DEMONSTRATION AND EVALUATION OF A TOTAL HOSPITAL INFORMATION SYSTEM

Final Project Report
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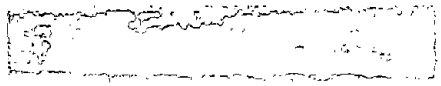

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16. Abstracts.
This report contains findings from the demonstration and evaluation of a comprehensive hospital information system at a general community hospital over a four-year period. The system is used in routine service and it is designed to handle patient records, bed census lists, drug files, employee records, purchase order forms, and medical records. It also provides a means for ordering medications, nursing services, and all other routine and special patient services, and controlled access to various records and ordering routines to prevent unauthorized use. At this hospital the system has proven to be cost-effective with labor savings accounting for 95 percent of the total savings derived. Other benefits include reduced errors, improved timeliness, and enhanced availability of medical information. The report also contains major sections on system implementation, validation, extension, and how economic benefits were realized and expanded for nurses, physicians, and patients.

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FOREWORD

This report documents the experiences of a general community hospital during the implementation and demonstration of a comprehensive hospital information system over a 4-year period. El Camino Hospital, working closely with the system vendor (Technicon Medical Information Systems Corporation) and the National Center for Health Services Research (NCHSR), not only achieved new heights in the utilization of such systems, but provided the environment for performing the most comprehensive evaluation of this type of technology to date. Although Battelle Columbus Laboratories had the responsibility for conducting the bulk of this evaluation under a separate contract with NCHSR, El Camino Hospital performed an extensive cost impact study of the system as documented in this report. The methodologies used in this study were independently reviewed and validated by NCHSR consultants. A follow-up cost study by Battelle currently is in progress.

Of equal importance are the sections of this report relating to the actual system implementation and how the staff was trained and motivated to use this revolutionary approach to hospital information communication and processing. The literally thousands of changes made to the system during the course of this demonstration, changes which evolved a system usable by all of the hospital personnel including physicians, are a direct result of the dedication and imagination of the El Camino Hospital staff.

The cooperative spirit which prevailed during the course of this demonstration and evaluation should serve as a model for future projects involving complex and costly technology. As Senator Alan Cranston stated in the *Congressional Record* (Vol. 121, No. 113, July 17, 1975), this project is

> "...a good example of how private hospitals, private physicians, and private industry can contribute importantly to advancing our ability to provide health care efficiently at the lowest possible cost for all who require it. It also illustrates the useful role of the Federal Government in supporting an objective and independent demonstration and evaluation for use by other hospitals considering such technology."

National Center for Health Services Research
Health Resources Administration
Department of Health, Education, and Welfare

ACKNOWLEDGMENTS

The number of individuals who have contributed in various ways to the success of this project exceeds both our capacity for enumeration and the limitations of space. However, our thanks to that unnamed cast of hundreds are no less heartfelt.

Among those to be singled out for acknowledgment are our two Project Officers---initially, Gerald S. Cohen, and subsequently, Richard M. DuBois, Ph.D., who commiserated, cajoled, encouraged, and ultimately kept the faith through our extended efforts. We are indebted also to the Advisory Panel of Consultants whose guidance proved to be most valuable. Editorial assistance in preparing this final project report was provided by Diane M. Ramsey-Klee, Ph.D., whose contribution is gratefully acknowledged.

Among the El Camino Hospital staff, special thanks is given to the Nursing Department as a whole for their continued support while enduring the frustration of the MIS system's birth pains. Particularly deserving of mention is Mrs. Marilyn Davis, Head Nurse on 4 West, and her capable staff who served as guinea pigs for early system tests and later as the nursing personnel on the pilot unit during system implementation. The contribution of the private practice physicians who make up the medical staff at El Camino Hospital also is acknowledged. They have given substantially in terms of time and endured frustration in dealing with this new technology. In particular, the probability of system survival would have been much lower had it not been for the efforts of Ralph J. Watson, M.D., who headed the MIS physicians' committee. Special thanks, too, go to El Camino Hospital department heads, administration, and R. E. Hawkins, Administrator, all of whom contributed above and beyond the call of duty in this experiment to improve the health care delivery process at the community hospital level.

Finally, we acknowledge with gratitude the contribution by the representatives of the vendor, Technicon Medical Information Systems, who put in innumerable hours of overtime to insure the success of the system.

John E. Gall, Jr.

John E. Gall, Jr.
Project Director

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1. INTRODUCTION

Background

In 1965, El Camino Hospital (ECH), a 464-bed general acute care facility in Mountain View, California, began a collaboration with a nearby aerospace firm, Lockheed Missiles and Space Company, to determine the potential of applying information science and technology to the solution of some of the acute problems facing the health care field. Initial examination revealed a health care delivery system plagued with a growing mountain of paper work, rising labor costs, and under-utilization of professional nursing skills.

Studies of major information-handling operations at El Camino Hospital and at other hospitals were conducted by Lockheed to determine the feasibility, design characteristics, and potential benefits of a computerized information-handling system. Based on the data gathered, in 1966 Lockheed embarked upon a prototype design of a total hospital information system which would be called "MIS" (Medical Information System). El Camino Hospital agreed to serve as the pilot hospital for demonstration and evaluation of this promising innovation.

Early design concentrated on the development of a hospital Business Office System (BOS), and by 1967 ECH had implemented a system encompassing Patient Billing/Accounts Receivable, Payroll, General Ledger, and Accounts Payable. The next step was to perfect, operate, and finally implement the clinical elements of a total hospital information system. Through the active participation of hospital staff in the evolution of design needs, clinical elements of the system began to reach fruition as requirements were drawn up by system development specialists. During 1968, to give hospital staff direct interaction with the system, on-line display and printer terminals were installed in the Doctors' Lounge and at one nursing station. By 1969, as system development expanded, more terminals were installed in Admissions, Laboratory, Radiology, EKG, Pharmacy, Food Service, and at an additional nursing station. During this period (1969-1970), a MIS Operations Committee composed of hospital and medical staff functioned as an advisory panel to provide guidelines for developments, while pilot parallel operations were carried out at each of these stations.

Beginning in 1970, members of the El Camino staff worked in conjunction with representatives from nine other San Francisco Bay Area hospitals to determine applicability in other hospitals and to offer suggestions for the final system configuration. By mid-year, many of these suggestions had been incorporated, and during April-June 1970, four physicians and the nursing personnel on one nursing station (a medical unit) were trained for actual prototype operation.

Beginning in August of 1970 and continuing for one month, the four physicians entered all orders for their patients' stay, and the nursing staff operated each of the nursing portions of MIS (except the nursing notes) in parallel with manual operation. At the same time, system performance was reviewed and evaluated by the MIS Operations Committee. This examination indicated that the design concepts appeared to be sound and that prototype operations functioned satisfactorily.

In April of 1970, Lockheed submitted a fixed-price proposal for the full installation of MIS, thus initiating an extensive evaluation conducted by a 45-man evaluation team including the management engineering staff and members of the hospital and physician staff. More than 18 man-months of effort were devoted to this task with major emphasis placed upon prediction of the potential cost benefits associated with system use, the hospital system performance characteristics, and system capabilities. The evaluators concluded that a computerized hospital information system was conceptually and economically feasible.

Following this evaluation of the Lockheed system, the hospital undertook an extensive evaluation of other vendors offering similar hospital information systems. Comparative analyses were performed by the hospital's management engineering staff and included investigation of the following elements for each system (where such data were provided by the vendor): (1) system philosophy, (2) installations and progress, (3) input/output devices and hardware configuration, (4) departments and functions covered, (5) system outputs, and (6) cost per patient day. It was determined that the Lockheed MIS service offered the most comprehensive and potentially cost-effective hospital information system available.

In the spring of 1971, El Camino Hospital and Lockheed entered into an agreement to install MIS in the hospital. The agreement specified that implementation costs would be borne by the vendor, and furthermore, because of the developmental nature of the system, that payments by the hospital for service would be made only as cost benefits were actually realized.

During the same period in the spring of 1971, Lockheed Missiles and Space Company entered into negotiation with the Technicon Corporation, a manufacturer of automated laboratory instruments located in Tarrytown, New York, for the acquisition by Technicon of the Lockheed-designed system. On May 28, 1971, Technicon concluded a purchase agreement with Lockheed for the Medical Information System, and for the skills of all project personnel who joined the new Technicon subsidiary---Technicon Medical Information Systems Corporation. This event effected no material change to the vendor-hospital contract.

Late in 1970, the National Center for Health Services Research and Development issued a request for proposal for a comprehensive, in-depth study of a real-time total hospital information system. Such a study, which had never been done before, would require new methodology and would entail the evaluation of a *comprehensive working system*, that is, a system which would be in full-time use by the hospital as the major nonoral communication tool and which would comprehend *all* the major functional elements of the modern hospital. Such a system would have not only the capability for handling patient care data, but also would provide hospital management information.

In 1971, the MIS project gained national recognition when in competition with the most promising similar projects in the United States it was awarded a 1-year $373,000 contract by the National Center for Health Services Research and Development to undertake this system demonstration and evaluation. The original contract was subsequently extended both in amount to $1,211,000 and in duration to December 1974.

To date, total investment in the development of the MIS system is estimated by the vendor to be roughly 20 million dollars. In addition to HEW reimbursed out-of-pocket costs for the demonstration, the hospital has contributed significant nonreimbursed effort.

Project Objectives

The general project objectives are spelled out in the following quotation from the initial contract documentation, "Description and Scope of Work."[1]

A. This contract seeks to demonstrate the feasibility and benefits of a hospital communications system that has the capability of both hospital management and patient care management. It is our intention to use for this demonstration a hospital information system (HIS) that is either already fully installed or ready to be installed. It is not our intention to support major hardware or software development work. It is recognized that since the advent of computer data processing technology, a number of academic as well as commercial organizations have developed and in some instances marketed hospital information systems. Generally, these systems were developed without full participation of potential user groups, and consequently have fallen short of the mark in meeting all the needs of hospitals in performing office management, medical records maintenance, and patient care management. While this contract is basically a demonstration and evaluation effort, it is understood that for the foregoing reasons certain developmental changes and innovations may have to be introduced into the system in the course of this project.

B. Specifically, in performance of this contract the contractor shall:

1. Provide a completely installed hospital information system. This HIS must be used in routine service and designed to handle the following functions: patient records, bed census lists, drug files, employee records, purchase order forms, and medical records. It should also provide a means for ordering medications, nursing services, and all other routine and special patient services, and must control access to the various records and ordering routines to prevent unauthorized use. Operating stations for the system should be located at nursing stations and other controlled access locations within the hospital. Specifically, the contractor must provide a system with hardware and software already developed that will service as many of the areas listed below as possible but at least items 1 through 5:

(1) Nursing Station
(2) Admitting Office
(3) Business Office
(4) Automated Service

a. Clinical Laboratory
b. Pharmacy
c. Physicians' Orders
d. Nurses' Notes

(5) Current Patient Medical Records
(6) Outpatient Records
(7) Epidemiology
(8) Chronic Disease Records
(9) Research Functions
(10) Automated History
(11) Continuing Education
(12) Patient Management

a. Diagnosis
b. Optimum Therapy
c. Planning

(13) Statistical Services
(14) Consulting Services

a. Emergency Information
b. Library
c. Referral

(15) Patient Monitoring
(16) Emergency Services
(17) Program Planning and Budget
(18) Community Integration

Hospital staff must be prepared to utilize this system as their sole method of operating; a parallel, manual system should not be maintained.

2. Assure the full installation and operation of the system within six (6) months of the date of contract. This assurance must be supported by letters of commitment from subcontractors, confirmed delivery schedules, etc.

3. With the approval of the NCHSRD Project Officer, a subcontract shall be let within thirty (30) days to an independent third party to contribute roughly three professional man-years to assist the contractor in performing a thorough on-site evaluation of selected medical, technological, organizational, and sociological factors related to the introduction of the hospital information system. In particular, the following hypotheses should be tested:

The computer-based hospital information system:

a. induces significant changes in the procedures and organization of hospital management and patient care;

b. is acceptable to staff;

c. increases efficiency, where efficiency is defined as cost per unit of output or the utilization of resources;

d. increases productivity, where productivity is defined as the number of patients processed per unit of time or the improvement in quality of the outcome; and

e. is cost effective.

Project Organization and Responsibilities

Pursuant to the contractual requirement specifying assistance by an independent third party in the evaluation of the system, the subcontractor team of Battelle Columbus Laboratories, Columbus, Ohio and KMB Health Systems, Palo Alto, California, was selected to conduct three of the four agreed-upon evaluation perspectives. They would be responsible for evaluating the impact of the system from medical, technical, and organizational standpoints. Following the initial evaluation phase and preparation by Battelle of an interim project report, continued evaluation activities in the medical, technical, and organizational areas were conducted solely by Battelle. A separate report issued by Battelle documents final findings in these areas.[2]

Responsibility for evaluation of the economic impact of the system remained with the hospital. To organize and direct this endeavor, the services of a consultant, Donald D. Norwood, associated with the Infor-Med Corporation, Palo Alto, California, a consulting firm specializing in health care information system activities, were acquired by the hospital. John E. Gall, Jr., Director of the Management Engineering Department at El Camino Hospital, served as Project Director.

The following Management Engineering Department staff members served as the primary hospital implementation team: Margo Cook, R.N. (Nursing); John Fleming (Nursing Cost Benefit Realization); and Richard Rydell and Charles Olsen (Ancillary and Support areas).

Scope of Report

This report documents El Camino Hospital's experience in demonstrating and evaluating a total hospital information system over the 3-year period of the contract awarded by the National Center for Health Services Research covering the time period July 1971 to December 1974. Part of the subsequent year was spent analyzing the cost and acceptance data collected during the course of the contract preparatory to writing the final report. Consequently, the date of this report is December 1975.

Hospital Description

El Camino Hospital is a 464-bed, 52-bassinet, nonprofit, tax-supported (district), short-term, general community hospital serving patients under the care of their own personal physicians. Opened in 1961, the hospital primarily serves the suburban communities of Mountain View, Sunnyvale, Los Altos, Los Altos Hills, and Cupertino, California and certain unincorporated areas adjacent to these cities.

The client population is relatively young [1973 patient age distribution: under 14 (12%), 14-64 (69%), 65 and over (19%)], of middle and upper-middle income level. Nineteen percent of the patients qualify for Medicare or Medi-Cal.

Patient days for 1974 totaled 123,089; there were 25,287 admissions including newborns in the same period. The average occupancy rate for 1974 was 66.3 percent (excluding newborns), and the average length of patient stay was 4.9 days for adults and children. For the year ending June 30, 1974, hospital expenses totaled $18,000,000.

Approximately 340 physicians practice almost exclusively at El Camino Hospital, and an additional 173 enjoy courtesy medical staff membership. All of the 19 specialties recognized by the American Medical Association, plus many subspecialties, are represented on the medical staff. Interns or residents are not normally employed at ECH.

In 1974, total hospital staffing averaged 990 full-time equivalents (FTE's), or 2.13 FTE's per bed. The nursing department represents the largest segment of employees with 409 FTE's. Of these, approximately 384 are involved in providing direct patient care. Sixty percent of the patient care was provided by registered nurses.

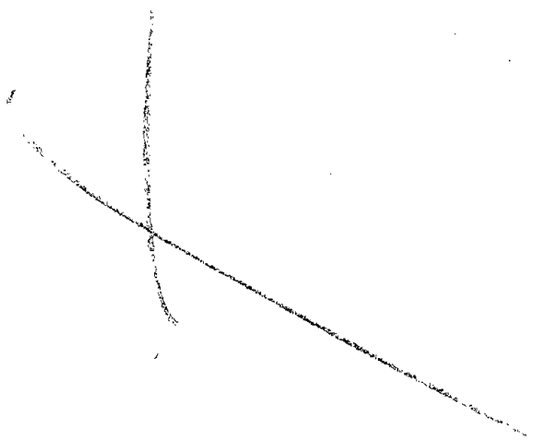
Included in the present services of the hospital are acute cardiac and intensive care, psychiatric facilities, kidney dialysis, and the latest inpatient and outpatient ancillary services. Diagnostic, surgical, and nursing facilities also are available for open-heart surgery patients. Area physicians also call upon the hospital for such diagnostic procedures as heart catheterization, electromyographic analyses of nerve function, blood gases, radioactive isotope studies of various body organs, and radiation therapy.

Although the hospital is not associated with a medical school, it does participate in several teaching programs for training of RN's, LVN's, radiology technicians, inhalation therapists, and medical technologists.

REFERENCES

1. Article I, Special Provisions, Contract No. HSM 110-71-128, June 23, 1971, Department of Health, Education, and Welfare, Public Health Service, Health Services and Mental Health Administration, National Center for Health Services Research and Development.

2. Barrett, J. P., Barnum, R. A., Gordon, B. B., & Pesut, R. N. *Evaluation of the Implementation of a Medical Information System in a General Community Hospital*. Final Report, December 19, 1975, Battelle Columbus Laboratories, Contract HSM 110-73-331, Department of Health, Education, and Welfare, Health Resources Administration, National Center for Health Services Research. NTIS Publication No. 248340.



2. CONCLUSIONS AND RECOMMENDATIONS

This report presents the results of the demonstration and evaluation of the Technicon Medical Information System (MIS) at El Camino Hospital. The Technicon MIS is a dynamic, interactive computer information system which substantially automates all clinical and administrative information handling. MIS interfaces with the nurse, physician, clinical laboratory, pharmacy, radiology, and other medical services. MIS also interfaces with the administrative functions of the hospital, such as admissions, business office, and medical records.

The hospital performed studies related to the economics of the Technicon System, in terms of both quantified cost savings and the means used to realize these savings. This report also documents the history of MIS implementation, discusses patient care benefits and user acceptance, and describes a planned extension of MIS on patient care quality assurance.

