was a clear subtheme in several interviews.[70, 71, 273, 274, 285, 287, 290, 292, 293, 300, 303-306] Evidence for this cultural ingraining is also found in surveys of health care workers done at LDS Hospital to evaluate acceptance of the HELP system.[110]
4. Such cultural ingraining, although pervasive, seldom results in unanimous adoption of health information systems as the uniform method of doing business. Despite implementation and educational efforts, holdouts and non-adopters always remain.[109, 110] Successful use of a HIS requires that the user at least partially shape his medical practice to conform with the demands of the system, a concession a minority of practitioners remain unwilling to make.[67, 307]
5. Additional evidence for an irreversible change in the enterprise is found in the existence of formal procedures to operate LDS Hospital in the face of a computer system breakdown. Although remarkably reliable with little downtime, the HELP system does have brief periods of unavailability. The most recent HELP system uptime data show system availability at 99.46 percent for 1998 and 99.77 percent thusfar for 1999.[308] In a hospital such as LDS where the computer system has become an integral part of clinical

care and support functions, the unavailability of the computer has the potential to seriously disrupt hospital operations. For this reason a "Computer Downtime Procedures" manual has been created to offer guidance in just such a situation.[309] This 53-page manual details by department specific procedures to be used to cope with an outage of the HELP system. Included are 14 downtime paper forms specifically designed for use only during computer system outages to record patient data and to order supplies, laboratory studies, and radiographic studies. The existence of such a manual is an indicator of the degree to which clinical computing has become the standard of patient care within LDS Hospital. Employee dissatisfaction with the inconvenience of relying on such a backup measure is indicative of the degree to which clinical computing has become the standard of care at LDS Hospital.[300]

DISCUSSION

There are plenty of good ideas if only they can be backed

with power and brought into reality.

Winston Churchill[310] (page 131)

There is nothing quite so complicated as simplicity.

Charles Poore[112] (page 769)

Overview

The data generated for this thesis present a complex picture of the state of affairs relating to the valuation of health information systems. This inevitable complexity may be distilled to a nucleus of basic concepts:

1. Historically, the development of health information systems has focused on feasibility. Only now with the ability of HISs to impact patient care having been amply demonstrated coupled with the advent of managed care has attention begun to focus on the evaluation of this innovation in health care delivery.
2. Having been developed incrementally over 40+ years without an eye toward the ultimate financial evaluation of this technology, a detailed

financial accounting of the genesis of the HELP system cannot be reconstructed. The pertinence of such startup costs would be in doubt in any case given the major technological advances in computer hardware, software, and systems resulting in markedly improved functionality at reduced cost. Technology has not been held static but has contributed a constantly shifting foundation upon which health information systems have been developed. Nevertheless, the seminal importance of the HELP system as a catalyst in the emergence of health information systems cannot be overemphasized.

3. Intermountain Health Care has invested and continues to invest substantial sums in its information technology. Approximately $158 million has been committed to date, and another $40 to $60 million is projected annually through FY 2004.
4. IHC's IT funding for clinical applications is increasing, while that for administrative and infrastructure is decreasing.
5. Similarly, LDS Hospital has invested and continues to invest substantial sums in its information technology. The LDS Hospital IT budget exceeds $5 million annually.
6. The HELP system coexists with other LDS Hospital information systems, rendering the identification of system-specific costs difficult to impossible.
7. With a few exceptions, information system benefits have thusfar been poorly identified and quantitated. IHC has commenced collaboration with the Scottsdale Institute to devise a framework for a standardized set of

measures to assess information system impacts in a consistent fashion between integrated delivery systems.

8. The technique of benchmarking is highly dependent upon the particular metrics chosen for comparing institutions, as well as the underlying comparability of the institutions themselves. Simplistic comparisons of financial ratios may easily overlook inevitable and important differences in information system functionality. While popular with administrators, benchmarking must thus be employed with caution.

9. The Holy Grail of a single readily determined global measure of health information system value does not exist. Amidst conflicting methodologies for valuing information systems, no single clearly superior approach has emerged. A pragmatic approach to this question must strike a reasonable balance between explicit, meticulous justification of every information system component versus a *laissez-faire* attitude. Ultimately, every health care enterprise must generate its own answer to the question,

   "How much time and effort must we invest in formal justification of this technology to management?"

   The correct answer is obscure, but must be derived keeping in perspective the fact that health information systems are rapidly approaching the status of essential infrastructure to compete in today's health care marketplace. Traditionally, the value of certain infrastructure such as the telephone has been so self-evident as to exempt it from formal cost justification. Health information systems are at this threshold, although the greater magnitude of capital investment does require close scrutiny of such major financial commitments, particularly with regard to the levels of system functionality. Health information systems remain a new technology for which industry standards are still incomplete and evolving rapidly. Once the industry approaches an equilibrium, a degree of information system standardization should surface. It must become possible to purchase a system with a specific baseline of functionality that will at a minimum perform certain basic tasks essential for any health care enterprise.

Accounting Challenges

In order to consider the fundamental building blocks of value, namely costs and outcomes, it is essential that the enterprise operate a system for data collection and reporting. For ease of discussion, this system is referred to as an accounting system, although in its most common usage within the business domain accounting is solely concerned with monetary values. To properly consider the value of health information systems, accounting must be reconsidered in a more global context as a mechanism to recognize and record important quantities, both financial and otherwise.

It is important to appreciate that existing accounting systems have arisen with an altogether different focus not ideally suited for the operations of the modern healthcare enterprise. The typical business accounting system is designed to track budgets, revenues and costs on departmental, divisional and enterprise-wide levels. Such is the hierarchical accounting system encountered in the research for this thesis:

IHC overall budget

IHC corporate information systems budget

Hospital budget

Hospital department budget

Accounts

Transactions.

While such a traditional orientation may have validity for a manufacturing firm, it is ill-suited to the fiscal, competitive and quality improvement realities of the service-oriented healthcare marketplace. In order to optimize its operations, the healthcare enterprise must be able to not simply track revenue and costs, but to identify these quantities per unit of service. The revenue and costs for the Department of Surgery are important, but the more important perspective from the standpoint of quality improvement is the ability to track these quantities in terms of procedure, e.g., revenue and costs per laparoscopic cholecystectomy. From the competitive point of view, the ability to perform this laparoscopic cholecystectomy less expensively than other hospitals in the area is the foundation for competitive advantage. For other illnesses which are not as concisely addressed as cholecystitis, a perspective embracing a longer time interval (often termed an "episode of care") will be necessary. Caring for the patient with carcinoma of the breast, for example, encompasses an entire list of health care interventions and services which, depending upon the individual patient's circumstances, may include diagnostic radiology, surgery, anatomical pathology, laboratory tests, chemotherapy, radiation therapy, physical therapy, psychology, and pharmacy. To know the costs involved in caring for a representative breast cancer patient, an "episode of care" point of view is essential.

The same accounting phenomenon is evident in the search for value in health information systems. IT costs tend to be accounted for on a departmental, hospital, or enterprise-wide basis rather on the basis of a given application or information system platform. This is the reason tracing the costs and benefits of the HELP system has been so difficult: the accounting threads are totally tangled and no one at IHC can readily identify what HELP costs for any given fiscal year, much less over the lifetime of the system.

Compounding the health care information system accounting problem is a phenomenon known as suboptimization.[304, 311] Suboptimization is embodied in the perversion and undermining of organizational goals in favor of parochial interests; this phenomenon has been termed "organizational schizophrenia" by James. Briefly stated, when budget dollars are invested in a health information system or in a specific computer application, the impacts as measured by dollars are commonly felt not in the information systems department making the investment but in the relevant clinical department or in ancillary departments. The Antibiotic Assistant application's development required resources from the LDS Hospital Department of Infectious Disease, but financial impacts in terms of decreased antibiotic costs, decreased adverse drug reactions, and decreased length of stay are evident in the pharmacy and overall hospital budgets. Properly marketed, this highly visible impact of a computer application may be leveraged into more business for IHC Health Plans, adding revenue which will be completely inapparent to the LDS Hospital Department of

Infectious Disease. The natural temptation is for each department to optimize its individual operations, but doing so will typically suboptimize the operations of the corporation as a whole. Organizational vision and leadership are essential to overcome such forces. To surmount the problem of suboptimization, it is necessary that at a minimum IHC top management have an appreciation of such fiscal realities and nurture IS applications which benefit the enterprise as a whole. Accounting systems may be devised to incorporate transfer mechanisms recognizing such large-scale benefits.

Others outside IHC have also observed that present accounting systems are ill-suited to consider knowledge gains which are too often not readily measurable in the preferred unit of accounting measure, dollars.[312] Simply stated, "investment in end-user systems must be measured in terms of its impact on the performance of an organization as a whole"[312] (page 22). Traditional accounting rules undervalue knowledge gains. Current accounting systems lag well behind the demands of the information age and need to be extended to allow incorporation of human as well as material assets.

Clinical Integration

In the final analysis, the thrust of health information systems is not technology for technology's sake, but rather the improvement of patient care. Amidst the shifting sands of HMOs, prospective payment, and managed care, the fundamental business of the healthcare industry is and remains clinical medicine. Health information systems facilitate this fundamental business by bringing the potential power of information to bear.

Integration refers to the combination or summation of different elements together to create a unified whole. In the health care marketplace, integration has signified the combination of the different facets of health care into a single organization. Those enterprises comprised of hospital, physicians and health plans are referred to as integrated delivery systems (IDSs) or integrated delivery networks (IDNs) (Figure 20, page 125); Intermountain Health Care is an example of such an organization. Such large organizations by their very nature tend to be diffuse and inefficient bureaucracies. It is not enough to simply fuse these different pieces together under a single name with a marketable logo and expect them to function efficiently together. Considerable effort is required to address the interactions of these individual components and to devise efficient and synergistic mechanisms for doing business. This process has been termed clinical integration and itself incorporates three key elements (Figure 31):

- Integrated clinical/ operations management structure
- Integrated incentives
- Integrated information management systems.[218]

Applying these three key elements to an enterprise focused on the primary business in the healthcare industry of patient care allows development of the necessary internal processes to accomplish this goal.

Disease management is one specific patient care initiative which hinges on the three key elements of clinical integration. Sometimes termed case management or care

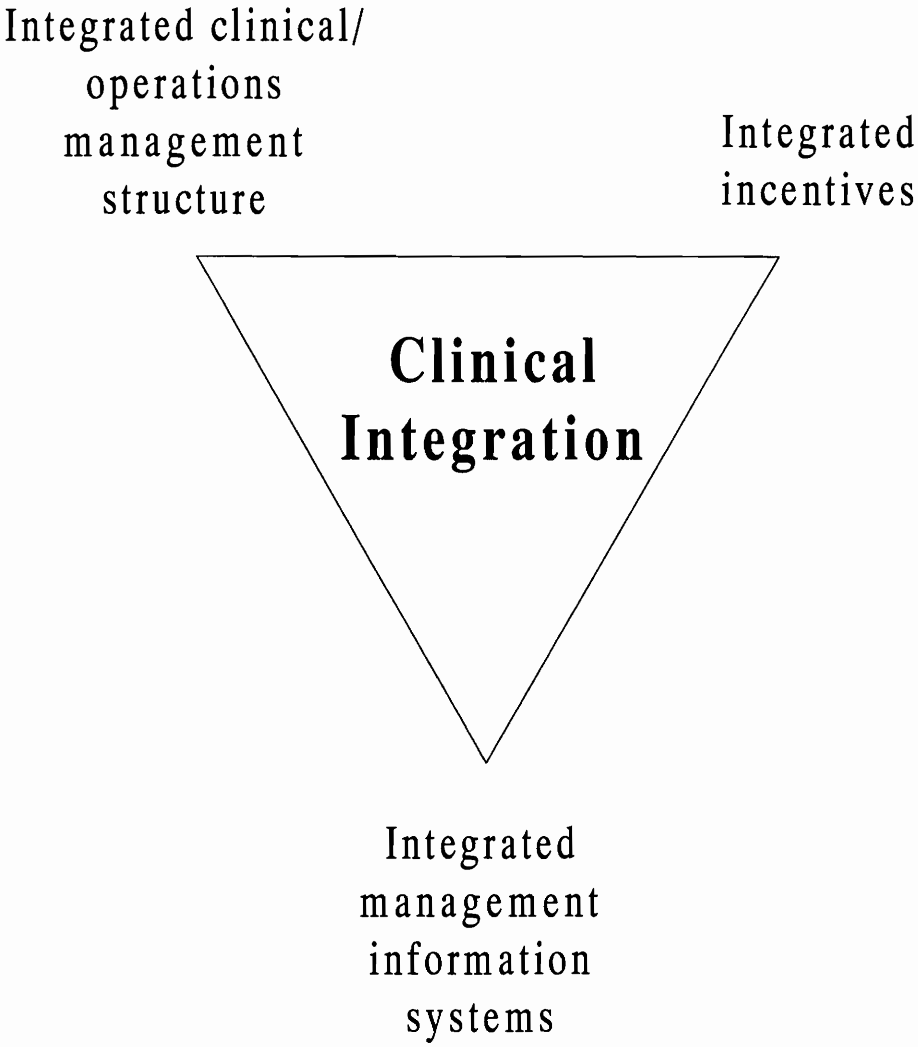


Figure 31
Components of Clinical Integration

management, disease management (DM) has been defined as the optimal management of the most common and costly acute and chronic disease states across the continuum of care.[313] DM comprises a process of patient care incorporating information systems, practice guidelines, patient self-management techniques, nonphysician support personnel, and an emphasis on collaborative care. The thrust of DM is to break down departmental barriers to more efficiently care for a group of patients with a given illness. At the most basic level, DM is a business strategy seeking to synthesize diverse elements of established clinical practice.[314] Any such multi-pronged approach involving multiple providers, services, and departments requires clinical integration as an essential element for success. The indispensable role for information systems in DM programs has been widely appreciated.[303, 313, 315-318] The impacts of DM programs at Lovelace Health Systems in Albuquerque, NM, have been substantial.[319]

- Increase in vaginal births after Cesarean sections (VBAC) from 18 percent in 1989 to 60 percent in 1996; Decrease in Cesarean section rate from 23 percent in 1989 to 13 percent in 1996;
- Decrease in average length of stay coronary artery bypass graft (CABG) from 12 days in the 1st quarter of 1992 to 7 days in the 3rd quarter of 1996;
- Decrease in average inpatient charges for coronary artery bypass graft (CABG) from ~$63,000 to ~$56,000 over the same time interval;
- Medical cost offset following the diagnosis and treatment of depression between January 1992 and December 1993 totaling $1.92 million; and

- Decreases in inpatient admissions for pediatric asthma from .25 to .07 per 1000.

While such outcomes cannot separate out the effect of the respective DM programs in each of these areas from other influences, the overall picture of multiple areas of clinical improvement paralleling the distribution of Lovelace's DM programs is impressive.

The impacts of clinical integration are evident at Intermountain Health Care in the computer applications supporting antibiotic use as discussed previously.[69, 75, 263, 264, 268] These applications, which may collectively be viewed as among IHC's earliest ventures into the realm of clinical integration, confer value by transcending departmental barriers to employ information for improved patient care.[320]

Additional evidence of the value of clinical integration lies in the extensive and ongoing quality improvement work done by Intermountain Health Care. James and his colleagues have undertaken approximately 65 clinical quality improvement projects which have in the aggregate generated nearly $30 million in net savings per year, slightly less than 2 percent of IHC's total operating costs.[218, 304, 321] Internal projections suggest potential quality improvements totaling in the $100 to $150 million range (~6 to 10 percent of IHC's overall cost of operations).[304] Information technology has been an essential element of these QI projects.

A third IHC example of clinical integration is the reengineering of surgical services at LDS Hospital.[322] Information technology played a crucial and indispensable role in this project by tracking altered outcomes and providing rapid feedback as processes were modified.[323] Information systems played a similarly indispensable role in a fourth IHC example of clinical integration within a critical care unit at LDS Hospital.[324] Tangible benefits of clinical integration were demonstrated both in terms of reduced costs (savings of $2.6 million over the 5 years of the study, a decrease approaching 30 percent) and improved clinical outcomes (glucose control, enteral feeding, antibiotic use, adult respiratory distress syndrome survival, laboratory use, blood gas use, radiograph use, and appropriate use of sedation).

Clinical integration may therefore be viewed as the ultimate indicator of value of health information systems. Without HIS, there can be no clinical integration; with HIS, information may be used advantageously to directly impact both the quality and the cost of health care delivery.

CONCLUSIONS

If you find a path without obstacles, it probably doesn't lead anywhere.

Frank A. Clark[112] (page 618)

Intermountain Health Care has over the last 40+ years been a pioneer in the development and implementation of computers in health care delivery. During this period, IHC has committed substantial resources to this effort, both in terms of dollars and personnel, and has as a result been widely recognized for its leadership and competence in this rapidly evolving area of health care. An entire industry of health care computing and health information systems has emerged based upon the demonstrated success of pacesetting institutions such as IHC. The remainder of the health care industry is now engaged in a major effort to emulate IHC's success by implementing information systems with a vision of transforming health care from a paper-based to an electronic process. Notwithstanding these achievements, the value of IHC's health information systems has heretofore remained remarkably ill-defined .

Although medicine has been criticized for lagging behind other industries such as banking and telecommunications in its adoption of information technology, the value of computers in these other domains is also uncertain. Those assessing the value of computers in the business world have uncovered no universal metric which defines value with clarity and invites translation to the health care domain. The coexistence of multiple information system valuation strategies as detailed herein and summarized in Figure 14 (page 111) bespeaks the absence of a superior approach to this problem. Indeed, for any such complex system layered upon system as is required to construct any information system, the multiple degrees of freedom yield impacts which are themselves complex and variable. For this reason, it is not surprising that the quantification of value of information systems has been so elusive.