The Battelle Columbus Laboratories evaluated the system from medical, technical, and organizational standpoints[1] concurrent with the hospital's economic evaluation. The independent verification of the cost effectiveness of MIS is the subject of a current study by Battelle for HEW scheduled for completion early in 1977. That study will contain Battelle's conclusions regarding cost effectiveness of the system. NCHSR consultants including Battelle have, however, reviewed and validated the cost-effectiveness methodology used by El Camino Hospital in this report.

This section presents El Camino Hospital's major conclusions and recommendations to HEW based on the findings of this demonstration and evaluation.

Conclusions

(1) Nursing Acceptance. Nursing acceptance of MIS, always high, continued to improve with time and experience until July 1974, when 92 percent of the nurses favored the system. Nurses perceived MIS as benefiting them in many ways, including a major reduction in clerical tasks, greater availability of patient data, improved legibility, and improved patient care planning (see Section 4).

(2) Ancillary Department Acceptance. Admitting, Pharmacy, Radiology, Laboratory, and other affected departments generally have shown good acceptance of MIS. This approval is due primarily to improved timeliness, completeness, accuracy, and availability of information, and to reductions in clerical work (see Section 4).

(3) Physician Acceptance. Physicians have increasingly accepted MIS until by August 1974, 61 percent of physicians who expressed a positive or negative opinion voted to retain and extend the system. Actual acceptance is even higher, since physicians who are major users of the hospital generally are also major users of the system (see Section 4).

(4) Cost Effectiveness. The Technicon System has proven to be cost effective at El Camino Hospital; that is, cost savings substantially exceed the system's cost. The net cost savings after paying for the system's cost are conservatively estimated to range from $3 to $5 per patient day. These favorable savings continue to increase with time (see Section 5).

(5) Cost Savings. Labor savings account for about 95 percent of the MIS cost savings, and nursing labor constitutes most of the labor savings. Major cost containment also has been demonstrated, both in terms of El Camino Hospital's cost trends after the installation of MIS compared to the pre-MIS period, and in terms of comparisons to similar hospitals in the surrounding area during the post-installation period (see Section 5).

(6) Analytical Methods. The foregoing favorable cost-effectiveness conclusions are supported by three independent analytical approaches. These approaches have been reviewed and validated by HEW consultants (see Section 5).

(7) Other Benefits. MIS provides a number of significant benefits which have additional economic consequences (e.g., reduced errors, improved timeliness, and enhanced availability of medical information). Because these benefits are difficult to quantify, they are excluded here. Hence, the favorable economic conclusions are believed to be substantially understated (see Section 5 and the Battelle Report[1]).

(8) Economic Benefits Realization. El Camino Hospital was successful in translating time saved by MIS in nursing and ancillary departments into staff reductions and/or staff increase avoidance, and hence into reduced costs. The hospital's Management Engineering organization was instrumental in facilitating the economic benefits realization (see Section 6).

(9) Catalyst for Change. In addition to the cost savings and cost containment described above, the introduction of MIS acted as a change agent, or catalyst, to effect improvements that theoretically could have been, but in practice probably would not have been implemented without MIS (see Section 6).

(10) Future Extensions. The hospital administration and the medical and nursing staffs recognize the future potential of MIS for further improvements in patient care and resource management (see Section 7).

Recommendations

In view of El Camino Hospital's highly successful experience with MIS, certain recommendations seem warranted.

(1) Differentiating Between Cost Lowering and Cost Raising Technology. In view of the general belief that sophisticated technology has contributed importantly to hospital cost inflation, care should be taken to clearly separate proven cost lowering technology such as MIS from cost raising technology in establishing governmental planning guidelines, reimbursement criteria, incentive programs, controls, and so forth.

(2) Achieving Cost Effectiveness. Hospitals considering the installation of a comprehensive medical information system with the expectation of achieving cost effectiveness should be prepared to commit the necessary level of administrative and staff support, including that of an adequate and competent Management Engineering organization.

(3) Considerations in Selecting a Medical Information System. Institutions intending to install a medical information system should seriously consider a system that is comprehensive, integrated, fully developed and tested, and user accepted. Such an approach avoids the high cost of development, the trauma associated with a drawn-out implementation period, and the high risk of failure.

(4) Attitude Toward Medical Information Systems. As the principal beneficiary of hospital cost savings, Government should facilitate and encourage the installation of medical information systems which are designed for direct professional use, are comprehensive in scope, and for which cost benefits have been proven.

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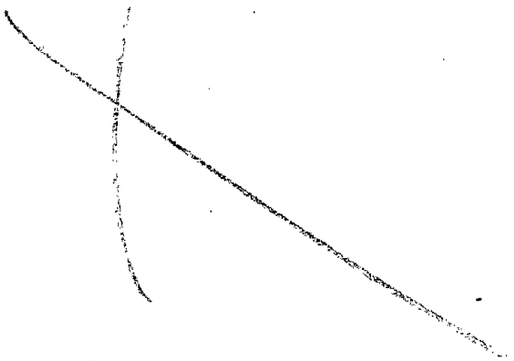
1. Barrett, J. P., Barnum, R. A., Gordon, B. B., & Pesut, R. N. *Evaluation of the Implementation of a Medical Information System in a General Community Hospital*. Final Report, December 19, 1975, Battelle Columbus Laboratories, Contract HSM 110-73-331, Department of Health, Education, and Welfare, Health Resources Administration, National Center for Health Services Research. NTIS Publication No. 248340.



3. MIS IMPLEMENTATION, VALIDATION, AND EXTENSION

Introduction

Before embarking on the subject of this section, an editorial note to the reader is in order. In setting down the history of the MIS implementation and demonstration experience at ECH, the authors initially sought to identify and distinguish three distinct phases of the project:

(1) Implementation---getting the system physically installed and operating, albeit perhaps not to the originally specified or intended performance levels.

(2) Validation---perfecting the operational, but imperfect system to arrive at a system configuration and performance levels which were satisfactory to hospital staff and personnel.

(3) System Extension---modifying and further developing the system to extend the capabilities of the system beyond the original design intentions.

One of the reasons for attempting to categorize activities in this manner was to emphasize that the El Camino implementation experience did not represent a typical implementation experience of a fully developed and tested system. Rather this section describes the birth pains of serving as the first installation for a developmental system, that is, one which had never been tested under operational conditions or operated successfully for some period of time.

Although the authors generally were able to separate activities and development work that represented "system extensions," it proved impossible to classify many activities as representing either implementation or validation, since the process of implementing and perfecting the system was an iterative one which extended over a period of three years. To illustrate this process, a satisfactory Emergency Room (E.R.) subsystem configuration was not realized until January 1974, more than two years after initial implementation began. When the original E.R. subsystem proved to be unacceptable, certain temporary measures were implemented to improve upon the most egregious deficiencies, and studies were begun to develop an improved subsystem. Because of the original nature of the work, such studies might better be classified as research rather than implementation or validation activities. Programming analysis, programming, testing, and implementation of the redesigned module followed. Further minor modifications typically were needed subsequently to refine the improved subsystem. In contrast, the statusing function was satisfactorily developed and made operational during the first months of implementation. Such a developmental sequence, as depicted in the preceding illustration, was typical of many improvements which were necessary to attain an acceptable system configuration.

Preparation for Implementation

Once it had been determined that the Technicon Medical Information System* would be implemented at ECH, many organizational preparations were set in motion. The pre-implementation tasks began in May of 1971 and continued until implementation actually began in January of 1972. It was of the utmost importance that new lines of communication between Technicon, ECH Management Engineering, Administration, and the various departments be put into effect and remain open and viable. Thus, a committee structure was developed, and various functions were outlined.

An Executive Committee, consisting of key administrative executives from ECH and Technicon, was established to oversee implementation and operation, make policy decisions, and review contract changes as well as system change requests.

An Implementation Team consisting of members of the Management Engineering Department was established to coordinate installation and operation throughout the hospital, integrating various departmental and nursing unit needs into a cohesive whole. This team would also keep administration and all departments abreast of the implementation progress.

Department Task Groups consisting of a representative from each department, one member of the hospital Management Engineering Department, and one Technicon MIS representative would relay departmental needs and operational methods and progress to the Implementation Team and the vendor.

The MIS Physicians' Committee, consisting of an active member from each Medical Staff department, would represent the physician's point of view. A member of the Implementation Team was a part of this group.

The MIS Nursing Committee, consisting of representatives from various specialties and all levels of nursing, would represent the needs in their areas. The nurse from the Implementation Team was a part of this group.

Once the organizational plans had been laid, the pre-implementation training program began. By dividing the computer into partitions as Technicon planned to do later for two or more hospitals, a *practice hospital* was developed which simulated real hospital operation for teaching purposes. Technicon prepared various user's guides and practical workbooks. One of the cafeteria's private dining rooms was temporarily converted into a training site with seven video matrix terminals (VMT's) and several printers installed in the area.

The training programs for nurses, physicians, and ancillary departments were designed around the user's specific needs and proceeded simultaneously, but separately. These programs were developed jointly by Technicon and ECH, with actual instruction conducted by Technicon.

* A description of the Technicon Medical Information System (MIS) is contained in Appendix A.

Nursing, because of sheer numbers and, more importantly, because of the centrality of this department in the hospital communications network, claimed the most attention. Formal, pre-implementation classes were conducted over a 6-week period from August 1 through September 11, 1971. Classes consisted of about seven registered nurses attending five 1-hour sessions over a 2-week period. The orientation covered the physical mechanics of MIS, actual methods of use (e.g., charting, care planning, and discharging), projected role changes, and benefits to be derived.

Physician training began in the fall of 1971 in sequential fashion, that is, physician specialties were trained in conjunction with the planned implementation of corresponding nursing stations. It was determined that one 2-hour session would be sufficient for a physician to become oriented to MIS. The average class size was originally planned to be five physicians, but in fact much physician training was individualized. Orientation included an overview, methods of writing orders, retrieving data, and the use of computer documents, with special emphasis placed on the concept of physicians' personal order sets.

Radiology, Pharmacy, Inhalation Therapy, Pulmonary Function, and Medical Records were oriented initially to MIS on a group basis within their own departments, with the actual departmental users trained individually according to their needs. Additional pre-implementation activity in the Pharmacy included preparation for conversion to a unit-dose medication system. This activity included packaging of medications not conveniently available in unit-dose form.

The Clinical Laboratory was treated differently and trained on a group basis first, then in three separate but related subgroups. The three areas covered were maintenance of laboratory processing tables; statusing; and clerical functions including collection, work sheet requesting, routing, test result entry, and billing procedures. Supportive written guides also were provided. In Admitting, formal training sessions were augmented by intensive practice sessions the week prior to actual MIS implementation.

Along with organizational and training preparation came the realization that psychological preparation for the installation of this relatively unfamiliar computer system in the hospital environment also represented a genuine need. Minimization of alienation and fear was a major concern. A key factor in generating anxiety was the difficulty hospital staff had divorcing themselves from present operations so as to understand the new system. In attempting to deal with this anxiety, the implementation team was constantly called upon to project for the staff the characteristics and qualities of the new system.

Equipment implementation proceeded in stages beginning with the installation of the 7-terminal training site and the establishment of implementation priorities for equipment installation. The number and sites for the video matrix terminals and printers were established based on factors including information volume and user concentrations. Actual installation of the hardware took place over the summer and fall of 1971.

Once actual installation of hardware was completed, various live evaluations were conducted to assure that the number of terminals was adequate, that response times were acceptable, and that the system possessed sufficient capacity to handle peak loads. One such test, a system saturation test of two and one-half hours duration, was designed to determine system performance under heavy use. Conditions imposed on the system were a full patient load (extrapolated four years hence), a complete range of activities and specialty information processing capabilities, hospital-wide routing of reports, and a peak hour traffic load. The full complement of printers and terminals was operated during the test by hospital staff. Satisfactory response times were observed over the two and one-half hour test span, although some minor hardware problems were encountered.

Another test was a "clock-driven" test to determine if all time-triggered printouts would print at the proper time in the right place. In October and November of 1971, simulations were run in the Laboratory, Radiology, and other ancillary departments with sample data. These tests were run both as a proof of the system and as an extra training experience. The results of these simulations were basically good with the exception of the Laboratory. In this department, the fact that the system had not yet been completed caused the personnel to develop incorrect concepts of what the system would do and negative attitudes toward the hypothesized configuration.

Technicon also conducted an analysis of disk file storage requirements to determine if the allocated space would be adequate. In addition, an audit was accomplished that tested the operation of the interface between the Medical Information System and the Business Office System, insuring that all charges were accurately and automatically accounted for in all departments.

Before implementation, copies of all video matrices were distributed to the respective departments so that they might check the displays for completeness and accuracy. Also, all user codes were issued, finalized, and checked under a control procedure designed to insure confidentiality. Each user was instructed that his code constituted his signature.

Once it had been determined that the system was capable of performing under the load of the saturation test and that printouts were being properly generated and distributed, a nursing unit was selected as the initial on-line check-out station. During November and December of 1971, 4 West, a 34-bed medical unit, was operated as the test unit with records on six patients at a time entered into the system. At this point, insofar as could be determined, each MIS function had been checked out and verified.

Plans were made to provide support for the nursing staff as the nursing stations were implemented. During the first week that a nursing unit became operational on MIS, one Technicon systems representative and one hospital RN would support regular unit personnel on the day and evening shifts. For the night shift, this support would be reduced to one hospital RN. For the second week, one RN would assist on each shift. During the first two weeks of implementation, Radiology and Laboratory would have day and evening support from their respective Technicon representatives, while Pharmacy and the Business Office would have only day support. A Technicon physician representative

would be available to assist doctors during heavy usage periods for the first few weeks of implementation on each unit. All Technicon departmental representatives would be on call on a 24-hour basis.

In addition to these provisions, an overall system support structure would be maintained. This support consisted of a Technicon MIS duty officer, a Technicon hardware technician, and an on-call ECH Management Engineering staff member. The duty officer would perform trouble-shooting for user and technical problems and would provide the liaison between the hospital authorities and the computer center regarding all problems and daily operational changes. The hardware technician would carry out maintenance and keep both terminals and printers in continuous operational status.

During pre-implementation, a schedule was developed projecting the sequential implementation of the 14 nursing units. The projection meant that the ancillary departments with the exception of Admitting would run in dual modes (manual and MIS) until all of the nursing stations were implemented. Since it was essential for patients to be registered in the computer before any other activity could be carried out, implementation of Admitting would precede the first nursing station and this department would convert its entire operation in the first week.

Four to six months were allotted for the implementation task. However, the implementation period lasted from December 28, 1971 until October 1972, exceeding the anticipated schedule by 100 percent. This protraction can be attributed to the large number of problems encountered. It may be illuminating to attempt to categorize these problems into two areas: (1) problems for which an immediate solution was necessary for the continuation of system operation or for continuation of the implementation program, and (2) system deficiencies which prevented the system from functioning as well as intended. These problems alternatively might be labeled "urgent" and "deferrable," respectively.

In addition to the many changes arising through resolution of problems, further alterations were undertaken to capitalize on *potential* capabilities of the system. Because these alterations exceeded the specifications of the original design configuration, they are termed "system extensions." These subsystem developments generally can be thought of as being highly desirable but not essential.

As discussed in the introduction to this section, although the intent of the threefold classification scheme was to clarify the implementation experience for the reader, it is not entirely satisfactory because the boundary lines between the three phases of the project were often blurred. For example, numerous developments classified as physician subsystem extensions were, in fact, <u>essential</u> to secure physician acceptance and thus constituted changes necessary to make the system work in the intended manner.

The implementation plan was designed on the basis that nursing units would be completely implemented in a sequential fashion and that ancillary departments would bear the brunt of operating with dual systems (manual and

MIS) throughout the implementation period. No method of implementation presented itself that would not require one or more departments to use both systems throughout implementation. Either the service areas would function in this way or the nursing units would be so obligated. At the time, it was felt that a complete conversion of the nursing units' information processing and patient records would present the least chance for untoward impact upon patient care delivery. Therefore, it was decided that once the admitting function was operational, the most likely place to start implementation was the nursing unit which had shown the most interest, served as the test bed and pilot unit, and whose esprit de corps seemed ideal for carrying the unit through the trauma of being number one.

Pre-implementation tasks, both at the hospital and at the vendor's site, reached completion just before Christmas of 1971, making it possible to convert Admitting during the lull between Christmas and the New Year.

System Implementation, Validation, and Extension

At the time that implementation began, MIS was a prototype of a system that was still in the latter stages of development. This fact was not fully appreciated until implementation was in process, necessitating many changes, both large and small, to achieve a fully operational system that performed the required functions and that was acceptable to users.

Admitting Department. In late December of 1971, the Admitting Department began entering all new patients to the system. Start-up support was present for most of the first week. The MIS admitting function was designed to duplicate the information processing of the Admitting Department as it had operated manually. Although the initial configuration did what it was supposed to do, before long it became apparent that improvements in the system could be made.

Initially, admission records were being printed on a real-time basis in the following departments: Nursing, Business Office, Housekeeping, Mail Room, and Admitting (for use by Admitting, PBX, and the Reception/Information Desk). Analysis indicated that Housekeeping, the Mail Room, and the Reception/Information Desk did not require this information on a real-time basis, but could use an Alphabetic Patient List generated twice a day in a batch mode. Paper usage and handling thus were substantially reduced.

Another system change that reduced errors enabled automatic assignment of patient identification numbers; initially these numbers had to be typed into the system after selection from a manual log book. An early change to the Admitting subsystem was to replace the Addressograph method of identifying patient documents with a label method, using a MIS printer with special label paper. The early conception of this scheme was derived from a disinclination to handle patient demographic data twice in the Admitting Department (the admission form and the Addressograph plate), since with MIS it could be reduced to a 1-time procedure. Once inaugurated, the multiple flexibilities of the label system became apparent. Labels could be used not only for documents, but for specimens as well. Changes in patient I.D. data, if entered in MIS, required only a light-pen selection to obtain a set of correct labels.

Direct admission of patients at the Delivery Room and in the Nursery represented another improvement which eliminated data transferral between departments, since the mother goes directly to the Delivery Room and the baby directly to the Nursery. This procedure was activated soon after the Delivery Room and Nursery became MIS-operational.