Health information systems unquestionably confer value upon their parent organizations while simultaneously incurring costs, both financial as well as culturally. The challenge is to appreciate prospectively the magnitude of benefits and costs to gauge the proper level of information technology investment by the enterprise. While there clearly can be both too little as well as too much investment in health information systems, the "right" amount of investment is poorly defined. Benchmarking data represent an attempt to distill this uncertainty down to a few readily grasped elemental financial ratios, but as has been pointed out, such efforts reflect an oversimplification providing false comfort to health care enterprise management. No single "right" amount of information system investment exists: what is "right" for a given health care organization depends upon its unique operational and competitive situation. In the final analysis, while certain non-clinical operational efficiencies inevitably result, the true value of a health information system lies overwhelmingly in its potential to improve patient care. IHC is one of the few organizations to thusfar exploit this potential.

Recommendations

1. Any health care enterprise seeking an answer to the value of its health information system must abandon benchmarking as a simple solution. Benchmarking numbers offer narrow comparisons between institutions which are seldom truly comparable. HIS benchmarking must be employed with caution and always with commentary on relative levels of IS functionality. lying behind the IS investments.
2. Recognizing that benchmarking will never be completely abandoned by management, IHC's participation in the Scottsdale Institute consortium is on target and should continue. Standardizing the approach to valuing information system benefits is overdue and will do much to permit valid comparisons between disparate systems and institutions.
3. Of the multiple available valuation strategies, the Measurement Systems approach most closely approximates the Scottsdale Institute initiative as well as IHC's own internal evaluations to date. Being both more explicit and less difficult to implement than the competing strategies, this approach is the best choice for future valuation efforts, allowing considerable flexibility to tailor application-specific metrics applicable to particular circumstances. Certain IT infrastructure may be considered exempt from rigid financial justification under the Strategic Value approach, but precisely which portions of IHC's IT qualify for this distinction will likely be a point for debate.
4. Accounting must be transformed from a vehicle for obfuscation to one of illumination. Given management's frequent insistence on evidence of information system value to justify capital investment, accounting systems must be devised to

provide the essential data for such assessments. The traditional hierarchical accounting system need not be abandoned, but it should be redesigned and augmented to allow a multidimensional accounting strategy, i.e., both a department-centric view as well as a system-centric view. Individual journal entries should allow "one-to-many" relationships such as are commonplace in relational databases. Retrieval of costs relative to a given information system or systems as well as relative to episodes of care will thus be facilitated. The greater challenge will be to create a similar multidimensional accounting structure on the benefit side of the equation.

5. Beyond its fundamental accounting structure, IHC should reconsider the tangled web of IT funding demonstrated at LDS Hospital. Is this current model which has evolved incrementally over 40+ years consistent with and conducive to the corporation's overall information technology strategy, or would a simpler budgetary structure be an improvement?
6. Health information systems must exit the era of development in which every system has been unique and noncomparable to any other. In its stead must emerge an era of standardization without which health care can never make the necessary transition to an electronic record keeping discipline. The ability for health care enterprises to innovate and to optimize their information systems to their specific needs must be preserved, but not at the price of incompatibility with other health information systems. These systems are far too complex and expensive to allow each system to be completely unique. Populating the health care industry with incompatible systems is a misguided and costly strategy destined for failure;

standards remain the answer to the universe. IHC's extension of its health information systems from its LDS Hospital origins to the other hospitals in the corporation is a necessary and prudent step to realize the benefits on an enterprise-wide scale.

Great works are performed not by strength but by perseverance.

Samuel Johnson[325] (page 593)

APPENDIX A

INTERMOUNTAIN HEALTH CARE

ANNUAL FINANCIAL STATEMENTS

	(Dollars in thousands)			
	1995	1996	1997	1998
Funds Available				
Patient services and non-patient activities				
Inpatient services	$752,990	$768,533	$798,310	$833,460
Outpatient services	$531,719	$586,351	$648,440	$674,777
Non-patient activities	$304,736	$402,631	$561,960	$647,833
Total patient services and non-patient activities	$1,589,445	$1,757,515	$2,008,710	$2,156,070
Uncompensated community services and contractual discounts				
Charity	($28,535)	($33,024)	($34,894)	($42,106)
Grants	($30,000)			
Bad debts	($34,471)	($36,610)	($53,479)	($44,562)
Medicare and Medicaid discounts	($264,386)	($291,754)	($339,259)	($389,608)
Total uncompensated community services and contractual discounts	($357,392)	($361,388)	($427,632)	($476,276)
Total funds available	$1,232,053	$1,396,127	$1,581,078	$1,679,794
Funds applied				
Salaries and benefits	$576,192	$641,565	$706,850	$748,669
Supplies and services	$195,394	$344,999	$428,777	$506,334
Business services, insurance, utilities, maintenance	$300,838	$228,793	$232,740	$237,435
Depreciation and amortization	$18,989	$93,294	$71,182	$78,800
Interest	$67,305	$20,116	$18,296	$17,178
Future needs	$73,335	$67,360	$123,233	$91,378
Total funds applied	$1,232,053	$1,396,127	$1,581,078	$1,679,794

APPENDIX B

INTERMOUNTAIN HEALTH CARE

OPERATING STATISTICS

	1995	1996	1997	1998
Acute admissions	102,246	104,573	110,275	113,188
Outpatient visits	3,765,005	4,170,585	4,575,517	4,620,785
Home care visits	408,951	435,578	399,487	284,668
IHC Physician Group outpatient visits	837,073	1,073,932	1,396,471	1,342,713
As % of total outpatient visits	22.2%	25.8%	30.5%	29.1%
Births	22,544	24,104	25,918	27,182
Emergency room visits	347,326	370,131	389,405	386,994

APPENDIX C

ELECTRONIC BIBLIOGRAPHIC RESOURCES

The following electronic bibliographic resources were used in the preparation of this thesis:

1. HealthSTAR
2. INFOTRAC Searchbank, Business Index ASAP
3. INFOTRAC Searchbank, General Reference Center
4. Medline
5. UNIS, Marriott Library, University of Utah.

REFERENCES

1. Bartlett J. Familiar Quotations. A collection of passages, phases and proverbs traced to their sources in ancient and modern literature. Fourteenth Edition. Boston: Little, Brown and Company, 1968.

2. Gunton T. Information Systems Practice: The Complete Guide. Oxford, England: NCC Blackwell, LTD., 1993.

3. Yovits MC. Information and data. In: Ralston A, Reilly ED, eds. Encyclopedia of Computer Science. Third Edition. New York: Van Nostrand Reinhold, 1993.

4. Turban E, Aronson JE. Decision Support Systems and Intelligent Systems. Fifth Edition. Upper Saddle River, NJ: Prentice Hall, 1998.

5. Microsoft Press Computer Dictionary. Third Edition. Redmond, WA: The Microsoft Press, 1997.

6. Robb FF. Some philosophical and logical aspects of information systems. In: Winder RL, Probert SK, Beeson IA, eds. Philosophical Aspects of Information Systems. Bristol PA: Taylor and Francis Inc., 1997:7-22.

7. Devlin K. InfoSense: Turning Information into Knowledge. New York: W.H. Freeman and Company, 1999.

8. Mingers J. The nature of information and its relationship to meaning. In: Winder RL, Probert SK, Beeson IA, eds. Philosophical Aspects of Information Systems. Bristol, PA: Taylor and Francis Inc., 1997:73-84.

9. Rose JS. Medicine and the Information Age. Tampa, FL: American College of Physician Executives, 1998.

10. Taylor J, Wacker W. The 500 Year Delta: What Happens After What Comes Next. New York: HarperCollins, 1997.

11. Rogers EM. Diffusion of Innovations. Fourth Edition. New York: The Free Press, 1995.

12. Duncan WJ, Ginter PM, Swayne LE. Strategic Management of Healthcare Organizations. Second edition. Cambridge: Blackwell Publishers, Inc., 1995.

13. Porter ME, Millar VE. How information gives you competitive advantage. Harvard Business Review 1985; 63:149-160.

14. Quinn JB. Intelligent Enterprise: A Knowledge and Service Based Paradigm for Industry. New York: The Free Press, 1992.

15. Nonaka I, Takeuchi H. The Knowledge-Creating Company. New York: Oxford University Press, 1995.

16. Evans PB, Wurster TS. Strategy and the new economics of information. Harvard Business Review 1997; 75:71-82.

17. Stewart TA. Intellectual Capital: The New Wealth of Organizations. New York: Doubleday / Currency, 1997.

18. Svelby KE. The New Organizational Wealth. San Francisco: Barrett-Koehler Publishers, Inc., 1997.

19. Drucker PF. The next information revolution. Forbes ASAP 1998:47-58.

20. Scott M. Value Drivers: The Manager's Framework for Identifying The Drivers of Corporate Value Creation. Chichester: John Wiley & Sons, 1998.

21. Thorp J. The Information Paradox: Realizing the Business Benefits of Information Technology. Toronto: McGraw-Hill, 1998.

22. Drucker PF. Management Challenges for the 21st Century. New York: HarperCollins, 1999.

23. Petzinger J, Thomas. The New Pioneers: The Men and Women Who Are Transforming the Workplace and Marketplace. New York: Simon and Schuster, 1999.

24. Shapiro C, Varian HR. Information Rules: A Strategic Guide to the Network Economy. Boston: Harvard Business School Press, 1999.

25. Strong DM, Lee YW, Wang RY. 10 potholes in the road to information quality. Computer 1997:38-46.

26. Prahalad CK, Krishnan MS. The new meaning of quality in the information age. Harvard Business Review 1999; 77:109-118.

27. Lucky RW. Information addiction. IEEE Spectrum 1999; 36(9):32.

28. Blum BI. Clinical Information Systems. New York: Springer-Verlag, 1986.

29. Stair RM. Principles of Information Systems: A Managerial Approach. Boston: Boyd and Fraser, 1992.

30. Perreault LE, Wiederhold G. System design and evaluation. In: Shortliffe EH, Perreault LE, Wiederhold G, Fagan LM, eds. Medical Informatics: Computer Applications in Health Care. Reading, MA: Addison-Wesley Publishing Company, 1990:151-178.

31. Turban E, McLean E, Wetherbe J. Information Technology for Management. New York: John Wiley & Sons, Inc., 1996.

32. Starr P. The Social Transformation of American Medicine. New York: Basic Books, 1982.

33. St. Leger MP, Hanken MA. The health information management profession. In: Abdelhak M, Grostick S, Hanken MA, Jacobs E, eds. Health Information: Management of a Strategic Resource. Philadelphia: W.B. Saunders Company, 1996:47-62.

34. Huffman EK. Health Information Management. Tenth Edition. Berwyn, IL: Physicians' Record Company, 1994.

35. Shortliffe EH, Barnett GO. Medical data: their acquisition, storage, and use. In: Shortliffe EH, Perreault LE, Wiederhold G, Fagan LM, eds. Medical Informatics: Computer Applications in Health Care. Reading, MA: Addison-Wesley, 1990:37-69.

36. Blois MS. Information and Medicine: The Nature of Medical Descriptions. Berkeley: University of California Press, 1984.

37. Jydstrup RA, Gross MJ. Cost of information handling in hospitals. Health Services Research 1966; 1(3):242.

38. Wilde DJ. Data quality. In: Abdelhak M, Grostick S, Hanken MA, Jacobs E, eds. Health Information: Management of a Strategic Resource. Philadelphia: W.B. Saunders Company, 1996:133-177.

39. Dick RS, Steen EB, Detmer DE. The Computer-Based Patient Record. Revised Edition. Washington, D.C.: National Academy Press, 1997.

40. Eddy DM. Practice policies - where do they come from? JAMA 1990; 263(9):1265-1275.

41. Wennberg JA. Professional uncertainty and the problem of supplier-induced demand. Soc Sci Med 1982; 16:811-824.

42. Eddy DM. Variations in clinical practice: the role of uncertainty. Health Affairs (Millwood) 1984; 3(2):74-89.

43. Sox HCJ, Blatt MA, Higgins MC, Marton KI. Medical Decision Making. Boston: Butterworth-Heinemann, 1988:406.

44. Eddy DM. The challenge. JAMA 1990; 263(2):287-290.

45. Chassin MR. Explaining geographic variations: the enthusiasm hypothesis. Med Care 1993; 31(5 Suppl):YS37-44.

46. Logan RL, Scott PJ. Uncertainty in clinical practice: implications for quality and costs of health care. The Lancet 1996; 347:595-598.

47. James BC. Three methods to manage clinical care. Salt Lake City, UT: Intermountain Health Care Institute for Health Care Delivery Research, Mini-Advanced Training Program, 6/28/99.

48. Wennberg JA. Dealing with medical practice variations: a proposal for action. Health Affairs (Millwood) 1984; 3(2):6-32.

49. Chassin MR, Kosecoff J, Park RE, et al. Does inappropriate use explain geographic variations in the use of health care services? A study of three procedures. JAMA 1987; 258(18):2533-2537.

50. Wennberg JA. The paradox of appropriate care. JAMA 1987(18); 258:2568-2569.

51. Volinn E, Diehr P, Ciol MA, Loeser JD. Why does geographic variation in health care practices matter? Spine 1994; 19(18S):2092S-2100S.

52. Terry K. Why treatment varies so greatly. Medical Economics 1997; February 10, :40-56.

53. Ashton CM, Petersen NJ, Souchek J, et al. Geographic variations in utilization rates in Veterans Affairs hospitals and clinics. N Engl J Med 1999; 340(1):32-39.

54. Wennberg JA. Understanding geographic variations in health care delivery. N Engl J Med 1999; 340(1):52-53.

55. McDonald C. Protocol-based computer reminders, the quality of care, and the non-perfectability of man. N Engl J Med 1976; 295:1351-1355.

56. Bosk CL. Forgive and Remember: Managing Medical Failure. Chicago: University of Chicago Press, 1979.

57. Brennan TA, Leape LL, Laird NM, et al. Incidence of adverse events and negligence in hospitalized patients: results of the Harvard Medical Practice Study I. N Engl J Med 1991; 324(6):370-376.

58. Leape LL, Brennan TA, Laird N, et al. The nature of adverse events in hospitalized patients: results of the Harvard Medical Practice Study II. N Engl J Med 1991; 324(6):377-384.

59. Leape LL. Error in medicine. JAMA 1994; 272(23):1851-1857.

60. Leape LL. Promoting patient safety by preventing medical error. J Am Med Assn 1998; 280(16):1444-1447.

61. Prager LO. Initiative begins to chip away at error rate. Am Medical News, December 7, 1998:8,9,11.

62. Berwick DM, Godfrey AB, Roessner J. Curing Health Care: New Strategies for Quality Improvement. San Francisco: Jossey-Bass, 1990.

63. Chassin MR. Quality of health care, part 3: improving the quality of care. N Engl J Med 1996; 335(14):1060-1063.

64. Chassin MR, Galvin RW. The urgent need to improve health care quality. JAMA 1998; 280(11):1000-1005.

65. Eddy DM. Money, medicine, and mathematics. Bull Am Coll Surg 1992; 77:36-49.

66. Kuperman GJ, Gardner RM, Pryor TA. HELP: A Dynamic Hospital Information System. New York, NY: Springer-Verlag, 1991.

67. Berg M. Rationalizing Medical Work: Decision-Support Techniques and Medical Practices. Cambridge: The MIT Press, 1997.

68. Slack W. Cybermedicine: How Computing Empowers Doctors and Patients for Better Health Care. San Francisco: Jossey-Bass, 1997.

69. Evans R, Pestotnik S, Classen D, et al. A computer-assisted management program for antibiotics and other antiinfective agents. N Engl J Med 1998; 338(4):232-238.

70. Grandia L. Interview, 2/16/99.

71. Pryor TA. Interview, 1/7/99.

72. Safran C, Herrmann F, Rind D, Kowaloff HB, Bleich HL, Slack WV. Computer-based support for clinical decision making. M.D. Computing 1990; 7(5):319-322.

73. Tate KE, Gardner RM. Computers, quality and the clinical laboratory: a look at critical value reporting. In: Safran C, ed, 17th Annual Symposium for Computer Applications in Medical Care. Washington, DC: McGraw-Hill, 1993:193-197.

74. Tate KE, Gardner RM. Nurses, pagers, and patient-specific criteria: three keys to improved critical value reporting. In: Gardner R, ed, 19th Annual Symposium for Computer Applications in Medical Care. New Orleans: Hanley & Belfus, 1995:164-168.

75. Classen DC, Pestotnik SL, Evans RS, Lloyd JF, Burke JP. Adverse drug events in hospitalized patients: excess length of stay, extra costs, and attributable mortality. JAMA 1997; 277(4):301-306.

76. Rosenstein AH. Information-based clinical decision support. New Medicine 1997; 1:135-141.

77. Bates DW, Leape LL, Cullen DJ, et al. Effect of computerized physician order entry and a tem intervention on prevention of serious medication errors. JAMA 1998; 280(15):1311-1316.

78. Hunt DL, Haynes RB, Hanna SE, Smith K. Effects of computer-based clinical decision support systems on physician performance and patient outcomes. JAMA 1998; 280(15):1339-1346.

79. Raschke RA, Gollihare B, Wunderlich TA, et al. A computer alert system to prevent injury from adverse drug events. JAMA 1998; 280(15):1317-1320.

80. van Bemmel JH, Musen MA. Handbook of Medical Informatics. Heidelberg: Springer-Verlag, 1997.

81. Drazen EL. Preface. In: Drazen EL, Metzger JB, Ritter JL, Schneider MK, eds. Patient Care Information Systems. New York: Springer-Verlag, 1995.

82. Geissbuhler A. Clinical information systems - what is the bottom line? J Am Med Informatics Assoc 1998; 5(6):585-586.