During early implementation, because all nursing units had not been implemented, Admitting temporarily acquired the data handling function with regard to transfers and discharges. This responsibility represented a large workload for a small department, and soon the responsibility was transferred back to nursing by implementing this one function on all of the nursing units.

During implementation, Admitting encountered serious system performance problems, since their heavy work period (1 P.M. to 3:30 P.M.) coincided with a peak overall hospital usage time; consequently, response time was substantially degraded. By streamlining the processing and upgrading the main computer, the system response time was significantly improved and the problem was eliminated. Later improvements in the admitting function involved (1) streamlined matrices, which minimized the entry of redundant information; (2) capability for the Emergency Department to transfer emergency patients to inpatient status; and (3) display of "census by type," enabling the chief admitting officer to monitor departmental activity and to make appropriate work assignments.

A pre-admission feature was developed early in the implementation phase. Although work on this feature has not been completed, as it exists, patients can be pre-admitted into MIS and orders can be written prior to their arrival at the hospital. The orders entered print in the appropriate ancillary department and are filed until the patient actually arrives. Pharmacy orders for some scheduled medications cannot be written in the pre-admit mode and must be entered after admission. At the time of admission, a summary of all pre-admit orders prints along with the admitting document at the nursing station. The plan to complete the pre-admit system (scheduled for 1975) calls for the ability to hold all orders in the system until actual admission, then to complete their processing.

Nursing. In preparation for the changeover of a nursing unit from manual information processing to MIS operation, detailed plans had to be made for the conversion of patient records to insure that accuracy was maintained, that confusion was minimized, and that no data were lost. Careful interface between the nursing staff and the Technicon staff was required. The conversion of the patient chart was planned for the first day, followed by initiation of operation by unit nursing personnel on the second day.

On the first day, Technicon staff manned the terminals to enter all current orders on patients housed on the nursing unit. During the second shift, comparison of the Kardex (manual system orders catalog) with the MIS Patient Care Plan was initiated to reconcile any discrepancies and to obtain updated, corrected MIS care plans for the night shift.

On the third shift, requests for Diet Lists and Unit Work Sheets were initiated. At this time, Nursing assumed responsibility for verifying the care plans against the Kardex and maintained these through the end of the shift. A verification that the patient's record was converted to MIS and checked by a nurse was included in each chart for historical purposes.

On Tuesday, January 4, 1972 at 7 A.M., actual operation of MIS began on Nursing Station 4 West. Census was restricted to 20 patients for approximately two and one-half weeks, a period of change expected to be the most difficult. Physicians entered orders into MIS while nurses used MIS for all reporting and ordering. Use of the unit-dose medication system at El Camino Hospital was phased in with MIS implementation on the nursing units. As a final check, the entire manual system was maintained for 48 hours in parallel with MIS operation. On the night shift, the first 24-hour Patient Summaries were printed out and placed in the patients' charts. At 7 A.M. on January 6, 1972, manual procedures ceased, and the operational status of "stand-alone" was realized. The only exception was laboratory ordering which was handled by both the manual and automated systems for approximately two more weeks. At midnight on January 7, automatic billing of patient charges was initiated on 4 West. During this time, the support to the unit consisted of at least one Technicon person 24 hours a day as well as an increase in nursing staff by one person on each shift. Management Engineering staff members were available in person around the clock.

Problems encountered during this first 2-week period included serious deficiencies in the Laboratory subsystem, lack of an order statusing mechanism for all ancillary departments, numerous problems regarding printouts, questions regarding the desirability of the 24-hour patient summary concept, lack of sufficient scheduling capabilities for medications, deficiencies in the IV ordering system, and problems with the diet lists as well as equipment problems coincident with power tests or failures. These problem areas were identified in addition to the myriad "bugs" encountered and corrected during this time. It quickly became evident that these problems would preclude moving ahead as rapidly as had been planned.

The significance of such problems is best exemplified by the "statusing problem." In the manual system, the nurse indicated a particular state of progress in the execution of an ancillary order by crossing out the order on the Kardex. This practice indicated to all concerned, for example, that the specimen had been obtained or the X-ray had been taken, that work had been initiated, and that although results were not necessarily available, they could be expected. In contrast, in MIS there was no way to indicate the progress, such as specimen collection. Thus, personnel responsible for getting the specimen or the X-ray results had no way of knowing when it was done. Until the problem was resolved, manual adjuncts were necessary to keep personnel adequately informed.

To achieve resolution of these early implementation problems as rapidly as possible, daily problem review sessions were held with the head nurse in attendance. In addition, several group meetings were held with 4 West nursing personnel to answer their questions and to allow them to express themselves regarding MIS operation. Regular meetings between nursing staff on the unit being implemented and Technicon and Management Engineering repre-

sentatives replaced the function of the MIS Nursing Committee in most instances during the period of implementation.

With the basic Laboratory subsystem functioning and the advent of a statusing mechanism, it was decided to implement a surgical unit to see if new light might be shed on old problems and to uncover problems peculiar to a surgery unit. In contrast to the two weeks planned, six weeks had been required for implementation of the first nursing station. Although all problems associated with operation on the first nursing station had not yet been solved, it was decided that further delay would be detrimental to the momentum already generated in preparation for the MIS system conversion. At this time it was also decided that on-the-job training in the form of one day spent on a MIS-operational unit would enhance the ability of personnel to visualize the change. This training was established for each subsequent nursing station immediately before its implementation.

On February 22, 1972, MIS was implemented on 2 East, a 34-bed surgical unit. Because of concern regarding system performance, similar parallel (manual and MIS) operations were planned. The system, however, performed with a sufficient degree of accuracy, and because of the difficulty in using two systems simultaneously, 2 East achieved stand-alone status after 24 hours. Several additional MIS problems unique to surgical patient care, such as the inefficiency of the pre-op check list system and the procedurally defective diet list, were uncovered.

Support for this unit, as well as for subsequent units, included one Technicon representative around the clock for one week, one nurse on each shift from a MIS-operational unit for two weeks, and Management Engineering staff either in the hospital or on call. This pattern of support was repeated for each unit on start-up. Census on 2 East was kept to 20 for about two weeks. Subsequent start-ups were accomplished without any attempt to control census.

During the period extending from January through March of 1972, equipment reliability was a constant source of irritation. While some "downs" were unavoidable, many were elective, resulting from decisions to halt MIS briefly to "fix something." To smooth operations, a policy was established insuring that no planned downs would be made without hospital concurrence, and that all "fixes" would be made at the 3 A.M. scheduled down. This policy allowed for genuine emergency downs and served to reduce user irritation.

Before moving on with implementation, the 24-hour patient summary issue was resolved. This document evolved under the assumption that presentation to the physician and nurse of all relevant patient data from the last 24 hours would be a desirable improvement over the conventional chart layout. Thus, the physician could, by reviewing one document, quickly assimilate all important recent patient information. Unfortunately, presentation of data by 24-hour slices made correlation over time and analysis of trends more difficult. When this facet of patient management was suddenly made more difficult, the importance of this capability was quickly realized. Consequently, the 24-hour summary was split into parts: Doctors' Orders, Nursing Records (quantitative measurements and medications), Nurses' Notes, and Ancillary Results, which were returned to their traditionally separate chart locations.

Another major problem with the concept of one document for 24 hours involved the requirement that all of the data be summarized at one time, for example, at midnight. To include the night shift nursing data for review at doctors' morning rounds, the optimum time for printing Nursing Records and Notes was 7:15 A.M. The optimum time for summarizing laboratory data was late afternoon, when the lab had processed and reported the bulk of its work and prior to physicians' evening rounds. The summary of doctors' orders still could be printed at midnight. Reorganizing summary data along more traditional lines allowed the generation of the component documents at more appropriate times. It is interesting to note that the format of the 24-hour Patient Summary, which was found unacceptable in general use, had been approved by the MIS Physicians Committee and had been used without complaint by physicians in the MIS development and testing phases.

Requests from users, particularly physicians, for a MIS replica of the 7-day medications summary that they found so useful as a part of the old manual system, led to development of such a document (see Figure 1) and its extension to a similar printout summarizing the last seven days of laboratory results. The latter has been further developed and refined as discussed in this section under Clinical Laboratory.

Early in April, it again was felt that further delay in the implementation of subsequent nursing stations might cause a loss in the momentum of change. Consequently, on April 11, 1972, 6 West, a 32-bed Gynecology unit, was implemented. The changeover progressed with little difficulty. Much of the credit should be attributed to the fact that many doctors developed and used personal order sets which allowed physicians to rapidly write orders for "typical" cases. On the previous units implemented, internists had not developed any personal order sets and only a few surgeons had availed themselves of this feature. The use of personal order sets from the beginning on 6 West freed nurses from having to spend time assisting doctors in entering their orders and allowed more time for nurses to cope with their own learning process.

The relative facility of start-up on 6 West prompted an ambitious implementation on May 2, 1972 of several closely related units---Maternity, Nursery, Labor and Delivery, and 2 North (a 12-bed short-term Gynecology unit). These four areas were implemented together because they shared patients and staff. Reaping the benefits of previous training and use of MIS on 6 West, the physicians made the adjustment from the manual system to MIS much more easily than had been the case in other units. Implementing this large an area all at once had several drawbacks. The first was the inability to either predict or control the maternity census, and unfortunately, census was unusually high during the period of implementation. Another problem involved the amount of support required, and although support was more than needed for one unit, it was insufficient for the total area. Thus, no area received the attention it should have. Lastly, a problem arose in the Nursery, where the use of patient care plans (so helpful in the care of adults) actually added paper work in the case of newborns. This result occurred because newborns generally are healthy rather than sick. Changes to care plans for the Nursery resolved this problem.

4WEST-2965 EL CAMINO HOSPITAL
1/26/74 1:24 PM PAGE 001

7MED

[redacted] CARMEN F 59 226B
301928 ADM: 01/20/74

7 DAY MEDICATIONS SUMMARY

MEDICATIONS GIVEN	1/20 AM	1/20 PM	1/21 AM	1/21 PM	1/22 AM	1/22 PM	1/23 AM	1/23 PM	1/24 AM	1/24 PM	1/25 AM	1/25 PM	1/26 AM	1/26 PM
DEMEROL-INJ: MEPERIDINE- 50MG. IM			7											
PHENERGAN-INJ: PROMETHAZINE- 25MG. IM			7											
TIGAN-INJ: TRIMETHOBE NZAMIDE- 200MG. IM			9	7										
MEPERIDINE- 50MG.TO. 100MG. IM				7	4 NN	10	7	9		2 8				
D5/LAC-RINGER.1000ML -21GTT/MIN. 85ML/H				6			6							
D5/.45% NACL.1000ML W. KCL 20MEQ 21GTT/MIN. 85ML/H					6 6									
D5/.45% NACL.1000ML- 21GTT/MIN. 85ML/H						6								

*(N) NUMBERS IN PARENS INDICATE TOTAL DOSES GIVEN FOR THAT DAY
ALL TIMES HAVE BEEN ROUNDED TO NEAREST HOUR.

LAST PAGE

Figure 1. Example of the 7-Day Medications Summary.

From a positive standpoint, this combined effort eliminated the frustration of using a dual system (manual and MIS) for OB-GYN physicians. Continuing this line of reasoning, Pediatrics was the next unit selected for implementation because pediatricians were already using the system in the Nursery.

System problems and difficulty in scheduling on-the-job training due to high census delayed implementation of the Pediatrics and Teenage Unit until May 30, 1972. The census remained high, complicating start-up. Furthermore, the question of whether the system should contain nursing notes was then becoming crucial. The problem of nursing notes involved two principal factors. From the vendor's point of view, the volume of notes entered far exceeded expectations and led to a system capacity overload with a resultant slow-down in response times. From the nurses' point of view, the notes were now legible in a new format. Now for the first time they could see the traditional nursing note problems, such as redundancy, inclusion of particular data for "legal" purposes only, and/or vague, general terminology. The nurses began asking what they could do to change this situation. At the same time, nursing station personnel were being plagued by VMT queuing that seemed to occur at peak charting times.

Because the status of computerized nursing notes was unclear, pediatric nurses were reluctant to accept this part of the system. Before continuing implementation, a decision was reached: (1) to implement no additional units with computerized nursing notes; (2) to allow the only medical unit implemented and Pediatrics to return to manual nurses' notes; (3) to establish a special committee in nursing to study the entire problem, recommend a solution, and/or develop a new methodology (a nursing consultant was hired to assist in this project), and (4) to continue using computerized nursing note procedures on the other units which had been implemented. The fourth policy was adopted in the belief that use of the computer medium would help stimulate new ideas and methodology regarding charting.

A 34-bed psychiatric unit, 1 South, was implemented on June 7, 1972. It had been decided not to involve the staff of this unit in on-the-job training and observation on another unit because it was thought that the significant operational differences of this unit would obviate any benefits. Experience proved this decision to be poor judgment. *The value of on-the-job training was not to see how one's own unit would function, but how a unit could function.* Also, the concept of extreme flexibility to meet patient needs under which this unit operated made it difficult for the staff to identify existing structure and modify it appropriately so as to use MIS effectively. Additional problems arose because the implementation of this unit followed so closely upon that of Pediatrics; thus neither unit received adequate support. The frustration level of implementation trauma thus was extended on both units.

By this time, a fairly clear picture of the implementation process could be defined. Every unit experienced an emotional response to MIS implementation, which lasted approximately one month. It was necessary for nursing personnel to relearn all methods of information processing. They were

required, during initial implementation, to think through each action instead of automatically performing it, resulting in mental strain, which surfaced in the form of exhaustion, anger, and frustration. Such reactions were most apparent during the second and third weeks of implementation, the first-week tension being modified by interest in the new system, the fourth-week tension abating due to increased familiarity with the system.

Another emotional phenomenon seen, though certainly to a much lesser degree, was fear---anxiety that the nurse would not be able to learn the new system. This emotional reaction was dealt with, when encountered, by supplying additional support during the initial learning and use stages.

The 5-bed Artificial Kidney Unit (AKU) began using MIS when an inpatient from a medical unit, whose medical record was on the system, began dialysis treatments. The implementation proceeded incrementally, closely tied to the implementation of the Outpatient Department. The AKU, which serves both inpatients and outpatients, had difficulty maximizing MIS potential. A typical AKU patient is treated as an outpatient with one or more inpatient episodes. This change in patient status causes problems in the computer rules for handling their medical records. These problems are being worked on but still exist.

Absence of support personnel held up further implementation until June 27, 1972, when 5 East, a 42-bed Orthopedic unit, commenced implementation. By this time, entry of nursing notes had been limited on certain nursing stations. No serious problems were experienced and remaining medical and surgical units were implemented with a minimum of problems. MIS operation was initiated on July 11 for 2 West, a 34-bed Surgical unit; on August 15 for 6 East, a 34-bed Isolation and Medical/Surgical unit; and on August 29 for 3 West, a 34-bed Medical unit.

During September of 1972, the critical care areas were implemented within days of one another to take advantage of their close interaction and yet to avoid the drain on support personnel that was experienced in the previous simultaneous implementation in Obstetrics. This approach, while more successful than the Maternity effort, still reflected problems associated with inadequate support.

Simultaneous with the implementation of the last unit, the long-standing problem of patient transfer disappeared. Previously, when a patient was transferred from a MIS unit to a non-MIS unit or vice versa, extreme care had to be taken to insure that the interface between MIS and the manual method was complete. The number of patient transfers at ECH was not extremely high; thus, the problem, though time-consuming, was tolerable.

Initially, the paper output at the nursing station was perceived by nurses to be excessive. MIS does, in fact, create a somewhat larger volume of paper on the unit. However, many MIS documents are temporary and are discarded after use. It is felt that the nurses' initial perceptions were exaggerated because organized methods had not been developed to deal with the paper-handling problem. As definite paper-handling procedures were implemented and responsibilities for these activities were assigned, complaints regarding paper volume diminished.

Once implementation had been completed, the major change projected for nursing was the development of a new nursing notes methodology. This project was begun in 1974 and continued into 1975. The only other major problem still to be resolved involved IV ordering, tracking, and charting. Although MIS allows such ordering and charting, technical considerations present severe problems for associating IV orders with accompanying medications. This difficulty has proven to be one of those apparently simple problems that turned out to have no easy solution. In 1974, a solution was reached, which is planned for implementation in early 1975. Nursing, however, was affected by most of the changes developed for other departments. Many of these served to further streamline the nursing portion of MIS. Three other factors were to be of constant concern to nursing: system reliability, methods and procedure changes to maximize the benefits derived through the use of MIS, and again, training. System reliability, because of its general nature, will be described at the end of this section. Methods and procedure changes are directly related to benefits realization and will be discussed in Section 6.

The training program developed for nursing during pre-implementation and continued through implementation set the pattern for new employee training over the next several years. This format included five hours of classes during the first week of orientation, with subsequent learning through on-the-job practice. Most nurses become proficient using MIS within a month to six weeks. Class hours have slowly been increased to eight hours as the entire system has grown in complexity.

Since implementation, two additional training needs have been identified. The first is the need to periodically retrain personnel on seldom used, but essential features of MIS. A second area requiring ongoing training concerns the continuing changes and improvements made to the system. Communication of simple, straightforward changes is handled satisfactorily through a weekly "change list" produced by Technicon and distributed to users, or by announcements appearing on the first video display users encounter at the VMT. For a complex change, the method of training representatives from each nursing unit, who in turn train the unit's staff on their shift, has been fairly successful.

Vocabulary has been another factor of concern in training. MIS has made it necessary to make very explicit and specific certain procedures that were undefined and taken for granted previously. For example, several new states of processing for doctors' orders have been introduced. Before MIS, only two states were defined: *written* and *discontinued*. With the advent of MIS, four states have emerged: *written*, *discontinued* and/or *complete*, *held*, and *deleted*. Each of these states had to be defined and the definitions transmitted clearly to all users. Success in this area of training has had a direct bearing on the accuracy of using MIS.

The project which began in an attempt to design a new charting methodology using the system, developed into a more comprehensive project which was entitled the Nursing Care Planning Subsystem. The Nurse Care Planning Committee, established in 1972 to study the problems of nursing notes, felt that the problems were much more comprehensive than just nurses' notes. They recommended establishment of a comprehensive, integrated system for

processing nursing care data. This system would include (1) a nursing care planning system; (2) a charting system designed to report the outcome of patient status as a result of nursing care given; and (3) a capability for feedback, which would enable nursing care audit. This system was to be developed in a manual mode, then transferred to the computer.

The first step in the development was to create a Nursing Care Planning method. The system, described by Mayers in *A Systematic Approach to the Nursing Care Plan*,[1] was adopted by the nurses at ECH. This method involves the identification of patient problems, expected outcomes (or problem resolutions), and nursing orders to accomplish the outcomes. Problems may be usual or expected for a given diagnosis, or unusual or unique to a given patient. In the process of learning the care planning method, the staff nurses developed Standard Care Plans. These were care plans created around diagnosis or condition, containing usual problems, expected outcomes, and appropriate nursing orders. The first volume (of a planned 3-volume set), containing 90 standard care plans for medical and surgical units, has been published[2] and is available at a cost of $20.00 from the publisher, K. P. Medical Systems, 713 Loma Verde Avenue, Palo Alto, California 94303. At the date of this report, more than 4,300 copies had been sold. Two additional volumes, covering care plans for maternal and child care and critical care units, will be forthcoming.

Integration of the manual standard care plans and the computerized care planning aspects of MIS presented a barrier to making operational this comprehensive nurse care planning method. It necessitated that an excessive amount of data, referenced in the standard care planning manuals, be keyed manually into the VMT's for merger with the existing computer-produced care plans. Thus, the next step was to incorporate the Standard Care Plans into the computer and simultaneously to develop a program for flexibly creating individual nursing care plans for any patient. This objective was accomplished for one unit (Orthopedics) on a pilot basis. It proved to be an effective way to perform care planning; however, the pilot experience revealed deficiencies in methodology which since have been corrected. ECH presently is planning further evaluation on the Orthopedics unit and subsequent expansion to the entire nursing department.

A second area of concern to the Nurse Care Planning Committee involved nursing notes. In the revised system, nursing notes would reflect the patient's status with regard to the expected outcomes and would only be written to indicate problems or progress toward goals (exception reporting). This system also has been implemented, at first manually and now on the computer in half of the nursing units. The remaining nursing units will be implemented on the computer in late 1975 and early 1976.

These two important steps have led to the development of an audit program, which was inaugurated during the latter part of 1974. This audit program compares the documentation of care planning and patient progress, as reflected by the patient care plan and the nursing notes, respectively, with actual patient problems, needs, and progress as evaluated through an interview with the patient by a nursing care auditor. This system currently is operated manually on a limited basis, and hopefully, will be expanded on a computer-assisted basis.

An additional by-product of the work on standard care plans involved the realization that care plans could be the source of data to augment the nurses staffing program that was operational at the hospital. The program consists of (1) Workload Forecasting---a prediction of future patient load (by unit); (2) Scheduling---assignment of work days by employee to meet forecast needs; (3) Recruitment---acquisition of staff and continuous identification and documentation of special staff skills; (4) Near-Term Allocation---adjustment in staffing patterns necessary because of variance between actual and forecast workload, unscheduled employee absence, and temporary special skill needs; and (5) Management Reporting and Control---operational data summaries to provide Nursing Administration with meaningful staffing control information.

It became obvious that the care plans could contain all of the data necessary to indicate the level of nursing care required. If this could be quantified, the computer then could calculate staffing requirement data on a shift-by-shift basis and provide these data on which to base allocation of personnel just prior to the oncoming shift. With the assistance of a consultant, a method for quantifying these data has been devised. It will be tested as soon as the Orthopedics unit is using the care planning system, including the modification. These extensions of the computer-assisted care plan, nursing audit, and staffing are discussed in more detail in Section 7 - Future Extensions.

Surgery. The surgery area was implemented incrementally as the surgical nursing stations were implemented, thus becoming involved with MIS in February of 1972 and not completely converted to MIS until September of 1972. There were problems in two areas. The MIS Operating Room (O.R.) subsystem was developed while the O.R. supervisor was on a leave of absence and thus without her involvement. As a result, certain items had been excluded. For example, Recovery Room charting was inadequate enough to require the development of a new reporting methodology by drawing upon more of the previously designed capabilities of the Nursing subsystem. A second and continuing problem related to the computer-generated Operating Room check list. As designed, its use was highly inefficient and required multiple handling of data. Due to the extensive programming necessary to make this a truly useful document and because of the relative ease of using the old manual document, improvement of this feature has been deferred as a system extension for future development.

Clinical Laboratory. As indicated under Nursing, it was immediately recognized, with the implementation of the first nursing station, that the Laboratory subsystem had serious problems. These problems were largely attributed to the following causes: (1) the laboratory portion of MIS was the last to be designed and thus had the least review and testing; (2) the design concept was unrealistic in some areas such as laboratory work organization; (3) the analysis of scheduling laboratory orders had yielded false conclusions because it focused upon paper work and did not include workload organization; and (4) the Laboratory subsystem is very complex, both internally and in its interface with the ordering system.

Laboratory personnel, in attempting to use the system, faced many problems as a result of these insufficiencies. Initially, they had no means of quickly identifying the "status" of a specimen, and because both Laboratory and Nursing collect specimens, this source of confusion was a serious problem that required early resolution (see also page 20).

The concept of scheduling, under which the Laboratory subsystem was designed, involved a situation in which doctors put schedules on only 20 to 30 percent of the tests and the Laboratory scheduled the rest. In fact, most tests were implicitly scheduled, based on receipt of the requisition by the Laboratory. For example, before the implementation of MIS, requisitions for tests to be done "tomorrow" were held on the nursing unit until 6 A.M. on the morning they were to be performed (an informal means of scheduling). MIS made no provision for this kind of control. As a result, requisitions came into the Laboratory in a random fashion and laboratory personnel had no knowledge of when the test was to be performed. Thus, use of the phone between the nursing stations and the Laboratory increased greatly in an effort to resolve these questions. The solution to this problem (i.e., provision for adequate scheduling via MIS) had secondary negative ramifications. Before the implementation of MIS, the doctors did not document the large majority of schedules for their laboratory tests. With the advent of MIS and if they used the VMT for order entry, the system demanded schedules for certain tests. This requirement to learn and use specific lab test schedules heightened negative responses to MIS. Over time, this requirement has ceased to be a problem and has, in fact, become a benefit as the incidence of inappropriately scheduled laboratory tests has decreased.

Laboratory personnel also had problems with the design concept of "batching." Batching involves listing multiple patients and their associated tests on one document. This concept was extremely beneficial when used in connection with documents for collecting specimens from the nursing units, as the system sorts and arranges the data by nursing unit and bed sequence. When applied to laboratory work sheets, however, the concept proved confusing and potentially dangerous because the system had not been designed to identify specimens so that they could be correlated with work sheets. Thus, individual computer-generated work sheets, comparable to those used under the manual system, were a necessary development (again very soon after implementation).

The initial design concept requiring each laboratory technician to enter his or her own results proved to be impractical and time-consuming, due to the unworkable concept of batch processing of work sheets. The short-term solution involved use of data entry clerks (four by the time implementation was complete). Thus, instead of eliminating transcriptions (a basic MIS design criterion), initial Laboratory subsystem inadequacies forced the temporary addition of transcription activity. Furthermore, the entry of test results was cumbersome. Streamlining this procedure by making access more rapid and by matching data entry format to the laboratory work sheets increased user acceptance and reduced the overtime caused by MIS. It is expected that the additional clerical work required for result entry can be reduced, due in part to an automated interface between MIS and blood analysis equipment (SMA 18 and Coulter-S) and the use of mark-sense card input for most other test result documentation.

In addition to Laboratory subsystem design problems, the peak time for laboratory data entry coincided with the hospital data processing peak (1 P.M. to 3:30 P.M.); consequently, the Laboratory was affected by the resulting general degradation in system response time. Entry of results was further complicated because there was no provision made for automatically printing specimen collection time with results. Originally, the system used the order time, unless an override was introduced. The specimen collection time was provided ultimately through the statusing system.

Although a number of corrections needed to make the Laboratory subsystem usable were instigated early, it was evident that major design changes were necessary. These changes proceeded along two different paths. One path involved the creation of an automatic interface between automated laboratory blood analysis equipment and MIS. A corollary development involved creation of a mark-sense card interface for manually recorded test results. The second path involved revision of the basic Laboratory subsystem programming to create a subsystem that could handle all of the specimen, date, and time identification requirements expeditiously.

The first automatic interface was accomplished with the SMA 18 in July of 1974. Currently, serology, urinalysis, and white blood counts have been converted to mark-sense cards, which then are read by an optical mark reader. Further work is in progress to develop interfaces with other equipment such as the Coulter-S counter. In October of 1974, new programming was completed and implemented. These accomplishments have substantially streamlined procedures and introduced new flexibilities into the Laboratory subsystem.

Until recently, personnel found using MIS a burden, and for a long time were hesitant to trust the system. This attitude can be ascribed to both system deficiencies as described above (the resolution of which was both difficult and time-consuming) and to the fear that MIS was less safe than the manual system had been. Over time, this fear has dissipated as MIS has proven reliable, and trust has increased as problems have been resolved.

Radiology. The Radiology Department was implemented incrementally as nursing stations began using MIS. This department suffered some of the same general system deficiencies that the Clinical Laboratory did. One of these deficiencies was the absence of a statusing system. The initial solution, although it met the needs of other departments, was inefficient in Radiology since it required seven light-pen selections to status each order. Improvements were required to make statusing possible in three steps per order. Another initial problem shared with the Laboratory was an inadequate scheduling system. Here, too, the scheduling matrices were not explicit enough to meet the needs of the physicians and Radiology, and required further development during the first two months of implementation.

The Radiology secretaries, who entered the results of Radiology examinations into the system, encountered an immediate problem with the keyboards associated with the terminals. The keyboards varied from their standard IBM Selectric typewriters in layout and, more significantly, were not as "fast" due to their particular mechanical-electrical design. A workload backlog soon developed in the department. Technicon developed a new keyboard which was superior to both the IBM Selectric and previous VMT keyboards, enabling productivity to increase by a factor of more than two.

A further adverse impact on reporting time was created by the false expectation that radiologists would use "normal" statements to describe radiology findings. These statements had been stored in MIS for simple light-pen selection in order to eliminate the need for keying repetitive statements into the terminal. The predetermined statements, however, did not conform closely enough to the styles of the individual radiologists and, therefore, were not

used by them. Consequently, personalized "normal" statements were developed by each radiologist for storage in MIS; their use has reached a level of about 30 percent of all results reported.

Formats, both of working documents in the Radiology Department and of results for the patient's chart, needed reworking in order to make the significant data stand out from subordinate identifying data such as file numbers. It also was necessary to separate the printing of radiology results from other ancillary results for separate filing in the chart.

As problems were resolved, the flexibility of MIS in handling typed data actually reduced the secretaries' workload. It was discovered that after transcription and before final radiologist verification, most reports needed only minor spelling and punctuation corrections. These corrections could be made on the video screen, eliminating the need to retype the entire report. In the meantime, a "preliminary" radiology report could be made available through the VMT as soon as it was keyed into the system. These "preliminary" reports were available for viewing by the patient's physician and on the nursing floors 11 hours earlier than under pre-MIS conditions.

The Radiology Department currently is facing a problem caused by the growth of patient files. The MIS system seems to offer the potential for a solution, but because of cost and time constraints, there has been no effort so far to explore avenues for solving this problem.

Pharmacy. A *unit-dose* medication program, consisting of a once-a-day exchange cassettes-cart system, was implemented concurrently with MIS for each nursing unit. It was decided that implementing MIS and unit dose simultaneously would necessitate only one change to the process of the medication delivery system and thus would be less traumatic than two major changes. A unit dose program had not been implemented previous to MIS implementation because of the cost and time factors involved in maintenance of manual records for a unit dose system. Although this change to the medication delivery system involved revision of one of the most firmly established systems in nursing, it was accomplished with a minimum of problems. This accomplishment may, in part, be attributable to the positive impact of the shortened turnaround time for medication orders, due both to the speed at which the order reaches the Pharmacy via MIS and the ease of sending the nursing unit an initial supply of medications that are *unit* packaged.

The implementation of the Pharmacy subsystem of MIS was relatively smooth, but problems did exist. Scheduling of drugs presented problems attributable to lack of user proficiency initially and lack of adequate scheduling options. Although options in the Pharmacy subsystem were extensive in contrast to the Laboratory subsystem which contained very limited scheduling options, there was further need to extend the pharmacy options so that drug schedules could be selected to meet patient needs rather than computer constraints. Because of the extent of the initial scheduling system, additions were relatively easy to accomplish, and by the end of 1972, the medication scheduling system allowed all of the options that users had indicated as being desirable.

Pharmacy was affected by a change in MIS that allowed the modification of drug schedule times without changing the drug order. Initially, Pharmacy received a copy of the change in the scheduled times. But, since distinguishing a change from an original order was difficult, Pharmacy was never certain whether to send the medication to the nursing unit or not. This confusion is an example of the problem caused by providing too much data. In this case, the data had no significance for Pharmacy and the problem was resolved by suppressing the printing of the schedule change in Pharmacy.

The most outstanding problem for the Pharmacy involved IV medications scheduled for addition to an IV solution. IV solutions are not classified as medications; additives are. Because of system architecture, the technical problem of combining the medication and IV solution order into a single order was extremely difficult to solve. This problem was not resolved until early 1975.

In 1973, it was recognized that patient allergy information residing in MIS could be routed to the pharmacist along with the patient's drug orders, thus allowing the pharmacist (who is most familiar with individual drug chemistry) to intercept potential allergic reactions. Currently, allergy information supplied and entered by doctors and nurses automatically prints in the Pharmacy, along with any drug order. This feature results in the interception of an average of one potential problem per day.

As part of the effort to motivate physicians to utilize the VMT interface more extensively, a set of drug information displays was developed, providing usual dose, route, expected side effects, and contraindications for a number of drugs. The value of such displays is difficult to evaluate objectively as there presently is no means of recording their use.

An area of the Pharmacy subsystem that, since the inception of MIS, has triggered interest in further development is the proposed creation of an active drug interaction system. Although the benefits of this application appeared obvious, a number of questions surfaced upon close scrutiny. Did an appropriate data base exist which would provide practical benefit to the typical private practitioner? How should such a data base best be utilized? Also, due to the relatively undeveloped state of the art with regard to drug interaction programs, selection of a clearly superior data base has not yet been possible.

Currently, developmental activity along this line has been deferred, pending answers to these questions. However, analysis of the applicability of a data base, developed by Dr. Stanley Cohen of the Stanford University Medical School, will be conducted in 1975. Dr. Cohen's drug interaction programs will be run against the El Camino Hospital patient data base and potential interactions will be identified. The significance of these findings then will be evaluated. If the results of the pilot study prove promising, an on-line link with the drug interaction programs at Stanford will be established such that notification of potential drug interaction problems can be sent to El Camino Hospital in a real-time fashion.

Medical Records. Difficulties in upgrading clerical procedures to keep pace with the introduction of new methods of hospital-wide information processing occurred during implementation in Medical Records. Difficulties began when the first nursing unit implemented discharged patients. These difficulties were attributable both to insufficient preparation as well as to the nature and function of the department. The pre-implementation training session covered only what MIS would do and neglected to prepare the staff for the changed physical appearance of the chart. The training did not address itself to the responsibility of the Medical Records Department for insuring the accuracy and completeness of the chart, or the procedural changes that the new chart format would necessitate in that department. Scrutiny of the MIS chart, which emulated that of the manual chart, resulted in more work because MIS charts presented new levels of detail. The old chart scrutiny methods were retained until numerous problems were resolved and the system proved to be reliable. It was necessary later to revise these methods to accommodate the new chart format.

MIS was designed to solve the obvious chart problems of illegibility and missing documents. Unfortunately, the small problems, which had always existed, became more evident because they were illuminated by the complete and detailed charts now available. For example, under the manual system it was difficult to determine whether the chart contained all of the orders that a physician had written. Under MIS, to eliminate any omissions, each order that a physician enters is automatically given a sequential number (easing the burden on Medical Records), while insuring that all ancillary departments had reported corresponding results.

Finally, many problems stemmed from the attempt to put a "new chart" format into an "old chart" processing system. Ultimately, it was necessary to develop and learn completely new work patterns to handle the MIS chart. This combination of inadequacies in preparing for the new system and initial frustrations in its use fostered a strong negative atmosphere in Medical Records, which was slow to dissipate.

A combination of the inadequacy of training, the need to scrutinize the charts, and the volume of problems uncovered soon resulted in a large backlog of work. This backlog was compounded by the fact that initially the physicians had to go to Medical Records to sign the orders for the last 24 hours of a patient's hospital stay. This requirement meant that 100 percent of the charts had to be held for physicians' signatures before they could be filed. The increased workload required Medical Records to increase its staff by as much as four and one-half full-time equivalents. As the problems were resolved, the added staff was reassigned to other tasks, including handling of the increased number of admissions.

The two other problems that seriously affected Medical Records involved lack of user proficiency in other departments and the physical similarity of all MIS documents. For example, if a new user at the nursing unit entered patient data incorrectly and neglected to revise it or was unaware of its existence, the error would print and be included in the patient's chart. Medical Records was forced to cope with these errors from other departments

until they were corrected and until users became more proficient. Because the Medical Records staff lacked a broad understanding of system function, operation, and the problems of data entry throughout the hospital, it was difficult for them to comprehend the continuance of these errors. However, as the system was perfected in all departments, errors decreased and in Medical Records confidence in the system's performance increased.