83. Lindberg DAB. The Growth of Medical Information Systems in the United States. Lexington, MA: Lexington Books/ D.C. Heath Company, 1979.

84. Degoulet P, Fieschi M. Introduction to Clinical Informatics. In: Hannah KJ, Ball MJ, eds. Computers in Health Care. New York: Springer-Verlag, 1997:242.

85. Dorenfest SI. Health care information systems. In: Wolper LF, ed. Health Care Administration. Gaithersburg, MD: Aspen Publishers, Inc., 1995:416-428.

86. Drazen EL. Methods for evaluating costs of automated hospital information systems. In: Blum BI, ed. Information Systems for Patient Care. New York: Springer-Verlag, 1984:427-437.

87. CPRI Work Group on CPR Systems Evaluation. Valuing CPR systems - a business planning methodology. Schaumburg, IL: Computer-based Patient Record Institute, 1997.

88. Summer W. A review of Iliad and Quick Medical Reference for primary care providers: two diagnostic computer programs. Arch Fam Med 1993; 2(1):87-95.

89. Berner E, Webster G, AA S, et al. Performance of four computer-based diagnostic systems. New Engl J Med 1994; 330(25):1792-1796.

90. Kassirer JP. A report card on computer-assisted diagnosis - the grade: C. N Engl J Med 1994; 330(25):1824-1825.

91. Miller RA. Medical diagnostic decision support systems - past present and future. J Am Med Informatics Assoc 1994; 1(1):8-27.

92. Warner HR, Sorenson DK, Bouhaddou O. Knowledge Engineering in Health Informatics. In: Orthner HF, ed. Computers and Medicine. New York: Springer-Verlag, 1997:262.

93. Bourke MK. Strategy and Architecture in Health Care Information Systems. In: Hannah KJ, Ball MJ, eds. Computers in Health Care. New York: Springer-Verlag, 1994:356.

94. Frisse MC. The business value of health care information technology. J Am Med Informatics Assoc 1999; 6(5):361-367.

95. Panko WB. Clinical care and the factory floor. J Am Med Informatics Assoc 1999; 6(5):349-353.

96. Starr P. Smart technology, stunted policy: developing health information networks. Health Affairs 1997; 16(3):91-105.

97. Crowe GD, Eckstein MG. Health information networks. In: Ball MJ, Simborg DW, Albright JW, Douglas JV, eds. Healthcare Information Management Systems. New York: Springer-Verlag, 1995:45.

98. Ozbolt JG. Personalized health care and business success: can informatics bring us to the promised land? J Am Med Informatics Assoc 1999; 6(5):368-373.

99. Tuttle MS. Information technology outside health care: what does it matter to us? J Am Med Informatics Assoc 1999; 6(5):354-360.

100. Rubin HA. Financial analysis overview: results from the worldwide benchmark report. Pound Ridge, NY: Rubin Systems Inc./ META Group, 1/16/98.

101. Baldwin G. Data systems may need some intensive care. American Medical News 3/22-29/99:27, 29.

102. Novak S, Ward P. META Group announces critical healthcare IT survival guide. 3/23/99. Available at http://domino.metagroup.com/newweb.nst/web/pressroom.

103. Vogel D. Healthcare IT Strategies: META Group, Inc., 10/13/99.

104. Anderson MR. Healthcare IT Strategies: META Group, Inc., 10/14/99.

105. Lorenzi NM, Riley RT. Organizational aspects of health informatics: managing technological change. New York: Springer-Verlag, 1995.

106. Caceres CA. The need for automation in health care. In: Blum BI, ed. Information Systems in Patient Care. New York: Springer-Verlag, 1984:20-26.

107. Willoughby KW. Technology Choice: A Critique of the Appropriate Technology Movement. Boulder, CO: Westview Press, 1990.

108. Metzger JB, Teich JM. Designing acceptable patient care information systems. In: Drazen EL, Metzger JB, Ritter JL, Schneider MK, eds. Patient Care Information Systems. New York: Springer-Verlag, 1995:83-132.

109. Fallon H. How to Implement Information Systems and Live To Tell About It. New York: Wiley-QED, 1995.

110. Gardner RM, Lundsgaarde HP. Evaluation of user acceptance of a clinical expert system. J Am Med Informatics Assoc 1994; 1(6):428-438.

111. Drazen EL. Physicians' and nurses' acceptance of computers. In: Drazen EL, Metzger JB, Ritter JL, Schneider MK, eds. Patient Care Information Systems. New York: Springer-Verlag, 1995:31-50.

112. Goodman T. The Forbes Book of Business Quotations. New York: Black Dog & Leventhal Publishers, 1997.

113. Barnhart CL, Barnhart RK. The World Book Dictionary. Chicago: World Book, 1990.

114. Sloane R. The Sloane-Dorland Annotated Medical-Legal Dictionary. St. Paul, MN: West Publishing Co., 1987.

115. O'Leary MO. Lexikon: Dictionary of Health Care Terms, Organizations and Acronyms for the Era of Reform. Oakbrook Terrace, IL: Joint Commission for the Accreditation of Healthcare Organizations, 1994.

116. Corey ER. Pricing: the strategy and the process. In: Dolan RJ, ed. Strategic Marketing Management. Boston: Harvard Business School Publications, 1991:253-269.

117. Porter ME. Competitive Advantage: Creating and Sustaining Superior Performance. New York: The Free Press, 1985.

118. Hill CWL, Jones GR. Strategic Management Theory: An Integrated Approach. Fourth Edition. Boston: Houghton Mifflin, 1998.

119. Strassmann PA. The Business Value of Computers: An Executive's Guide. New Canaan, CT: The Information Economics Press, 1990.

120. Remenyi D, Money A, Twite A. Effective Measurement & Management of IT Costs and Benefits. Oxford: Butterworth Heinemann, 1995.

121. Band WA. Touchstones: ten new ideas revolutionizing business. New York: John Wiley and Sons, 1994.

122. Grochow JM. Information Overload: Creating Value with the New Information Systems Technology. Upper Saddle River, NJ: Yourdon Press, 1997.

123. Parker MM, Benson RJ. Information Economics: Linking Business Performance to Information Technology. Englewood Cliffs, NJ: Prentice Hall, 1988.

124. Strassmann PA. The Squandered Computer. New Canaan, CT: The Information Economics Press, 1997.

125. Teach E. How to succeed in IT. CFO 1997; July:37-43.

126. Kimball-Baker K. What's the ROInfo in MCOs? Healthcare Informatics 1998; April:50-58.

127. Church GJ. Do computers really save money? Time 10/12/98.

128. Blinder AS, Quandt RE. The computer and the economy: will information technology ever produce the productivity gains that were predicted? The Atlantic Monthly 1997; 280 (6):26-31.

129. Gibbs WW. Taking computers to task. Scientific American 1997; July. Available at: http://www.sciam.com/0797issue/0797trends.html.

130. Keyes J. Solving the Productivity Paradox. New York: McGraw Hill, 1995.

131. Landauer TK. The Trouble with Computers. Cambridge, MA: The MIT Press, 1995.

132. Lewis T. Why the economy is so good. Computer 1998; May:110-112.

133. The technology payoff- now productivity is finally bursting out... Business Week 6/14/93.

134. Magnet M. The productivity payoff arrives. Fortune 1994; 129(13):79.

135. What computers are for. The Economist 1/22/94.

136. Brynjolfsson E, Hitt L. Paradox lost? Firm-level evidence of high returns to information systems spending. February 1994. Available at: http://ccs.mit.edu/CCSWP162/CCSWP162.html

137. Hitt L, Brynjolfsson E. Creating value and destroying profits? three measures of information technology's contributions. 1994. Available at: http://ccs.mit.edu/CCSWP183.html.

138. Strassmann PA. Information Payoff: The Transformation of Work in the Electronic Age. New York: The Free Press, 1985.

139. Strassmann PA. The Politics of Information Management. New Canaan, CT: The Information Economics Press, 1995.

140. Silverman DC. The electronic medical record system: health care marvel or morass? The Physician Executive 1998; 24(3):26-30.

141. Wysocki Jr. B. Some firms, let down by costly computers, opt to 'de-engineer'. The Wall Street Journal 4/30/98; 138 (84):A1.

142. Rochlin GI. Trapped in the Net: The Unanticipated Consequences of Computerization. Princeton, NJ: Princeton University Press, 1997.

143. Klein S. Contingency planning for healthcare: countdown to the new millenium. MD Computing 1999; 16(4):30-32.

144. Frisse ME. Computers and productivity: is it time for a reality check? Acad Med 1998; 73:59-64.

145. Barnett GO. The use of computers in clinical data management: The ten commandments. 1970. Available at: http://www.ics.mgh.harvard.edu/10comm.htm.

146. Stead WW, Lorenzi NM. Health informatics: linking investment to value. J Am Med Informatics Assoc 1999; 6(5):341-348.

147. The NLM PubMed Project. National Library of Medicine, 11/9/98. Available at: http://www.ncbi.nlm.nih.gov/PubMed/overview.html.