Many chart problems were solved as nurses and clerks learned to distinguish permanent documents from work sheets and were careful not to throw away the permanent documents. As Medical Records became familiar with the various printouts, they ceased to appear similar and were easier to categorize. Specific changes were made to printout formats so that a single glance was sufficient to distinguish permanent from temporary chart documents. Medical Records profited greatly from these changes.

The volume of paper that Medical Records had to contend with was overwhelming at first. The initial attempt to ease the load was to provide this department with a "burster" (a device for automatically separating perforated computer-printed pages). Subsequent efforts were directed at eliminating all redundant documents and developing a test results summary, which consolidated test results. Consolidation facilitated checking for omissions while reducing the amount of paper in the chart (an important factor for storage).

The development of the computer code signature for orders quickly reduced the backlog of charts needing physician signatures, and the recent development of using the computer code signature for discharge summaries has eliminated much of the backlog of incomplete charts waiting for discharge summary signatures.

Much of the negative attitude and the many problems which arose in this department could have been avoided had it been possible to provide adequate Management Engineering support to the department through the implementation period. Over time, however, the department has adjusted well, a sense of trust in MIS has developed, and the accuracy and completeness of charts has reached a level impossible with a manual system.

Central Service. Central Service was converted to MIS usage relatively smoothly. This department began MIS operation concurrent with the first nursing unit. The early elimination of admit notices for Housekeeping and the Mail Room, which were deemed inefficient and which were being printed in Central Service, greatly reduced the amount of paper handling there.

Probably the most significant problem involved the organization of Central Service items by category on the ordering matrices. Items were difficult to find in the display chain, and rather than search for an item, the nurse often would key it in. Since it is not possible to code free text entries with a charge, these keyed-in items have to be charged manually by Central Service. In November of 1972, new matrices designed to facilitate locating items became available. Items were cross-indexed alphabetically and by category. A special display also was created consisting of commonly ordered items.

The original printed requisition supplied Central Service with only the patient's room number and not the ordering location. Thus, if an item were ordered by the Recovery Room, the item would be sent to the patient's nursing station. Although this problem was quickly rectified, it is representative of the subtleties of hospital operation which may be easily overlooked, particularly if the system designer is not intimately familiar with the area in question.

One needed improvement, still outstanding, is the capability to print all nonreturnable items for one patient on one requisition. This development would reduce the paper handling in Central Service as well as facilitate simultaneous delivery of all items. While technically easy to do, it would require recoding of every matrix. Recoding is a time-consuming process requiring 100 percent accuracy and so, at present, this improvement has received a low priority.

Food Service. As with other departments, Food Service began using MIS when the first nursing unit was implemented. As originally designed, the Food Service subsystem printed doctors' diet orders and a diet list for each nursing unit in the Dietary Department. Also printed were all admit, transfer, and discharge notices. These notices were later discontinued and the data incorporated into the Diet List. The initial configuration did not take into consideration the fact that nurses often modify doctors' orders, making them more specific (e.g., "diet as tolerated"). Also, more than one diet order can exist at one time. For example, a patient's diet orders could read "regular diet" and "NPO post-midnight." Someone must determine which order applies to the meal in question. Because of these two factors, the diet lists were often confusing to the Dietary Department. To resolve the problem, the diet list currently is printed on the nursing unit, checked by a nurse, annotated if necessary, and then sent to Dietary.

Design requirements for a more satisfactory diet list have been developed. However, the vendor has been reluctant to expend effort in this area since it appears to function as is. As the Food Service subsystem exists, it violates system design philosophy which emphasizes direct data transmission from data source to user without intervention by third parties. When this intervention comes from another department (in this case Nursing), the user department (Food Service) becomes dependent on the intermediary (Nursing) for data that affect the entire operation of the user department.

Outpatient Department. The use of MIS by the Outpatient Department was implemented in late May of 1972. Implementation encountered minimal problems. By that time, MIS operation on several nursing stations had stabilized and approximately 40 percent of inpatients were on the system.

The major problem in the Outpatient registration subsystem was one of computer processing priorities. Orders for tests could not be entered until the computer updated the file to include registration of that patient. Because of processing priorities, this file update often took up to ten minutes, causing delays in the ancillary department where the tests were to be run. This procedure has been changed so that the outpatient clerk can register a patient and enter an order immediately thereafter.

Another problem that manifested itself involved matching the purge cycle for outpatient records with the elapsed time from test to results. Experimentation has shown that a variable time span is the most efficient in meeting user needs without impacting negatively on system capacity (by storing records no longer needed). To this end, Technicon plans to purge an outpatient's file after checking that all orders and results are completed rather than purging it within a predetermined time frame.

Emergency Room. In July of 1972, the Emergency Room subsystem was tested at the hospital. Numerous problems were experienced with incorrect charges, patient transfers, incompleteness of selections, and specialized emergency room (E.R.) requirements. By September, MIS hospital-wide operations had stabilized somewhat and the effort to implement the E.R. was renewed. Emergency room personnel had been trained to use MIS in July of 1972, but by the time that implementation was imminent in the fall, the system design had changed drastically and retraining was necessary. Because the Emergency Room would need to process patients even during the daily downtime (2 A.M. to 3 A.M.), an important part of training involved skilled use of the manual back-up system. Thorough testing of the redeveloped system was undertaken on all three shifts, with vendor and hospital staff providing support. One component of the Emergency Room subsystem was the specially developed emergency room chart. For this document, NCR paper was used on the printers, and the emergency room record was printed out in triplicate when a patient was registered. Because the printers are the nonimpact type, three separate printouts were required.

On October 23, 1972, the Emergency Room began full-time operation on MIS. Unfortunately, concurrent with implementation the E.R. experienced record workload demands as they struggled to adapt to a new set of work tools and a new approach to their work. Originally, two video matrix terminals and one printer had been deemed sufficient for E.R. use. It soon became apparent that a third terminal was necessary on evenings, weekends, and holidays to provide the registration capability needed to handle a peak volume of patients in a short period of time. To solve this problem an arrangement was made whereby a terminal in a nearby ancillary department could be moved into the E.R. during the peak hours, which conveniently coincided with non-use hours in the ancillary department.

Problems experienced in the first month of emergency room implementation included inadequacies in the chart format, delays, difficulties in transferring a patient to inpatient status, insufficient information selection capabilities, and the need to be able to register a patient with minimal data. (This latter requirement might mean using a pseudonym for the real name and correcting it later.)

By mid-January of 1973, the problem of transferring patients to inpatient status had been resolved, information matrices were made complete, and a quick registration mode was created. Also, some changes were made to the chart format, making it more usable.

In spite of efforts to speed up the printing of the E.R. chart, the delay associated with production of the three copies of the E.R. record, following VMT entry of patient registration data, continued to be a nagging problem. This aggravation was especially true when several patients arrived simultaneously, causing the emergency room personnel to focus on MIS data processing rather than on their task of providing patient care. This situation led to legitimate frustration and negative attitudes toward MIS. These perceptions negated the obvious positive benefits of ease in charging and in communicating with other departments.

During the spring and summer of 1974, a new design concept for the E.R. chart format was conceived. It consisted of a preprinted tri-part form with a block designed for a label. The label was produced by MIS (in triplicate) and contained all of the registration data (see Figure 2). It reduced the printing from 180 lines (three pages) to 30 lines (one-half page). It also meant that a chart was available to begin processing even before the label reached it in situations where immediacy of care was critical. With the implementation of this E.R. chart format in August of 1974, MIS became a viable tool for the Emergency Room. Frustration with MIS was markedly reduced, and staff now view MIS as an adjunct rather than a hindrance to their work.

Business Office. El Camino Hospital had installed a Business Office System (BOS I), which was operated by the same vendor, approximately three and one-half years before MIS was implemented. The BOS system included patient billing/accounts receivable, payroll and personnel statistics, accounts payable, and general ledger. Thus, transition in the Business Office to use of the entire hospital information system was relatively simple. As El Camino Hospital departments began using MIS, implementation involved the elimination of keypunch input to the computer and the automatic collection of charge data through MIS. Correction of charges and entry of cash receipts were handled by one clerk through use of the light pen and keyboard at a VMT. An auditing procedure was initiated by the Controller to ensure that charges were being properly collected by MIS and channeled into the Business Office System.

Other Departments. Implementation of MIS in Inhalation Therapy was accomplished with few problems. With the exception of changes to some matrices, the largest obstacle for Inhalation Therapy was the lack of a dedicated VMT and printer, devices which were not warranted because of this department's small volume of information processing. While using a printer elsewhere is not a significant compromise, using available VMT's situated in other areas is inconvenient and occasionally delays entry of data on therapy.

Basically, the same problems existed for the Pulmonary Laboratory, except that the lack of a printer was more important. At first, the nursing unit receiving this department's requisition printouts discarded many orders as scrap paper. This situation was remedied immediately and operations now are functioning smoothly.

The EKG-EEG Department uses MIS primarily as a source of requisitions for tests and to enter billing data. Results from EKG's include data generated by the physician reader and the actual tracing. Initially, an

EL CAMINO HOSPITAL EMERGENCY DEPARTMENT RECORD
Mountain View, Ca. 94042

ROOM #

This is to certify that I (we) the undersigned, consent to the administration of whatever anesthetics and the performing of whatever treatments or operations which may be necessary or advisable in the opinion of the attending physician. I hereby agree to pay for all services and supplies rendered and authorize release of any information necessary to obtain payment for services from any third party.

Signature

Relationship

Witness

Physician notified Arrived

Patient complaint:

Nurses Notes:

Medications:

PATIENT NAME: [redacted]
CASE NUMBER: 710558
PHYSICIAN: FULLER, T. P., MD
BIRTH DATE/AGE/SEX: 01/30/15 60 M
GUARANTOR: [redacted]
STREET ADDRESS: [redacted]
CITY, STATE, ZIP: CUPERTINO CA 95014
PHONE: [redacted]
PATIENT'S ST. ADDRESS: SAME
CITY, STATE, ZIP:
PHONE/MAR. STAT: MAR
BROUGHT BY: SELF
PRIMARY INSURANCE: GROUP
ID, GROUP, COVERAGE: NA
INSURED/RLTN: PT
SECONDARY INSURANCE:
ID, GROUP, COVERAGE:
INSURED/RLTN:
ACCIDENT LOCATION:
DATE TIME:
EMPLOYER: CIVIL SERVICE-SECU
STREET ADDRESS: RITY
CITY, STATE, ZIP: MOFFETT FIELD
WORK PHONE/S.S.#:
RESP. REL/RLTN.: [redacted] WIFE
STREET ADDRESS: SAME
CITY, STATE, ZIP:
HOME PH/WORK PH.:

History, Exam, Diagnosis and Treatment/Disposition:

Disposition: ☐ Home ☐ Hospital ☐ Other Time Out

Instructions to Patient:

Form 217 (Rev. 2/74)

Physician

Figure 2. Emergency Room Record Showing Label.

attempt was made to report abnormality/normality via MIS. It soon became evident that this information was redundant and so was discontinued. Sending the reader's findings with the tracing was sufficient, requiring no transcription and keeping the two items together.

A format change effected to streamline the work flow in EKG involved transformation of the requisition into a combination requisition/work sheet. This procedure results in only one piece of paper per order, routed from the EKG technician to the physician reader and finally to the patient's chart.

Physicians. The physicians experienced the implementation process as nursing units housing their patients were started up. Thus, the internists and general practice physicians were the first to experience MIS. All physicians were trained prior to the beginning of implementation. This situation proved to be unfortunate in two respects. Because implementation of the system took much longer than expected, there was a substantial lag for many physicians between training and actual use of the system. Consequently, the effectiveness of training, which had already been compromised somewhat by compression of the program to accommodate the physician's limited free time, was further vitiated by the extended separation of learning and actual use. In addition, due to the many changes which had been effected, the system differed in many details from the learning model. Fortunately, use of the system is fairly self-explanatory, once the basic concept (which changed little) is understood.

As a nursing unit was implemented, support for the physicians was provided at peak physician usage times by the vendor representative responsible for the physician interface. He was assisted by a physician-consultant to Technicon. While helpful, this help did not meet all of the needs for support since problems often arose when these people were not available, forcing the physician to revert to the manual method without a solution to his problem.

Training updates for the physicians have been carried out by printed newsletters, graphic displays, departmental meetings, and individual contacts. In spite of these efforts, physician training on a continuing basis has been inadequate. As a result of this fact, system developers have realized that new features must be made available in such a fashion that the physician is forced to be aware of their existence by the design of appropriate display chains.

The fact that physicians only used the system for a short period of time each day tended to extend the learning period. In addition, the technique of using the video screen and light pen for writing medical orders required the physician to somewhat restructure his thought processes. For example, a doctor may manually write the following medication order:

50 mg Demerol, PO, QID PRN.

With MIS, this order would appear as follows:

DEMEROL, TAB 50 MG, #1, PO, QID, PRN PAIN.

The learning experience was further hindered by the existence of dual systems during implementation, which required physicians to switch back and forth between new and old techniques, depending on the location of their patients.

Although the option to hand write orders was not made available originally, early system problems prompted the adoption of this alternative for those physicians who chose not to use the system. This alternative continues to be valuable for physicians who rarely admit patients to ECH.

In spite of this very trying learning environment, most physicians in the hospital have been willing to use the system for ordering as well as for retrieval. One of the early improvements, which has been most instrumental in this success (particularly in Surgery and Gynecology), was the development of personal order sets. These order sets are available to the physician in essentially unlimited numbers. They are stored and readily available for use in one of two fashions: either by selecting individual items from the set or by selecting the entire set at one time. One method (i.e., selecting the entire set) is best for routine treatment of certain problems such as postpartum orders in Obstetrics. These orders are essentially standard on all cases and used as routine order sets. The other method (i.e., selecting individual items) is used in conjunction with a long order set which includes several choices in the various categories of orders. For instance, in a postoperative order set, several diets, IV orders, orders for nursing care, and/or medications may be listed. For any patient, the physician is able to select the specific orders that he wishes, thus providing the ability to quickly and easily individualize ordering for each patient. It soon was found that these order sets could be readily developed to cover 90 to 95 percent of all orders on a postoperative patient. These order sets have been widely used, and at this time there are some 600 to 650 sets stored within the computer. In addition to these personal order sets, there are standard order sets available to all physicians. These sets have been developed for some areas of Surgery and Pediatrics, but their widest usage has been in the routine orders for the Cardiac Care Unit and the Artificial Kidney Unit. It is apparent that extension of such work in these areas could produce decided benefit in establishing levels of care and standards of treatment for various disease categories.

In addition to the problems of learning to "write" orders on a VMT, a second major problem area involved physician interface with the paper chart. As discussed earlier under Nursing, the traditional format of the chart was initially changed to present all patient data for a 24-hour period on a single written report. Because this configuration made correlation over time difficult, it was soon abandoned and reversion to the old format effected.

Although effort was expended in designing chart documents and coordinating them with hospital and medical staff, the deficiencies did not materialize until system implementation was complete. While the typewritten material was basically more legible, line after line of a single size type seemed to make important results and data less accessible than in the well-laid-out, color-coded report sheets of the manual chart. This shortcoming was resolved first by developing formats with clear headlines and introducing special paragraphing to set off significant data. Efforts were undertaken to

emphasize important items in the chart and to use standard locations for name and vital patient data. Data identified as unnecessary were deleted. At the same time, Technicon developed within the computer system the ability to print with three different sizes of font and the ability to overprint certain items to make them stand out. New characters were adopted for the printers, making it possible to make dark lines and block letters. These changes were introduced into many areas of the chart to highlight important items and also were incorporated into many requisitions to mark stat. items and items such as abnormal numerical laboratory data.

One of the most frequent complaints heard concerning the paper chart was the lack of color coding. For example, the inability to review changes in urine characteristic was felt by many physicians to be a severe handicap. The final solution to this problem was the development of comparative reporting for all laboratory results (see Figure A-8 and accompanying text).

Another frequent physician complaint, with respect to the chart, involved the sheer volume of paper produced by the system, forcing doctors to pore over voluminous printed output to find important patient information. Although a substantial increase in chart paper resulted partly from the addition of new documents (e.g., a current orders summary) and through some redundancy of data, the primary source of the problem involved fundamental formating characteristics of the computer-produced chart documents. Under the manual system, daily entries of doctors' orders and medications were written on preprinted sheets and ancillary results were posted to backing sheets, usually several to a page. Daily updating of computerized chart documents, however, involved production of a new page for each category of data entered. Thus medications given, new orders, and various ancillary determinations each effect the entry of a separate page into the chart, although the particular data being reported usually require only a fraction of the 8½ by 11 inch page. Lengthy stays or acute, complex cases quickly produced charts of unmanageable size.

A number of steps have been taken to ameliorate the dysfunctional impact of this design characteristic. Patient charts, as they are used on the nursing units, are "thinned" to retain only the most current and hence relevant data. All of the permanent chart documents that are temporarily thinned out of the working chart are restored to the historical chart for its final storage in Medical Records. The new comprehensive comparative laboratory report eliminates single printout pages for lab tests and displays all lab results for the last seven days in one document. After discharge, test results are reprinted as one continuous summary. This practice substantially reduces chart bulk for medical record storage.

Another significant problem area involved the video chart. In the early development of the system, there were many problems with hardware reliability as well as many basic software faults such as those affecting scheduling of medications and laboratory work. These problems intensified the original distrust for the "black box" and its handling of orders. Only as the system has improved to the point where its reliability exceeded that of the manual system have these fears disappeared.

Some physicians were alienated by early problems of slow response and system downs, and reverted to the old handwritten order sheets. Most have since returned to VMT order entry as system operation has stabilized. Many displays in the physician ordering chain had to be modified more than once before they contained the proper data, in the right sequence, with as few sequential displays as possible. This type of modification is still going on, although most of the major changes were accomplished in 1973 and early 1974.

A major achievement in the use of the computer system in the hospital has been the development of the necessary factors for acceptance of the computer sign-on codes in lieu of signatures on orders entered by the physician himself through the VMT. Prior to the acceptance of the sign-on codes in lieu of signatures for physicians, it was necessary to make two programming changes to realize satisfactory security of the system. The first of these changes involved an automatic sign-off if a physician fails to sign himself off when he finishes using a terminal. Failure to sign off presents an obvious opportunity for a breach of security (e.g., unauthorized users could retrieve data or write orders under the physician's code). Thus, criteria were developed to automatically sign the physician off the terminal under the following two conditions of inactivity: (1) a time period of three minutes without any terminal activity, and (2) a delay exceeding 20 seconds in re-initiating terminal activity after entering orders. For the latter situation, the short sign-off time was chosen since it conformed to the normal circumstance under which a physician would use a terminal and walk away without pressing the "off" button. These parameters have been satisfactory for physician usage and have not been inconvenient.

The other major programming change involved insuring that the physician selected the correct patient name at the initiation of the ordering sequence. Prior to entering the orders into the system, all of the orders and the patient's name are displayed for review. The concern existed that the patient's name would not be reviewed at the same time that the orders were reviewed. This possibility was confirmed after several physicians inadvertently entered a set of orders on the wrong patient. This problem has been solved by the development of a confirmation display which requires re-selection of the patient's name.

Another major area of system development for the physicians has been the addition of a medical information data base. This data base acquisition has been a slow and difficult process, primarily from the standpoint of obtaining and verifying data as well as developing adequate display techniques and self-explanatory routes of access. The first category of data to be developed was the Antibiotic Sensitivity Survey. This survey is maintained by the Bacteriology Laboratory of El Camino Hospital and was introduced in fixed displays into the system and updated on a quarterly basis. Further information categories have been developed, including Laboratory Interpretation Aids, which display normal values for laboratory tests and the usual clinical situations in which these tests may be elevated or depressed. Another form of this presentation indicates useful laboratory tests by disease categories. In addition, some work has been done on developing normative information on

selected types of drug therapy. A small branching program has been developed for the presentation of nuclear isotope evaluation of thyroid disease. A heparinization guide and a hyperlipemia work-up information display also are available. Another major item introduced has been a Surgical Abstract Index. These abstracts are produced on a commercial basis by two local surgeons who read and abstract the major articles from eight American surgical journals each month. These abstracts, with citations, are published monthly on 3 by 5 inch file cards. This data base has been introduced into the computer system, and currently a total of approximately 2,000 display pages are available. It is anticipated that approximately two years of these data will be stored in the system. The data are stored on disk and are instantly available by light-pen selection.

The system also is used to provide day-to-day information on scheduled medical meetings and to convey information to the physician on general bed availability. It is interesting to note that the expansion of the physicians' data base came about largely as a matter of *quid pro quo*. In exchange for the effort needed to break with the past and to adopt this entirely new format for ordering, numerous items have been developed which can save the doctor's time as well as enhance his practice. As a result of physician interaction with MIS, a number of extensions have been proposed. Presently under development are additional improvements to the user interface, a diagnosis coding system, and a utilization review project.

The task of continually improving the physician user interface began before implementation and will continue even beyond the tasks currently envisioned. The present set of contemplated improvements was developed through a thorough analysis of the physician interface, which drew heavily on direct physician experience. The analysis pointed up areas where MIS seems difficult to use. One such area concerns identification of authorship of medical orders displayed on the VMT. At present, orders displayed on the VMT carry no authorship information. This feature can prove frustrating for physicians who use the VMT as a primary data source when several physicians are involved with the same patient. Although identification of authorship can be made through the chart, as physicians rely more and more on the VMT "chart," the need for this improvement becomes increasingly important. To avoid cluttering the limited display space, identification will be limited to physician's initials.

A second area of improvement involves provision of data in both chronological *and* reverse chronological order. MIS was designed to provide data chronologically; however, in many situations this ordering proves to be inadequate. Exclusive reliance upon reverse chronological order is equally inadequate; thus, flexibility must be provided to view the data in either order depending on the need.

A third area of effort focuses on modification of printouts for the chart to highlight essential data elements and to de-emphasize material that is not important to the physician. For example, necessary identification data associated with each order will be subordinated while the medical content will be highlighted.

The inclusion of automatic diagnosis coding, currently under development, was begun as the groundwork for other projects that would involve retrieving diagnostic-related data from patient records. After investigating several options in coding, it was decided that the best coding system for MIS, at this time, involves coding each diagnosis with H-ICDA[3] codes. This coding is being done in a hospital-specific manner, attempting to capture 80 to 90 percent of all patient diagnoses at ECH.

To assist in meeting hospital utilization review needs and compliance with PSRO[4] legislation, a quite extensive utilization review module has been developed in the system. Utilizing both the batch-processed information available through the BOS system and the real-time capabilities of MIS, this subsystem can select patients for review, provide real-time assistance in the review procedure, and supply discharge printouts documenting the utilization review activity on each patient.

Each day a printout is produced by the MIS system, listing all patients to be reviewed that day. Patients are included on this list if they meet any of the following conditions: Admitted the preceding day, current length-of-stay equals the 50th percentile of the average length-of-stay for the given admitting diagnosis (based on Professional Activities Study [PAS] tables), or re-review on this date has been specified by the utilization review nurse at an earlier review. Review candidates are listed by nursing unit. The following supplemental information accompanies the patient's name: Patient number, financial class, admit date, sex, age, bed number, actual length-of-stay, admit diagnosis, physician, and authorized length-of-stay.

The utilization review nurse may then use any VMT in the hospital to review pertinent available chart information such as current medical orders, diagnosis, nursing activity, patient care planning information, and admitting information. While reviewing each case, she may enter into the system appropriate comments regarding her review of the patient in question such as "patient to surgery tomorrow." This review commentary is accumulated over all reviews and may be printed at patient discharge as an appendage to the final patient care plan. The resulting document, adequate for third party payment or review, provides information on patient diagnosis, treatment, course, and utilization review activity.

Subsequent re-reviews are scheduled at the time of review by entry of a specific re-review date through the VMT, or are prompted by the automatic 50th percentile of average length-of-stay criteria. It has been found that roughly 90 percent of the individual patient reviews can be accomplished using medical information available through the VMT.

Work is also underway in cooperation with a large-scale utilization review project entitled, *Decision Analysis for Concurrent Medical Review*, funded by the National Center for Health Services Research and headed by Professor Don C. Holloway, School of Public Health, University of California at Berkeley. The focus of this cooperative study is the development of computerized screening models for automatic selection of review candidates.

System Support

The implementation of a system of this nature requires three types of support. The first is support (or maintenance) for the mechanical equipment. The second is support (or monitoring) of system performance, and the third is support for the people who must learn to use this system and integrate it into their work patterns.

The initial approach to these requirements at ECH involved (1) 24-hour coverage by "Rounds Technicians" for maintenance (preventive maintenance and replacement of failed units) of hospital-based equipment; (2) 24-hour on-site coverage by a vendor representative for system performance, problems, and user difficulties; and (3) monitoring of system performance and user problems by the four members of the hospital Management Engineering staff who were responsible for system implementation from the hospital's perspective. Personnel in the latter category generally were on site during the day and on call during the evening and night.

In addition, as new units were implemented, special support was provided by both hospital and Technicon staff as discussed earlier. Physician support was provided by a hospital physician and by a physician consultant to Technicon. As the implementation began, each department was also supported by the Technicon representative responsible for the area in question.

Because conversion of areas differed in time span and intensity, the special support was correspondingly different. For example, the support for a nursing unit involved two people located at the nursing station around-the-clock for one week and one person for the second week. Physician support generally involved a vendor representative covering the daily peak periods of physician usage. Support for ancillary departments generally involved one person in the area during the first week as the first nursing station was implemented and then on call. This support was re-established when a major change was made during the implementation period.

Since implementation, when a major change is made such as the conversion to new laboratory programs in late 1974, support is provided for one to three days over appropriate time periods in the hospital areas involved. The other categories of support also changed. Toward the end of the implementation period, the need for the 24-hour on-site support was reduced due to the fact that the vast majority of the "bugs" associated with the new system had been identified and corrected. This support was reduced gradually, first by having the Rounds Technicians handle users' problems and document problems over the hours 12 midnight to 7 A.M. This procedure was subsequently extended to cover the period from 5 P.M. to 8 A.M. Although the Rounds Technicians could not always solve the nonmaintenance type of problems, these individuals served as a focal point for documenting problems. By this time, it was apparent that problems fell into two classes. Some things needed immediate attention because they represented barriers to essential hospital operation and were generally related to overall system features. Resolution often required calling in support personnel to resolve them immediately. Most other problems could be classed as nonurgent and could wait for resolution until the normal working day. The support function provided by the Rounds Technicians has remained nearly constant and continues to serve as the focal point for documenting problems.

The support furnished by the Management Engineering staff began to shift in emphasis soon after implementation had been completed from a focus on problems and system performance monitoring to a focus on realization of benefits and toward extending the potential benefits of MIS. This shift took place gradually over 1973-1974. By the end of 1974, the performance monitoring and user assistance functions had dropped from about two FTE's to one-half FTE.

System Reliability: Timeliness, Accuracy, and Availability

The attributes of timeliness, accuracy, and availability are combined in the user's mind to make up reliability. These qualities are essential if a system is to operate in an institution whose product is patient care.

The perception of *timeliness* is a relative phenomenon. For example, under a manual system, it could take a nurse 30 minutes to transcribe a set of orders for a patient who had just suffered a heart attack. Since she worked consistently for the full 30 minutes, she would most likely feel that the orders had been transcribed on a timely basis. With MIS, she could transcribe this same set of orders in five minutes. If, however, the system were to be nonfunctioning for an additional five minutes while she was working on those orders, her perception of project accomplishment time most likely would include the delay. Thus, even though the total time was one-third the comparable manual system time, she would feel that MIS was not timely. This concept of timeliness proved to be a significant factor in user acceptance throughout the hospital. Careful monitoring of system utilization and performance statistics (e.g., volume of users at peak periods and measurement of actual delays in system response) along with careful monitoring of user perception of system performance over a 20-week period established standards for satisfactory system performance. Long-term experience has indicated that a response time of one second for changing fixed displays and not more than three seconds on the average for retrieving data are desirable and realistic performance goals. Historically, these performance levels have not always been met. The initial hardware configuration utilized an IBM 370/145 with an IBM 360/50 for back-up. By May of 1972, it was evident that system performance was dropping well below tolerance levels during peak use periods, particularly 1 P.M. to 3:30 P.M. The immediate solution involved streamlining of programs. For example, disk accesses for single patient admission were cut in half. It was evident, however, that even with streamlined programs, the 370/145 was inadequate to support the hospital. In November of 1972, Technicon converted to a 370/155 with the 370/145 as back-up. This changeover has proven adequate for both El Camino Hospital and a second 270-bed hospital in San Francisco that shares the same computer.

A second degradation in response time developed as the volume of data entered into Patient Care Plans increased. By mid-1973, the printing times had increased from the original 20 minutes to 45-60 minutes. This degradation in turn slowed all other system functions. Resolution was accomplished by programming changes made to speed up the generation and printing of reports.

There are periodic recurrences of intermittent system slowdowns, which usually are symptomatic of an undetected problem, sometimes a bug in the software but most often a hardware fault. The extent of this response degradation is extremely difficult to quantify because of its subjective and random nature. Consistent system monitoring is required to detect this kind of slowdown, and only if identified early can serious response time degradation be avoided. This kind of slowness, when it occurs, causes a high degree of frustration for system users.

Accuracy, another aspect of reliability, has not been a significant problem area and has represented a point of excellence since system implementation. While problems do arise, they can be tracked and corrected. The ability to track a piece of data from start to finish has been the key in developing user trust in MIS. Studies done by Battelle Columbus Laboratories[5] indicate a significant increase in the accuracy of the handling of physicians' orders, delivery of care, and its documentation in the chart.

A third aspect of reliability involves *availability*. System "downs" are caused by software "bugs," hardware failures, and human/system interactions. Downs classified under the latter heading are usually a result of computer operator error or nonallowable user actions for which system impact countermeasures have not been developed. One example of such nonallowable user interactions involved expansion of the patient data base beyond planned capacity. Each time that capacity was exceed, MIS went "down." The resolution of this problem was increased storage. Originally, two disks were assigned for the hospital patient data base. In 1973, it became evident that two disks were insufficient and a third was added.

To accomplish its task, a hospital provides 24-hour-a-day service. In this setting, it would seem that a MIS system must also be available 24 hours a day. In reality, there is sufficient lull between the hours of 2 A.M. and 4 A.M. to provide for an hour of system unavailability, which is used to create a duplicate set of transactions for back-up purposes. Users on the night shift quickly integrated this period of unavailability into their work patterns. System unavailability at any other time causes delays in patient care. The following discussion of system availability or "uptime" incorporates this 23-hour system "day" as a base line. The history of system reliability can be easily analyzed in terms of the percent of time MIS is available. Since July of 1972, looking at 6-month averages, average uptime has risen from 98.9 percent to 99.3 percent. More specifically, in terms of average minutes of downtime per day, the figures are as follows:

July-December 1972	=	15.18
January-June 1973	=	13.08
July-December 1973	=	10.34
January-June 1974	=	10.62
July-December 1974	=	7.86

The amount of average downtime varies by shift. For the period July to December 1974, it was split in the following way: 3.9 minutes for days, 1.4 minutes for evenings, and 2.5 minutes for nights.

The frequency of downs is equally significant. Recent historical figures indicate that MIS is down only once every two to three days on the day shift, once every five days on the evening shift, and once every seven days on the night shift. Users tolerate this level of downtime because only rarely do the downs exceed 10 to 15 minutes. However, when downs are greater than 15 minutes and especially if they come at critical times, such as a shift change, they cause delays in patient care, user frustration, and perhaps overtime. But in the aggregate, the excellent history of available time has been a significant factor in user acceptance of MIS at the hospital.

The extensive history of MIS system change at ECH has been a direct result of (1) the fact that MIS was a developmental system when implemented at ECH (it continued to be so regarded until August of 1974 when the hospital formally accepted the system on the basis of a 5-year contract), and (2) the desire, as the hospital staff became interested in the system, to extend its capabilities beyond the original design specifications. Thus, changes represented necessary correction of operational problems as well as implementation of new concepts. The distinction between these areas is not always clear. As mentioned in the introduction to this section, one may view MIS system performance from three perspectives: (1) actual operational performance as originally implemented, (2) performance according to design intent or specification (operation as its designers intended), and (3) performance of a configuration which realizes all of the potential capabilities of a real-time total hospital information system (system extension). Unfortunately, the boundaries of these three perspectives are constantly shifting, depending on system growth and viewer outlook.

Since the fall of 1971 when the vendor-hospital relationship was established, all requests for changes have been documented. To date, there have been about 4,500 requests. This number of changes has not actually been implemented because of two factors. Sometimes a request for change has, on analysis, proven to be unsound, either from the hospital's or the vendor's point of view. In other instances, a general improvement in performance has eliminated the need for the change. The remaining 3,500 system changes which have been implemented represent operational problems, design deficiences, and system extensions. A major number were the direct result of programming "bugs" in MIS. This kind of operational problem was very prevalent during 1972 and continued into 1973. By the end of 1974, incidence of program "bugs" had fallen to about a dozen a month. New features constantly being added to the system account for this small, but continued level of "bugs." Improvements may contain a "bug," disclose a here-to-fore hidden problem, or bring into existence a new problem, caused by the complexity of interaction within the system. Because changes tended to produce problems, they have been made on a once-a-week basis. This schedule reduces monitoring for problems and makes it easier to isolate the source of a given problem.

Another entirely different kind of change is represented by normal hospital growth or modification of internal operations. These changes could be as simple as the addition of a new drug to the pharmacy displays, or as complex as the relocation of several nursing stations. As MIS functions correlate with the specialty of the nursing unit, unit reorganization involves reorganization of a number of system control tables. Because of the flexibility of MIS, it has not been difficult to accomplish these changes at the desired time.

The last group of changes can be termed refinements to MIS. Again the scope varies. They can be as easy to accomplish as the reorganization of data on a matrix to simplify user access, or as complex as implementing a new Laboratory subsystem. The design philosophy of flexibility, which the developers of MIS considered vital, has proven to be a significant factor in MIS becoming a total hospital information system that reflects the hospital operation rather than a system that constrains the hospital to fit into its mold.

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4. PATIENT CARE BENEFITS AND USER ACCEPTANCE

Hospital-Related Patient Care Benefits

The aspects of the MIS system which appear to have most direct benefit to the patient are primarily the result of the system characteristics of timeliness, accuracy, data availability, and assumption of clerical tasks formerly performed by hospital personnel. The first place where the patient benefits from the system is when he is admitted to the hospital. The admission process, although essential for the functioning of the hospital, often is frustrating to the patient. MIS makes it easier to gather and process data before the actual arrival of the patient (pre-admission system), thus shortening the process. It also makes possible admission of the patient at his point of entry to the hospital (Admitting Office, Emergency Room, Delivery Room, or Nursery), and necessitates the collection of data only once (although these data subsequently will be processed many times and will appear on many different forms). Lastly, MIS immediately transmits admission data to appropriate departments and facilitates the patient's interaction with departments such as the Laboratory and Radiology before actually being admitted to the nursing station.

The physicians' orders, which direct the course of events for the patient's stay in the hospital, represent a second place where patient benefits are seen. A desirable situation exists when the care ordered by the doctor and the care received by the patient are the same, unhampered by misinterpretations, transcription errors, and lost requisitions. MIS brings this goal much nearer realization than any manual system can. There is no need to transcribe orders with MIS. They are transmitted verbatim to the proper location. Nor does MIS lose orders. This aspect has been carefully monitored and over three and one-half years of operation, MIS has been reliable. Interpretation errors are reduced because doctors, nurses, laboratory technicians, pharmacists, and others all work from a common data source. Using this data source has required standardization of terms. The clarification such standardization introduces is illustrated by the area of medication schedules. Consider an order for medication---"every four hours for four days." The element "for four days" can be interpreted as four 24-hour periods or four calendar days. If the order were written at 10:00 P.M., a variance of four doses for the patient could result depending on the interpretation. With MIS, "for four days" always means four calendar days. Additionally, MIS requires completeness of orders. This feature means that the physician is encouraged to clearly document what he had planned for the patient, eliminating errors to the patient because an order was incomplete.