148. AHA Resource Center: HealthSTAR Database. American Hospital Association, 1998. Available at: http://www.aha.org/resource/facts.html.

149. Boddie J. The Information Asset: Rational DP Funding and Other Radical Notions. Englewood Cliffs, NJ: Yourdon Press, 1993.

150. Masys DR. Proceedings, Annual Fall Symposium, American Medical Informatics Association. Nashville, TN: Hanley and Belfus, Inc., 1997.

151. Chute CG. Proceedings, American Medical Informatics Association '98 Annual Symposium. Orlando, FL: Hanley and Belfus, Inc., 1998.

152. van Bemmel JH, McCray AT. Yearbook of Medical Informatics, 1997.

153. van Bemmel JH, McCray AT. Yearbook of Medical Informatics, 1998.

154. Remenyi DSJ, Money A, Twite A. A Guide to Measuring and Managing IT Benefits. Manchester: NCC Blackwell Limited, 1993.

155. Van der Zee HTM. In Search of the Value of Information Technology. Tilburg, The Netherlands: Tilburg University Press, 1996.

156. Carter S, Sullivan AC, Broderick M. The computer-based patient record: the Jacobi Medical Center experience. In: Steen EB, ed. Second Annual Nicholas E. Davies CPR Recognition Symposium. Washington, DC: Computer-based Patient Record Institute, Inc. 1996: 51-74.

157. Kian LA, Stewart MW, Bagby C, Robertson J. Justifying the cost of a computer-based patient record. Healthcare Financial Management 1995; 49(7):58-64.

158. Grandia LD, Pryor AT, Willson DF, et al. Building a computer-based patient record system in an evolving integrated health system. In: Steen EB, ed. First Annual Nicholas E. Davies CPR Recognition Symposium. Washington, DC, Computer-based Patient Record Institute, Inc. 1995:5-33.

159. Bakke K, Galvin MS. The Clinically Related Information System (CRIS): a CPR pilot using primary care advice rules and reminders In: Steen EB, ed. Second Annual Nicholas E. Davies CPR Recognition Symposium. Washington, DC, Computer-based Patient Record Institute, Inc. 1996:35-49.

160. Tang PC, Boggs B, Fellencer C, et al. Northwestern Memorial Hospital. In: Overhage JM, ed. Fourth Annual Nicholas E. Davies CPR Recognition *Award of Excellence* Symposium, Washington, DC, Computer-based Patient Record Institute. 1998:9-53.

161. Chin H, Brannon M, Dworkin L, et al. Kaiser-Permanente Northwest. In: Overhage JM, ed. Fourth Annual Nicholas E. Davies CPR Recognition *Award of Excellence* Symposium, Washington, DC, Computer-based Patient Record Institute. 1998:55-100.

162. Teich JM, Glaser JP, Beckley RF, et al. Toward cost-effective, quality care: the Brigham Integrated Computer System. In: Steen EB, ed. Second Annual Nicholas E. Davies CPR Recognition Symposium, Washington, DC, Computer-based Patient Record Institute, Inc. 1996:5-34.

163. Khoury A, Siemon C, Mills G, Kalata M. The Medical Automated Record System of Kaiser Permanente of Ohio. In: Teich JM, ed. Third Annual Nicholas E. Davies CPR Recognition Symposium, Washington, DC, Computer-based Patient Record Institute. 1997:5-72.

164. Bozeman TE, Harvey K, Jarrell I, et al. The development and implementation of a computer-based patient record in a rural integrated health system. In: Teich JM, ed. Third Annual Nicholas E. Davies CPR Recognition Symposium, Washington, DC, Computer-based Patient Record Institute. 1997:73-97.

165. McDonald CJ, Tierney WM, Overhage JM, Dexter P, Takesue B, Abernathy G. The three-legged stool: Regenstrief Institute for Health Care. In: Teich JM, ed.

Third Annual Nicholas E. Davies CPR Recognition Symposium, Washington, DC, Computer-based Patient Record Institute. 1997:99-123.

166. Kaplan RS, Norton DP. The balanced scorecard- measures that drive performance. Harvard Business Review 1992; 70(January-February):71-79.

167. Rubin H. Dispensing the measurement myths. Computerworld 1994; 28 (33):37.

168. Friedman CP, Wyatt JC. Evaluation Methods in Medical Informatics. New York: Springer-Verlag, 1997.

169. Hubbard D. Everything is measurable. CIO 11(4); 11/15/97. Available at: http://www.cio.com/archive/enterprise/111597_checks_content.html.

170. Carlson W, McNurlin B. Basic principles for analyzing IT value. I/S Analyzer 1992; 30 (10):1-15.

171. Coffey RM. How a Medical Information System Affects Hospital Costs: The El Camino Hospital Experience; *Research Summary Series*. Hyattsville, MD: National Center for Health Services Research, Office of Health Research, Statistics, and Technology, Public Health Service, U.S.Department of Health, Education and Welfare, 1980:17.

172. Carter K. Primary care computer system vital to El Camino. Modern Healthcare 9/11/87:84-86.

173. Blum BI. Information Systems for Patient Care. In: Blum BI, ed. Information Systems for Patient Care. New York: Springer-Verlag, 1984:3-19.

174. Bradley E, Campbell JG. Information System Selection: Methods for Comparing Service Benefits. In: Blum BI, ed. Information Systems for Patient Care. New York: Springer-Verlag, 1984:438-445.

175. Forsythe DE, Buchanan BG. Broadening our approach to evaluating medical information systems. In: Clayton PD, ed. Fifteenth Annual Symposium on Computer Applications in Medical Care. Washington, DC: McGraw-Hill. 1991:8-12.

176. Drazen EL. Beyond cost-benefit: an assessment approach for the '90s. In: Clayton PD, ed. Fifteenth Annual Symposium on Computer Applications in Medical Care. Washington, DC: McGraw-Hill. 1991:13-17.

177. Nauright LP, Simpson RL. Benefits of hospital information systems as seen by front-line nurses and general hospital staff. J Nurs Admin 1994; 24(4S):26-32.

178. Woodward RS, Boxerman SB. The value of risk-reducing Information. Journal of Medical Systems 1994; 18(3):111-116.

179. van der Loo RP, van Gennip EMSJ, Bakker AR, Hasman A, Rutten FFH. Evaluation of automated information systems in health care: an approach to classifying evaluative studies. Computer Meth Biomed 1995; 48:45-52.

180. Curtis C. A computer-based patient record emerging from the patient sector: the Decentralized Hospital Computer Program. In: Steen EB, ed. First Annual Nicholas E. Davies CPR Recognition Symposium, Washington, DC: Computer-based Patient Record Institute, Inc. 1995: 55-95.

181. Kolodner RM. Computerizing Large Integrated Health Networks: The VA Success. New York: Springer-Verlag. 1997:515.

182. Wyatt JC. Hospital information management: the need for clinical leadership. BMJ 1995; 311(7/15/95):175-180.

183. Lock C. What value do computers provide to NHS hospitals? BMJ 1996; 312 (6/1/96):1407-1410.

184. Donaldson L. From black bag to black box: will computers improve the NHS? BMJ 1996; 312(6/1/96):1371-1372.

185. Heathfield HA, Buchan IE. Current evaluations of information technology in health care are often inadequate. BMJ 1996; 313 (10/19/96):1008.

186. Balas EA, Austin SM, Mitchell JA, Ewigman BG, Bopp KD, Brown GD. The clinical value of computerized information services. Arch Fam Med 1996; 5(May):271-278.

187. Glaser J, Teich J, Kuperman G. Impact of information events on medical care, Healthcare Information and Management Systems Society, 1996.

188. Bates DW, O'Neil A, Boyle D, et al. Potential identifiability of preventability of adverse events using information systems. J Am Med Informatics Assoc 1994; 1(5):404-411.

189. Manning J, McConnell EA. Technology assessment: A framework for generating questions useful in evaluating nursing information systems. Computers in Nursing 1997; 15(3):141-146.

190. McLean R. Cost-volume-profit and net present value analysis of health information systems. Topics in Health Information Management 1998; 19(1):39-47.

191. Weinstein MC. Foundations of cost-effectiveness analysis for health and medical practices. New Engl J Med 1977; 296(13):716-721.

192. Detsky AS, Naglie IG. A clinician's guide to cost-effectiveness analysis. Ann Int Med 1990; 113(2):147-154.

193. Enthoven AC, Wilson NA. Health-care financing and technology assessment. In: Shortliffe EH, Perreault LE, Wiederhold G, Fagan LM, eds. Medical Informatics: Computer Applications in Health Care. Reading, MA: Addison-Wesley, 1990:585-619.

194. Fryback DG. Technology evaluation: applying cost-effectiveness analysis for health technology assessment. Decisions in Imaging Economics 1990; 3:4-9.

195. Eddy DM. Cost-effectiveness analysis: a conversation with my father. J Am Med Assoc 1992; 267(12):1669-1675.

196. Eddy DM. Applying cost-effectiveness analysis: the inside story. J Am Med Assoc 1992; 268(18):2575-2582.

197. Russell LB, Gold MR, Siegel JE, Daniels N, Weinstein MC. The role of cost-effectiveness analysis in health and medicine. J Am Med Assoc 1996; 276(14):1172-1177.

198. Russell LB, Siegel JE, Daniels N, Gold MR, Luce BR, Mandelblatt JS. Cost-effectiveness analysis as a guide to resorce allocation in health: roles and limitations. In: Gold MR, Russell LB, Siegel JE, Weinstein MC, eds. Cost-Effectiveness in Health and Medicine. New York: Oxford University Press, 1996:3-24.

199. Garber AM, Weinstein MC, Torrance GW, Kamlet MS. Theoretical foundations of cost-effectiveness analysis. In: Gold MR, Siegel JE, Russell LB, Weinstein MC, eds. Cost-Effectiveness in Health and Medicine. New York: Oxford University Press, 1996:25-53.

200. Glandon GL, Buck TL. Cost-benefit analysis of medical information systems. In: Anderson JG, Aydin CE, Jay SJ, eds. Evaluating Health Care Information Systems: Methods and Applications. Thousand Oaks, CA: Sage Publications, 1994:164-189.

201. Negroponte N. Being Digital. New York: Alfred A. Knopf. 1995.

202. Dertouzos ML. What Will Be: How the World of Information Will Change our Lives. New York: HarperCollins, 1997.

203. Cocowitch VA, Fickenscher KM. The Turnaround Imperative: A Learder's Guide for Survival in a Turbulent Health Care Environment. Tampa: American College of Physician Executives, 1996.

204. Shortell SM, Gillies RR, Anderson DA, Erickson KM, Mitchell JB. Remaking Health Care in America: Building Organized Delivery Systems. San Francisco: Jossey-Bass, 1996.

205. Coile RCJ. The Five Stages of Managed Care: Strategies for Providers, HMOs, and Suppliers. In: American College of Healthcare Executives, ed. Chicago: Health Administration Press, 1997.

206. Herzlinger RE. Market Driven Health Care: Who Wins, Who Loses in the Transformation of America's Largest Service Industry. Reading, MA: Addison-Wesley, 1997.

207. Irwin R. What is FUD? 1998. Available at: http://miss.wu-wien.ac.at/~mitloehn/EvilEmpire/fud.htm.

208. Turner J. Keeping computing's FUD factor at bay. 1998. Available at: http://www.csmonitor.com/durable/1998/11/19/p15s2.htm.

209. Glandon GL, Shapiro R. Benefit-cost analysis of hospital information systems: the state of the (non)art. J of Health and Human Resource Admin 1988; 11(Summer):30-92.

210. Semich JW. Here's how to quantify IT investment benefits. Datamation 1994; 40(1):45-48.

211. Taninecz G. What's the ROI? Industry Week 1996; 245(18):45-48.

212. Glaser JP. Beware "return on investment". Healthcare Informatics 1997 (June):134-138.

213. Kuttner R. The American health care system: health insurance coverage. N Engl J Med 1999; 340(2):163-168.

214. Woolhandler S, Himmelstein DU. When money is the mission: the high costs of investor-owned care. N Engl J Med 1999; 341(6):444-446.

215. Parker MM, Trainor HE, Benson RJ. Information Strategy and Economics. Englewood Cliffs, NJ: Prentice Hall, 1989.

216. Parker MM, Benson RJ. Applying service management principles to information systems organizations: an introductory discussion. St. Louis, MO: Center for the Study of Data Processing, School of Technology and Information Management, Washington University, 1989:17.

217. Gardner RM. Better medicine is better business: strategic use of clinical information. Medical Information Systems Physicians' Association, 13th Annual Transition Users and Educational Conference, Anaheim, CA: 10/4/98.

218. James BC. Deployment: clinical integration. Salt Lake City, UT: Intermountain Health Care Institute for Health Care Delivery Research, Mini-Advanced Training Program, 8/13/99.

219. Farbey B, Land F, Targett D. How ot Assess Your IT Investment: A Study of Methods and Practice. Oxford: Butterworth-Heinemann Ltd., 1993.

220. Latimer EW. Assessing the impact of ambulatory computer-based medical record systems. MD Computing 1999; 16(2):44-46.

221. Bensaou M, Earl M. The right mind-set for managing information technology. Harvard Business Review 1998; 76(September-October):119-128.

222. Yoshimura N, Anderson P. Inside the Kaisha: Demystifying Japanese Business Behavior. Boston: Harvard Business School Press, 1997.

223. Sethi SP. Japanese Business and Social Conflict: A Comparative Analysis of Response Patterns with American Business. Cambridge, MA: Ballinger Publishing Company, 1975.

224. Hayashi S. Culture and Management in Japan. Tokyo: University of Tokyo Press, 1988.

225. Aoki M, Dore R. The Japanese Firm: The Sources of Competitive Strength. New York: Oxford University Press, 1994.

226. Hunt B, Targett D. The Japanese Advantage? Competitive IT Strategies Past, Present and Future. Oxford: Butterworth Heinemann, 1995.

227. Frohman AL. Technology as a competitive weapon. Harvard Business Review 1982; 60(January-February):97-104.

228. The Computer-based Patient Record Institute. 10/7/98. Available at: http://www.cpri.org.

229. College of Healthcare Information Management Executives. 1998. Available at: http://www.chime-net.org.

230. Society HIaMI. The ninth annual HIMSS leadership survey. Healthcare Informatics 1998:55-74.

231. Healthcare Information and Management Systems Society. Ninth annual HIMSS leadership survey. 1998. Available at: http://www.himss.org/publications/survey/ia/report.htm.

232. IHC Mission, 1998. Available at: http://www.ihc.com/overview/mission.html.

233. IHC Quick Facts. Intermountain Health Care, 1999. Available at: http://www.ihc.com/media/facts.

234. IHC Facts:Overview. Intermountain Health Care, 1999. Available at: http://www.ihc.com/media/facts/overview.html.

235. IHC Annual Report 1997. Intermountain Health Care, 1999. Available at: http://www.ihc.com/overview/ar1997/mission.html.

236. Jensen B. Interview, 4/27/98.

237. Wagner N. The IHC health chain dominates Utah: is that healthy? The Salt Lake Tribune. Salt Lake City,UT. May 17, 1998:A1, A4-5.

238. Health Plan Options: Large Group Plans. Intermountain Health Care, 1999. Available at: http://www.ihc.com/healthplans/introduction/health_plans/hp_options/large_group.html.

239. Health Plan Options: Small Employer Plans. Intermountain Health Care, 1999. Available at: http://www.ihc.com/healthplans/introduction/health_plans/hp_options/small_employer.html.

240. Health Plan Options: Personal Plans. Intermountain Health Care, 1999. Available at: http://www.ihc.com/healthplans/introduction/health_plans/hp_options/personal.html.

241. IHC Health Plans, 1998. Available at: http://www.ihc.com/healthplans/products.html.

242. Olson D. Interview, 5/7/98.

243. Wharton T, Wharton G. Facts about Utah. Utah. Oakland, CA: Compass American Guides, Inc., 1995.

244. Wharton T, Wharton G. The Wasatch Front. Utah. Oakland, CA: Compass American Guides, Inc., 1995.

245. Utah Department of Health. 1998. Available at: http://hlunix.hl.state.ut.us/had/consumer/hmosv/page8.html.

246. Health Plans: Introduction. Intermountain Health Care, 1999. Available at: http://www.ihc.com/healthplans/introduction/health_plans/accreditation/.

247. Wagner N. Health industry in Utah exhibits disturbing vital signs. The Salt Lake Tribune. Salt Lake City, UT. 5/3/98:N26.

248. Hoovers Online. Hoovers Company Information, 1998. Available at: http://www.hoovers.com/.

249. Lagnado L. Columbia sets $1.2 billion hospital sale. The Wall Street Journal. New York, NY. May 20, 1998:A3.

250. Wagner N. Paracelsus selling its Utah hospitals. The Salt Lake Tribune. Salt Lake City, UT. 8/18/99:C4, C8.

251. Dew L. Personal communication re Health Sciences Revenues, 4/22/99.

252. Gebhart R. School of Medicine response to SLVAMC budget problems, 6/14/99.

253. Wagner N. U. expands its share of health care. The Salt Lake Tribune. Salt Lake City, May 27, 1998:A1.

254. Department of Professional Licensure Utah State Department of Commerce. Interview, May 27, 1998.

255. Wagner N. Altius buys Intergroup Health Plan. The Salt Lake Tribune. Salt Lake City, UT, 7/7/99:C1, C8.

256. Wagner N. Health group to sell Utah HMO. The Salt Lake Tribune. Salt Lake City, 11/26/97:C8.

257. Blue Cross and Blue Shield of Utah, 1998. Available at: http://www.BCBSUtah.com/opt.htm.

258. Burton TN. United HealthCare to acquire Humana. The Wall Street Journal. New York, NY. 5/29/98:A3.

259. Utah Department of Health, 1998. Available at: http://hlunix.hl.state.ut.us.

260. Gardner RM, Pryor TA, Warner HR. The HELP hospital information system: update 1998. Int J Med Inf. 1999; 54(3):169-182.