Another area in which the patient benefits is the timeliness of service. Patients benefit when orders are carried out promptly after initiation and appropriate results are available promptly after determination. This capability is best exemplified by the order for a stat. medication, which may reach the nursing unit two to five minutes after being ordered. In a manual system it would take that much time just to transmit the order to the Pharmacy.

Patients benefit because information necessary for any member of the health team to plan and to implement care is available to that member in an appropriate format. One easily overlooked but essential example is legible, complete patient identification information. Another example is allergy data. Allergies to medication are printed along with a prescription, while food allergies are printed on the Diet Orders List.

While some may feel that accurate charging will increase the patient's bill, it is our contention that it is to the patient's benefit to be charged for a service received at the time the service is documented as having been provided. This accounting is totally feasible through MIS, and thus a patient pays only for what he receives.

Lastly, the patient benefits as health care personnel are freed from the need to concentrate time and effort on information processing and instead can use this time and energy in other means of patient care.

Hospital Acceptance

Nursing Acceptance and Benefits

Long before the actual implementation of the MIS system at El Camino Hospital, nurses were interested in its potential and took an active role in early data gathering and evaluation. During the implementation of MIS, the nurses played a key role in supporting the system during the trying time when problems were great, physicians' support was not strong, and users in the ancillary departments were coping with the burden of running a dual system.

It could be said that during 1972 the nurses as a whole were supportive of MIS. During this time there were no formal polls of nursing personnel. To say that the nurses were supporters is not to say that they were uncritical. One aspect of their support involved the honest, thoughtful criticisms presented by nurses which led to many improvements.

During 1973 the thrust of the benefits realization program (see *Nursing Cost-Benefit Realization* in Section 6) involved a detailed analysis of work changes introduced by MIS or made possible because of the existence of MIS. Because the objective of the benefits realization phase involved reduction of the nursing staff, the MIS system was viewed as threatening to nurses. This perceived threat led to certain amounts of anger directed toward the system by this group, temporarily reducing the degree of their support.

However, as the benefits realization program was carried out, nurses recognized that they could continue to provide the same or better care at reduced staffing levels. This realization coupled with the hospital policy of achieving staff reduction only through natural attrition seemed to renew the nurses' faith in MIS. Attitudes once again became positive, and in July of 1974 a poll of 360 nursing personnel yielded 316 responses. Of those voting yes or no, 92 percent were in favor and 8 percent were negative.

One of the reasons for this acceptance is thought to be that nursing saw the system as *their* system as opposed to Technicon's system. Another reason for acceptance resides in the benefits seen by nurses. Some of these were perceived as immediate benefits, while others were viewed as developmental items for the future. MIS benefits nursing in a number of ways. The most obvious way is the decrease in clerical tasks required of the nurses. Another way involves the ability to shift more of the clerical tasks to the unit clerk. This shift is made possible by the decrease in transcription and reduced requirement for checking the accuracy of orders.

A second area of benefit relates to the greater availability of data. This data availability pertains to both the printed form and to the VMT. The printing of patient care plans for each shift makes it possible for the nurse giving the care to have a copy of the complete care plan. Nurses no longer are dependent on a Kardex, which often is in use by the nurse transcribing orders or checking medications.

A third area of benefit arose through the gradual shift in responsibility to its appropriate location. Because nurses no longer were involved in the transcription and distribution of orders, questions regarding departures from expectations were now properly channeled to the respective departments instead of directed at nurses. The age-old question to nursing, "Why wasn't this test done?" no longer was appropriate. The nurses' perception of themselves as care givers rather than as transcriptionists also was a benefit, although for a time this concept was a source of conflict between nurses and the physicians who were nonusers of MIS.

Nurses benefited by seeing care plans and nurses' notes in a legible format. The new legibility soon prompted questions regarding the necessity and desirability of traditional nursing note content and practice. In the area of nurses' notes, the new technology helped break old habits relative to the "how" and "why" of nurses' notes. Nurses also saw that MIS had the potential for helping to solve the data management problems inherent in nurse care planning. This insight led to a long-term project to develop a care planning system compatible with MIS. In the process, Standard Care Plans[1] were documented for the disease processes and problems commonly seen at ECH. The benefits of changes in nurses' notes and potential capability in the nurse care planning area have shifted the emphasis in nursing from time-consuming paperwork to nursing care processes. The potential inherent in these benefits has only served to increase the support that nursing as a whole affords to MIS.

Ancillary and Support Department Acceptance and Benefits

Admitting Department. The patient registration function was implemented in toto throughout the hospital in December 1971. Admitting registration records, patient locater lists, and census reports were utilized by various departments. After the initial period of implementation, which included improving system response time during the heavy patient admitting period (1 to 4 P.M.), acceptance by users was good. Faster and easier registration of patients reduced patient delays and improved the effectiveness of the admitting clerks. Service personnel were aided by the improved accuracy, timeliness, and organization of information needed by them.

Pharmacy. The Pharmacy implemented MIS and a *unit-dose* medication system simultaneously. The ability to easily establish unit dose as a by-product of MIS resulted in good user acceptance. Clarity of the medical order, improved turn-around time on stat. and routine orders, allergy recognition, and patient medication profiles enhanced the general operation of the Pharmacy.

Radiology, Nuclear Medicine, and Radiation Therapy. Improved clarity of medical orders, schedules, and indications were benefits for the radiologists and technicians. Video access to the patient chart is utilized by radiologists. The medical transcriptionists benefited from MIS after the installation of "typewriter" keyboards that allowed them to increase their report productivity. Their acceptance is good. Some radiologists actively use standard or normal interpretive statements available through MIS, but others rarely do. Radiologist acceptance is mixed.

Central Service. Improved clarity of the medical order, improved turn-around time, and automatic charging resulted in good acceptance of MIS in Central Service.

EKG and EEG. Combining the order requisition and the work sheet on a MIS printout benefited the EKG technician, as did access to patient information. Acceptance is good.

Dietary. Food service developments and improvements were only partially implemented. Diet Orders Lists presently are not produced as designed. Consequently, acceptance of MIS is only fair in this department.

Physical Medicine. Improved medical order processing is a benefit to the therapist and resulted in good acceptance of MIS.

Clinical Laboratory. Initially, the Laboratory required additional clerical labor, both for planned manual entry of results into MIS and in support of subsystem malfunctions that caused work delays for the first period of implementation. Automatic interfacing of laboratory test equipment relieved some of the clerical workload, and subsystem design improvements minimized the work delays. Medical orders are more complete, better organized, and are clearer. User acceptance of MIS is mixed.

Pulmonary Function Laboratory and Inhalation Therapy. Improved medical order processing, charting, reporting, and charging have resulted in good acceptance of MIS by these technicians.

Medical Records. Medical Records implemented MIS by utilizing registration information on all patients as of December 1971 and by using MIS documentation as each nursing unit implemented MIS through September of 1972. User acceptance was poor during the first year. System problems and paper volume were early factors contributing to negative reactions and were compounded by insufficient preparation and a lack of understanding of the impact of the change. Later, summarized and organized chart documents lessened volume and audit problems, while the results of system studies improved the work flow. As MIS reliability was established, user acceptance in this department increased to an appropriate level.

Emergency Department. The Emergency Department was implemented last and suffered initially from poor system methodology. To Emergency Room (ER) personnel, it appeared that their service to patients had been affected adversely at times because of the system, and initially, user acceptance was poor. The ER subsystem was improved in 1974 with the implementation of a registration "label." Presently, user acceptance of MIS is good.

Physician-Related Patient Care Benefits

In general, physician-related patient care benefits are associated with the automated information processing attributes of timeliness, accuracy, completeness, and availability. A second class of patient care benefits derives from the expanded information base made available to the physician through the VMT. Physician-related patient care benefits may be categorized under several headings.

First, the MIS system acts to insure that the execution of orders is more consistent with the physicians' intent. Orders are more *complete* because (a) order completeness is a requirement for successful order entry (e.g., a drug order without an appropriate schedule will not be accepted), and (b) the structure of the system (specifically the Physicians' Master Guide, personal order sets, and standard order sets) reminds physicians to attend to all facets of patient management such as activity, diet, and so forth, as well as to the critical elements of diagnosis and therapy. Care is more complete because patient care requirements are documented for nursing personnel in individual patient care plans. These patient care plans are used as working documents to insure that a high degree of compliance between "given" care and "intended" care is achieved.

The marked improvement in the *accuracy* with which physician directives are processed implies that care given reflects more accurately the physicians' intent. Multiple transcriptions and the attending transcription errors are eliminated, as are problems relating to the illegibility of handwritten orders. Errors or delays associated with "lost" medication cards or ancillary requisitions are generally nonexistent. Hourly medications-due lists insure that scheduled medication is delivered on time, as do the automatic reminders that print out when scheduled medications are not given or charted on time. The unit-dose system, which the hospital was able to install without incurring the typical additional pharmacy labor cost, further reduces medication administration errors. Finally, documentation of the patient's current orders and nursing needs on patient care plans which the nurse can keep with her while delivering patient care reduces the need to rely on memory.

Increased *availability* of information also is important for improving compliance with physicians' orders. Each patient's current medical orders are readily available for viewing by authorized personnel anywhere in the hospital. Thus, a physician taking calls for another doctor may easily determine what orders are current for the patient. Laboratory and Radiology staff may review the patient's current medications to assess their impact upon diagnostic studies. Pharmacists may review the patient's drug profile to ascertain

potentially dangerous drug interactions. Essential parts of the patient's chart are "available" to physicians throughout the hospital. They can read this electronic chart or write orders in it from any VMT. For nursing personnel, the availability of the physician's current orders is substantially improved through hard-copy documentation that they can carry with them (the care plans and their updates) and the current orders on the VMT.

Finally, significant improvements in the *timeliness* of information processing contribute substantially to increased compliance with physician intent. Doctors' orders entered at a VMT are transmitted instantly to the intended receivers, whether they be ancillary departments or nursing personnel. Thus, response to these requests begins sooner. Because of clerical assists within ancillary departments, work can proceed faster. Communication in the opposite direction also is improved, and results are returned more rapidly or therapeutics are instituted earlier. Because results are available sooner to nursing personnel and physicians, responses to changes in patient condition can be made sooner.

A second area of physician-related patient care benefits concerns direct informational assistance made available to the physician through the VMT's. This assistance is available for (a) interpreting clinical results, (b) prescribing therapy, or (c) ordering diagnostic tests.

With respect to interpretation of data, perhaps the single most valuable development is the comparative laboratory report which allows rapid comparison of test values over time and across categories. Further interpretive assistance is available through laboratory test interpretation information and data specifying therapeutic and toxic levels of various drugs.

The doctor is assisted in prescribing therapy in a number of ways. Normal dosages, route, and schedule are present on the drug ordering displays. Various therapeutic guides are available including respiration therapy, heparinization, drug information, and current antibiotic sensitivities. Potential allergy reactions are reduced by associating patient allergy information with all drug orders in the Pharmacy. The physician also may be aided in his search for appropriate therapeutics by the extensive "shopping lists" available at the VMT. For example, the displays list most of the drugs available in the hospital formulary, all laboratory tests, radiologic procedures available, and so on. Assistance rendered in ordering diagnostic tests includes an extensive array of radiology indications, a radioisotope ordering guide, a hyperlipemia work-up guide, and the laboratory test information guides mentioned above.

Lastly, the system provides a number of assists for physicians in their practices. These include comprehensive patient insurance and billing information, patient lists by physician, patient location information, medical announcements, office summary of inpatient diagnostic results, a simplified discharge summary, standard and personal order sets, and a pre-admit ordering capability.

The above recounting of what appears to be an extensive set of capabilities having substantial direct or indirect benefits for the physician may seem to be incongruous with the somewhat less than overwhelming physician acceptance discussed in the following paragraphs. This incongruity is thought to be a function of (a) the rather traumatic introduction to the developmental system that ECH physicians received, and (b) a general lack of appreciation of the physician-related patient/practice benefits enumerated above and potential future physician benefits associated with continued development. Also, it has been discovered that individual physician acceptance is closely allied with nonsystem characteristics such as medical specialty, intensity of hospital usage, and proficiency with MIS.

Physician Acceptance

As discussed under *System Implementation, Validation, and Extension* in Section 3, physicians were alienated at first by (a) the system's rather incomplete state of development initially; (b) the numerous operational difficulties such as "bugs," downs, user delays, and promised capabilities which simply did not yet work; and (c) the lack of physician-oriented applications that as *quid pro quo*, so to speak, might partially compensate doctors for breaking with old habitual routine and enduring the frustration of learning new, not yet highly refined ways of computerized medical information handling.

Early in the implementation of the system there were many technical problems in both hardware and software which have slowly been resolved during the ongoing operation of the system. These problems produced a great deal of user animosity among the physicians. For example, it became obvious that any response time for data retrieval which exceeded three seconds or any response time for fixed displays which exceeded one second was undesirable. Basic software faults which affected scheduling medication, scheduling laboratory work, and so forth also tended to adversely affect the physician users and their response and willingness to use the computer terminals.

The concerns of physicians about their interface with the terminals has been of great interest. There originally was a great distrust for the "black box" and its handling of orders. Only as the system has improved have these fears disappeared. Two other points of physician concern are the following.

1. The physician was requested to learn an entirely new technique of ordering for his patients which initially gained him very little benefit. The physician normally is not aware of the range of paperwork and paper distribution which the various staff personnel in the hospital are required to carry out in order to complete the physician's orders.

2. The physician was required to reorganize his thinking processes along the line of the computer display sequence. This requirement included learning the positions of various items in the display chain so that they could be accessed easily. In addition to this new experience, the mere fact of sitting down to a computer terminal and using the light pen rather than a pencil to write orders required a readjustment and relearning of thought processes.

As it has turned out, most physicians in the hospital have been willing to do this and most of the physicians have quite successfully mastered the technique of ordering within the system. As problems have been pointed out by users, the system has been modified to correct these problems and this process will continue on an indefinite basis. For those physicians who do not desire to enter orders through the VMT, the hospital has adopted a policy of allowing written orders to be handed to the nurse as in the past.

The introduction of the new developmental system sharply dichotomized many of the active physician staff members into opposing camps---those who favored continued testing and development of MIS and those who wished to be rid of it immediately. Those who opposed the new system were particularly vociferous in their efforts to publicize the deficiencies of the system. Ultimately, this activity served to focus remedial effort in a healthy way on the more glaring system drawbacks.

Three polls were conducted during the period of system implementation and validation. These were simple, subjective polls conducted by hospital administration which sought to gauge the extent of physician frustration or tolerance concerning the developmental activity. The first poll, taken just as implementation was completed in November of 1972 (numerous deficiencies were still to be corrected), showed 47.5 percent favoring continued development, 42.9 percent in favor of discontinuing the system, and the remainder expressing no opinion. Roughly the same split was observed at the second polling in September of 1973, even though numerous improvements had been carried out. It has been suggested that perhaps the largest single change influencing greater physician usage involved improving the accessibility and viewing format for laboratory and radiology results in the VMT's. In August of 1974, the third poll revealed continued improvement: 56 percent voted to keep the system; 35 percent still wished to abandon the project; while 9 percent held no opinion. For those expressing an opinion, these results translate to 61 percent for the system and 39 percent against (see Table 1). The reader must be cautioned, however, against extrapolating El Camino Hospital physician acceptance findings to potential installations of a fully developed system.

Some physicians who were alienated by the developmental experience still use the system but only in a limited way, for example, for retrieval of diagnostic results which have not yet reached the paper chart. It is also likely that these so-called "limited" users are largely unaware of the extent and number of improvements made in the ordering capabilities. It is our opinion that physician acceptance would be considerably more widespread in absence of the painful developmental experience. *This supposition is borne out by the way in which physicians new to the hospital since the implementation of MIS learn and use the system quite readily.* Perhaps even more important to this casual evaluation by physicians was the general absence of rigorous evaluation data citing the benefits and drawbacks of the system. While an interim evaluation project report has been published,[2] it is doubtful that many physicians acquainted themselves with the findings. Secondly, the results of numerous evaluation studies referred to in this document were not final in nature. Thus, physicians had little in the way of objective data upon which to base their judgments.

TABLE 1

POLL RESULTS OF THE EL CAMINO HOSPITAL MEDICAL STAFF REGARDING PERMANENT COMMITMENT BY THE HOSPITAL TO ACCEPT THE MIS SYSTEM (AUGUST 1974)

Total Ballots Mailed: 350 *Total Ballots Returned: 263*

Name of Department	Total Active/ Associate Members by Department	Voted YES (Accept MIS)	Voted NO (Not Accept MIS)	No Opinion
Anesthesia	14	6	1	0
Dentistry	30	7	4	8
General Practice	48	13	16	6
Medicine	62	22	27	2
Obstetrics/ Gynecology	27	16	6	2
Pediatrics	22	13	8	0
Psychiatry	47	17	11	1
Surgery	78	45	16	3
Miscellaneous*	22	7	5	1
TOTALS	350	146 (56%)	94 (35%)	23 (9%)

Of those 240 physicians responding YES or NO:

61% YES
39% NO

* Includes Emergency, Pathology, Physical Medicine, and Radiology.

Acceptance and utilization of the system have been strongly correlated with physician specialty. The system is best accepted by the Obstetrics/ Gynecology Department. In mid-1974, approximately 90 to 95 percent of all orders were being written directly into the computer system by the physicians in this department. Approximately 80 percent of orders from the Department of Surgery were entered into the computer by physicians in this department, while only 30 percent of internists' orders were so entered. Over all specialties, an average of 70 percent of all orders currently are entered directly into the computer system by the physicians. It should be noted that these percentages reflect a comparison of handwritten orders versus orders directly entered into the computer system. Verbal and phone orders are excluded. Separate studies have been made, however, which show that the pattern of verbal and phone order usage has not changed before and after the introduction of the computer system.