261. Warner HR, Olmsted CM, Rutherford BD. HELP - A program for medical decision-making. Computers and Biomedical Research 1972; 5:65-74.

262. Halford G, Pryor TA, Burkes M. Measuring the impact of bedside terminals. In: Stead WW, ed., 11th Annual Symposium for Computer Applications in Medical Care. Washington, DC: IEEE Computer Society Press. 1987:359-362.

263. Classen D, Evans R, Pestotnik S, Horn S, Menlove R, Burke J. The timing of prophylactic administration of antibiotics and the risk of surgical-would infection. N Engl J Med 1992; 326(5):281-286.

264. Pestotnik S, Classen D, Evan R, Burke J. Implementing antibiotic practice guidelines through computer-assisted decision support: clinical and financial outcomes. Annals of Internal Medicine 1996; 124(10):884-890.

265. Kuperman G, James B, Jacobsen J, Gardner R. Continuous quality improvement spplied to medical care: experiences at LDS Hospital. Med Decis Making 1991; 11(Suppl):S60-S65.

266. Willson D. Survey of nurse perceptions regarding the utilization of bedside computers. In: Ozbolt JG, ed., 18th Annual Symposium for Computer Applications in Medical Care. Washington, DC: Hanley & Belfus. 1994:553-557.

267. Evans RS, Classen DC, Stevens LE, et al. Using a hospital information system to assess the effects of adverse drug events. In: Safran C, ed. 17th Annual Symposium for Computer Applications in Medical Care. Washington, DC: McGraw-Hill. 1993:161-165.

268. Classen DC, Pestotnik SM, Evans RS, Burke JP. Computerized surveillance of adverse drug events in hospital patients. JAMA 1991; 266(20):2847-2851.

269. Nelson BD, Gardner RM, Hedrick G, Gould P. Computerized decision support for concurrent utilization review using the HELP system. J Am Med Informatics Assoc 1994; 1(4):339-352.

270. Gardner RM, Hulse RK, Larsen KG. Assessing the effectiveness of a computerized pharmacy system. In: Miller, Randolph A., ed. 14th Annual Symposium for Computer Applications in Medical Care. Washington, DC: IEEE Computer Society Press. 1990: 668-672.

271. Peck M, Nelson N, Buxton R, et al. LDS Hospital, a facility of Intermountain Health Care, Salt Lake City, Utah. Nursing Administration Quarterly 1997; 21(3):29-49.

272. Allen P. Impact of implementing a computerized nursing information system on the medical 4th south and surgical 5th floor at McKay-Dee Medical Center. Salt Lake City, UT: Intermountain Health Care, 1993.

273. Allen P. Interview, 12/9/98.

274. Bowes L. Interview, 1/5/99.

275. Bowes L. Clinical workstation benefits. Salt Lake City: Intermountain Health Care, 1999.

276. Areas where IS technology could reduce IHC costs: IHC Medical Informatics Internal Report. Salt Lake City, UT: Intermountain Health Care, 1998.

277. Loch A. Secret societies. Healthcare Informatics 1998 (November):68-76.

278. Collaborative I: evaluating ambulatory clinical systems, draft metrics directory. Dallas, TX: Scottsdale Institute, 1998.

279. Jones A. Chambers Dictionary of Quotations. Edinburgh: Chambers Harrap Publishers Ltd., 1996.

280. Friis RH, Sellers TA. Epidemiology for Public Health Practice. Gaithersburg, MD: Aspen Publishers, Inc., 1996.

281. Beaglehole R, Bonita R, Kjellstrom T. Basic Epidemiology. Geneva: World Health Organization, 1993.

282. Timmreck T. An Introduction to Epidemiology. Sudbury, MA: Jones and Bartlett Publishers, 1998.

283. Technology Quotations. 1998. Available at: http://www.ee.usyd.edu.au/tutorials_online/topics/online/quote1.html.

284. Keen PGW. Shaping the Future: Business Design Through Information Technology. Cambridge, MA: Harvard Business School Press, 1991.

285. Jacobsen J. Interview, 3/17/99.

286. Jensen R. Interview #2, 1/20/99.

287. Warner Sr. HR. Interview, 3/15/99.

288. Jensen R. Interview #1, 12/8/98.

289. Baird D. Interview, 1/27/99.

290. Clayton P. Interview, 3/15/99.

291. Gardner R. Interview, 2/3/99.

292. Haug P. Interview, 2/24/99.

293. Huff S. Interview, 3/2/99.

294. Jensen R. Interview #3, 3/17/99.

295. Marshall DH, McManus WW. Accounting: What the Numbers Mean. Boston: Irwin/McGraw-Hill, 1999.

296. The Healthcare Management Council I. Intermountain Health Care Urban Central Region, HMC Electronic Product Forecasting Spreadsheet, 1998.

297. Pincetl P. UUHSC capital and operating budget figures, 7/26/99.

298. Gibson S. TCO: fact or illusion? PC Week 1997; 14(27):21, 22, 25.

299. Paul LG. Finding your way in the TCO maze. PC Week 1997; 14(27):7, 25.

300. Nelson N. Interview, 3/3/99.

301. Massaro TA. Introducing physician order entry at a major academic medical center: I. Impact on organizational culture and behavior. Academic Medicine 1993; 68(1):20-25.

302. Massaro TA. Introducing physician order entry at a major academic medical center: II. Impact on medical education. Academic Medicine 1993; 68(1):25-30.

303. Green J. Interview, 12/9/98.

304. James B. Interview, 4/7/99.

305. Malcolm C. Interview, 3/31/99.

306. Smith T. Interview, 3/24/99.

307. Patton GA. The two-edged sword: technology's role in the shaping and control of medical practice. Salt Lake City, UT: Department of Medical Informatics, University of Utah, 1999.

308. Gardner RM. HELP System Uptime Data: Intermountain Health Care, 1999.

309. Computer downtime procedures. Salt Lake City, UT: LDS Hospital, 1992.

310. Hayward SF. Churchill on Leadership: Executive Success in the Face of Adversity. Rocklin, CA: Prima Publishing, 1997.

311. James B. Tracking healthcare costs. Salt Lake City, UT: Intermountain Health Care Institute for Health Care Delivery Research, Mini-Advanced Training Program, 8/13/99.

312. Gunton T. Business Information Technology: End User Focus. New York: Prentice Hall, 1988.

313. Friedman N. Disease management: what, who, when, where, why? A Practical Guide to Disease Management, Lovelace Health Systems, Albuquerque, NM, 2/23/97.

314. Scott L. It's all in the delivery; disease management: the right care at the right time. Modern Physician 1999; 3(9):30-40.

315. Brailer DJ. Information technology: the heart of disease management. Dis Manage Health Outcomes 1997; 1(5):227-232.

316. Hickey M. What is disease management? A Practical Guide to Disease Management, Lovelace Health Systems, Albuquerque, NM, 2/20/97.

317. Metzger J. Cross-continuum care management: new models. In: Drazen E, Metzger J, eds. Strategies for Integrated Health Care: Emerging Practices in Information Management and Cross-Continuum Care. San Francisco: Jossey-Bass, 1999:123-159.

318. Metzger J. Cross-continuum care management: information management challenges. In: Drazen E, Metzger J, eds. Strategies for Integrated Health Care: Emerging Practices in Information Management and Cross-Continuum Care. San Francisco: Jossey-Bass, 1999:160-181.

319. Episodes of Care report card. A Practical Guide to Disease Management, Lovelace Health Systems, Albuquerque, NM, 1996.

320. Evans RS. Interview, 8/24/99.

321. James BC. Managing clinical processes: doing well by doing good. Salt Lake City, UT: Intermountain Health Care Institute for Health Care Delivery Research, Mini-Advanced training Program, 6/28/99.

322. Kelly DL, Pestotnik SL, Coons MC, Lelis JW. Reengineering a surgical service line: focusing on core process improvement. Am J Med Quality 1997; 12(2):120-129.

323. Pestotnik SL. Interview, 8/24/99.

324. Clemmer TP, Spuhler VJ, Oniki TA, Horn SD. Results of a collaborative quality improvement program on outcomes and costs in a tertiary critical care unit. Crit Care Med 1999; 27(9):1768-1774.

325. Frank LR. Quotationary. New York: Random House, 1999 .

326. IHC Mission. Intermountain Health Care, 1998. Available at: http://www.ihc.com/overview/mission.html/.

327. Clayton PD, Anderson RK, Hill C, McCormack M. An initial assessment of the cost and utilization of the Integrated Academic Information System (IAIMS) at Columbia Presbyterian Medical Center. In Clayton PD, ed. Fifteenth Annual Symposium for Computer Applications in Medical Care. Washington DC: McGraw-Hill, 1991:109-113.