Another topic pertinent to physician acceptance has been the notion that the labor displacement impact of the system on hospital staff may affect the level of patient care. One of the basic criteria for system acceptance has been cost effectiveness. Analysis of savings projected that the bulk of anticipated savings would accrue through nursing labor reduction. This concern was also shared by the hospital administration, and cuts have been made only gradually and with extreme diligence so as not to affect the level of care. The goal of cost effectiveness has been reached, and substantial nursing staff reduction has been made. Objective evidence is available from the Battelle evaluation[3] which indicates that the amount of direct patient care has not diminished. It must also be observed that neither is there any subjective evidence to suggest a deterioration in care.

In summary, it is our opinion that even though a substantial number of the physicians voted against retaining the system in August of 1974, the system *is* workable for physicians, but it requires willingness on the part of the physicians to change their methods. Our principal basis for this opinion is that more than 70 percent of all orders are being entered directly by physicians. Another basis for this opinion is that the major users of the hospital, in general, are also major users of the system.

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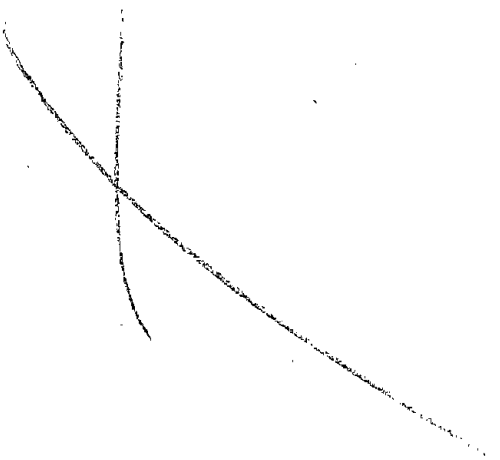

5. ECONOMIC IMPACT

Introduction

The economic impact created by the introduction of a total hospital information system into a hospital environment is highly complex and not yet fully understood. This phenomenon embraces not only a variety of economic effects (direct labor, indirect labor, changes in the volume of service units delivered, cost avoidance, cash flow, material cost changes, and throughput), but also encompasses a broad spectrum of physical impact points including all nursing stations, ancillary services, and support services.

The cost side of a cost-benefit balance sheet is usually straightforward and relatively easy to deal with. However, the accounting of cost benefits is not as easy. The primary economic rationale for considering such a system is composed of the following factors: (1) substitution of relatively fixed-price capital equipment for hospital labor, particularly nursing labor, which has risen sharply in cost over the last ten years; (2) production of information which enhances decision making; and (3) improvements in the quality of care delivery. The state of evaluation art currently is not capable of furnishing much in the way of quantitative *economic* evaluation of the latter two factors. With respect to labor displacement, the bulk of this substitution takes place in the clerical aspects of nursing activities, which constitute roughly 15 to 25 percent of the average nursing workload in a medium-size hospital. In particular, through work sampling studies at El Camino Hospital, clerical activities were found to consume, on the average, 18 percent of the nursing unit staff time prior to implementation of MIS. Of the total *potential* savings estimated for the MIS system at El Camino Hospital, roughly 95 percent represent labor benefits, the large bulk of which arises in nursing. Other areas having significant labor cost benefits include major ancillary services (viz., Pharmacy, Central Service, Inhalation Therapy, Radiology, and the Clinical Laboratory), and certain support services (Business Office and Admitting). The remainder is made up of certain revenue benefits, materials savings, and minor cost avoidance. Because the labor component of the documented cost benefits not only is of much greater importance in terms of magnitude but also presents a substantially more difficult evaluation problem, the major emphasis in the analysis of economic impact has been devoted to that component.

Summary of the Economic Impact

The labor cost benefits resulting from the installation of a medical information system can be measured before implementation by the use of predetermined time standards. The result is a measure of predicted time savings or potential labor reductions. Other methodologies may be used to measure the actual time saved after the system is installed and operating for some time, resulting in measures of realized labor reductions. Whereas the former method provides a measure of *workload* reduction, the latter provides measures of *work-force* reductions. The latter methodologies also have the advantage of comparing not only actual staff reductions to time savings, but they also can be used to compare actual staff levels after implementation with projections

of what staff levels would have been if operations had continued under the manual system. Thus, they can be used to estimate staff increase avoidances as well as staff reductions, which can be translated into cost avoidances and cost reductions.

Over the 4-year time period during which the study was conducted, it became obvious that no single measure or method of appraising cost benefits was entirely satisfactory---each had its drawbacks. To meet the variety of methodological needs outlined above and in consideration of the dynamics of the benefits realization process, a research strategy incorporating three independent perspectives evolved. Each perspective has an associated measurement model. In addition, while changes in labor patterns over time were measured by the three research instruments, changes in hospital diagnostic mix and patient age were monitored, and the impact of these changes was evaluated with respect to observed changes in labor. The three perspectives and corresponding models are the following:

- Potential Labor Savings. Methods Time Measurement (MTM) model comparing the time for performing clerical tasks of the manual method versus the MIS method.

- Hospital Internal Labor Impact. Comparison of trends in nursing labor hours per patient day and selected ancillary labor hours per admission *actually* expended two years after implementation with labor hours *expected* under the manual system for the same time period.

- Inter-Hospital Labor Trend Comparison. Comparison of trends in *actual* nursing labor hours per patient day and per admission, and selected ancillary labor hours per admission at El Camino Hospital and at six similar nearby hospitals during two 18-month periods, before and after implementation. In order to eliminate the effect of unequal weighting caused by seasonal variations, trends were computed for the first and last 12 months of the 18-month period, as well as for the entire 18 months. Accordingly, this model provides a range of cost benefits resulting from the different time periods and the different nursing measures (i.e., nursing hours per patient day and per admission).

The monthly dollar value of the labor savings calculated by means of these models is presented in Table 2. These values represent total hospital labor savings and include the effect of increasing labor cost and traffic growth over a 5-year contractual period, from fiscal year (FY) 1975 to fiscal year (FY) 1979. The table entries constitute the average monthly savings for this 5-year period.

As shown in Table 2, total net MIS cost benefits, after deducting for system costs, range from -$17,724 to +$98,714 per month, with two models estimating monthly savings of $23,668 and $38,969. The difference between the values serves as a reminder that the *true* cost benefits of the system lie somewhere within this broad range. A more realistic but still conservative estimate is that net cost benefits lie between $30,000 and $50,000 per month, or between $3 and $5 per patient day.

TABLE 2

NET MONTHLY COST BENEFIT ($ AND $ PER PATIENT DAY)
AS MEASURED FROM THREE INDEPENDENT PROJECTIONS

	Potential Labor Savings Model	Internal Labor Impact Model	Inter-Hospital Labor Trend Model	
			Minimum	Maximum
System Savings				
Total Labor Savings (MIS)[1]	$ 93,955	$109,256	$ 52,563	$169,001
Total Nonlabor Savings (MIS)[2]	6,513	6,513	6,513	6,513
Business Office System Savings[2]	13,000	13,000	13,000	13,000
TOTAL SAVINGS	$113,468	$128,769	$ 72,076	$188,514
Monthly Service Cost				
System Service	-$ 82,750	-$ 82,750	-$ 82,750	-$ 82,750
System Supervision Terminal Hardware Support	- 3,750	- 3,750	- 3,750	- 3,750
Material (Printer Paper)	- 3,300	- 3,300	- 3,300	- 3,300
TOTAL COSTS	-$ 89,800	-$ 89,800	-$ 89,800	-$ 89,800
Net Monthly Cost Benefit				
A. Dollars	$ 23,668	$ 38,969	-$ 17,724	$ 98,714
B. Dollars per Patient Day[3]	$ 2.37	$ 3.90	-$ 1.77	$ 9.88

[1] Average monthly savings calculated for a 5-year contract, FY 1975-FY 1979.

[2] Evaluated at cost (5-year contract, FY 1975-FY 1979).

[3] Based on FY 1975 average of 9,994 patient days per month.

The Potential Labor Savings Model represents time savings resulting from the elimination and simplification of tasks; hence, this model considers cost reductions only. The other two models represent comparisons of actual costs to projections of what costs would have been without MIS; thus, these models consider both cost reductions and cost avoidances. Since the cost-benefits realization process occurred over several years, and total staffing levels reflected efforts to concurrently reduce staff in some areas and minimize increases in other areas, it was impossible to segregate labor reductions from labor increase avoidances.

The Internal Labor Impact Model nursing savings are based on nursing hours per patient day. During the two post-implementation years analyzed, the hospital's length-of-stay decreased by 4.1 percent from 5.08 to 4.87 days. Thus, savings are more conservative than if the measure of nursing hours per admission had been used.

The Inter-Hospital Labor Trend Model savings vary widely. Based on the conservative measure of nursing hours per patient day, they range from -$17,724 to +$22,177 per month. A more liberal estimate based on the measure of nursing hours per admission results in a savings ranging from $25,719 to $98,714 per month. In both cases, the lower estimates are based on regressions for the first 12 months and the higher estimates are based on regressions for the last 12 months of the 18-month period, with the regressions for the total 18 months lying approximately in the middle of these ranges.

It should be noted that the two models using regression analysis did not project savings based on extrapolation of the regression lines. Rather, the end point of each regression line was used as the starting point for projecting FY 1975 - FY 1979 savings. In the case of the Internal Labor Impact Model, this point was January of 1975 (the midpoint for FY75), the first year for which savings were projected. In the case of the Inter-Hospital Labor Trend Model, the end point was December of 1973. For all three models, labor costs are projected to increase at a rate of 8.5 percent annually for the FY 1975 -FY 1979 period. This 8.5 percent increase is composed of salary inflation and traffic growth. This projection is a conservative figure for the geographical area in which El Camino Hospital is located. The projected savings for the two regression models are based on the early post-implementation periods of two years and 18 months after implementation, before the cost-benefits realization process had been completed. Thus, these projections once again are conservative.

To the labor cost benefits must be added nonlabor cost benefits, as documented under *Nonlabor Cost Benefits* later in this section, and cost benefits ascribed to the Business Office System (BOS). Because the Business Office System is marketed separately by Technicon and has, in fact, been operational at the hospital for a number of years prior to the implementation of MIS, the cost benefits were evaluated previous to the initiation of this study by the hospital and were found to exceed the costs of the system. For purposes of this analysis, the cost benefits of BOS are equated to its monthly service cost.

Only benefits actually converted to payroll dollars or other cost reductions were included. Labor time savings which were not realized through payroll reductions, but which were available for enhancement of direct patient care, were excluded from the cost benefits. Also, no attempt was made to place a monetary value on the numerous and varied "value added" benefits, such as fewer medication errors, reduced incidence of drug allergy reactions, improved turn-around time of diagnostic test results, and so on.

It can be concluded from the data presented in Table 2 and from the conservative accounting of cost benefits that MIS has been proven to be highly cost effective at El Camino Hospital, with cost savings substantially exceeding system costs. It also can be seen that the great majority of savings are in labor, primarily nursing labor. Major cost containment also has been demonstrated, both in terms of El Camino Hospital's cost trends after the installation of MIS compared to the pre-MIS period, and in terms of comparisons with similar hospitals in the surrounding area during the post-installation period. These favorable conclusions are supported by the three independent analytical approaches. An analysis comparing patient age and diagnostic mix between El Camino Hospital and the similar area hospitals showed no significant difference in these factors. Thus, no other external factors, other than the introduction of MIS, can be found to explain the favorable experience at El Camino Hospital. Internally, the only major change was the introduction of an active utilization review program in conjunction with the implementation of MIS.

It is also clear that the benefits realization phase is a necessary ingredient of the implementation process, if cost effectiveness is to be attained. Further studies are being conducted under separate contract to provide more definitive statements of the cost effectiveness of MIS.

Labor Impact Measurements

While it was apparent early in the evaluation that major investigative effort should be concentrated on the analysis of labor savings, particularly in the analysis of nursing savings, the complexity of the research task was increased by a number of complicating conditions and somewhat dissimilar research requirements. Complications included the following factors:

1. The dynamic nature of the system over the course of the project;

2. Exogenous variable effects: occupancy, staffing, and diagnostic mix;

3. Determination of the best time point(s) for benefits measurement; and

4. The lack of quantitative nursing station staffing criteria by which base-line staffing conditions could be equitably established (i.e., were nursing staffing levels used in the manual system analysis at an optimal level and thus directly comparable to optimal staffing levels which might be achieved under MIS system operation?).

With regard to research goals, a number of considerations pertaining both to the system itself and to the demonstration project made it extremely desirable, if not mandatory, that the appraisal of the economic impact of the system be made both in terms of its ultimate *potential* and in terms of those benefits which had been actually *realized* at some particular point in time.

It appeared evident that realization of the system's promise might lag implementation substantially and that empirical measurements of labor savings taken in response to investigative research deadlines might fall considerably short of that mark. Subject to uncertainty regarding the realization of benefits were (1) the system itself, (2) the user, and (3) the "benefits realization process" whereby potential labor savings are *realized* through job reorganization and staff reductions. It is this "benefits realization process," separate and distinct from implementation, which undertakes to translate labor savings spread piecemeal through many employees into full-time-equivalent aggregates or other sizable units amenable to staffing reduction.

Because the system had been conceived and developed largely in a non-hospital environment, although with substantial hospital assistance and certain in-house nursing and medical capability, it was felt that numerous changes would be required, resulting in a significant time delay before the system could operate according to design specifications. These changes involved individualization of the system to El Camino Hospital peculiarities, changes to rectify problems, and system improvements. Also, with the experimental nature of the system and the magnitude of the changes to be effected in nursing job content, roles, and work organization, it was not known with certainty how rapidly implementation could progress. Consequently, it was difficult to plan the realization process or to estimate how rapidly it could progress. In addition, unless the benefits realization process had been carried out on the units to *realize* the labor savings through staffing reductions, observations aimed at measuring time savings in information processing might be obscured by changes in idleness, pace, conversation, and so on. Thus, at the inception of the project, it was uncertain (1) whether savings would be visible prior to completion of the realization process; (2) what percentage of the potential benefits could actually be realized; and (3) how difficult it would be to carry out the realization process.

The initial quantitative research tool chosen for potential labor savings was the well-known industrial engineering technique of Methods Time Measurement (MTM). Methods Time Measurement is a technique used to measure work tasks by breaking down activities into small standardized elemental motions, each of which has a standard time value associated with its performance at a normal pace. Specific time standards have been developed to measure clerical work. Using these standards, clerical work on which the information system would have an impact was measured as it was performed manually, prior to MIS implementation and as it would be performed in the computerized setting. The difference in the workloads (before and after) represents the *potential* theoretical work displacement achievable through the implementation of the system.

In order to account for the natural growth trend of the nursing workload (i.e., what would the manual workload have looked like later?), an Internal Labor Impact Model was developed to project what the *expected* nursing staffing would have been under the manual system. In this way, expected staffing could be compared with actual staffing and the difference between "what might have been" and what actually occurred could be determined.

Both the Potential Labor Savings Model and the Internal Labor Impact Model focused only on El Camino Hospital data. A drawback of these two models is that they lacked the experimental control of a comparison with similar hospitals. In particular, while cost changes within the hospital would be illuminated, possible cost containment effects would not. Thus, for example, if cost trends in similar nearby hospitals had risen significantly and those at ECH had not changed, a cost containment effect might have been operative. Internal studies, of course, would not document this effect. To meet this need, a comparative study of cost trends and morbidity patterns was undertaken in six similarly sized hospitals within a radius of 20 miles of El Camino Hospital.

To meet the variety of methodological needs outlined above and in consideration of the dynamics of the benefits realization process (discussed in Section 6), a research strategy incorporating three independent perspectives evolved. Each perspective has an associated measurement model. In addition, while changes in labor patterns over time were measured by the three research instruments, changes in hospital diagnostic mix and patient age were monitored, and the impact of these changes was evaluated with respect to observed changes in labor. The three perspectives and corresponding models are as follows:

Perspective	Model
Potential Labor Savings (theoretical model)	Methods Time Measurement (MTM) model of clerical work before and after implementation.
Hospital Internal Labor Impact (empirical model based on nursing labor hours per patient day and ancillary labor hours per admission)	Comparison of actual monthly nursing and ancillary hours expended two years after implementation with labor hours *expected* under the original manual system.
Inter-Hospital Labor Trend Comparison (empirical model based on nursing labor hours per admission, nursing labor hours per patient day, and ancillary labor hours per admission)	Comparison of trends in expenditure of nursing and ancillary labor hours of six similar nearby hospitals and El Camino Hospital for two 18-month periods, before and after implementation.

Two criteria, labor hours per admission and labor hours per patient day, were used across and within models. From an economics standpoint, the criterion of labor hours per admission is attractive because it represents cost per unit of output, and presumably, the proper output variable for a hospital should be well bodies rather than the number of sick ones currently "in process." However, there are conditions under which use of labor hours per admission is less appropriate. This situation may be the case, for example, when the denominator of the ratio differs considerably for the comparative data or when the trend of the denominator so varies. Thus, when measuring changes in productivity under conditions wherein the base-line variable changes in value, care must be taken to make certain that the difference in the value of the ratio does not result from a change in the base line rather than through variation in the variable of concern. Thus, nursing hours per admission could decline simply because of an increase in the number of admissions. If the increase in admissions, in fact, did not increase the nursing workload (e.g., patient days declined in balance to the marginal increase in nursing workload---this situation could be achieved through a reduction in length-of-stay), then the ratio of nursing hours to admissions would not be a good indicator of nursing productivity. Under these conditions the ratio might measure changing conditions more accurately than the variation in the productivity of nursing labor.

If the effects of the impact of increasing admissions on nursing labor were known in a quantitative fashion, then one could separate the component of change associated solely with exogenous variation (e.g., length-of-stay) from the change in the productivity of nursing labor. It is known that the effect of increased admissions on nursing labor is pronounced, i.e., for each new admission there is a substantial amount of labor associated with that admission on the nursing unit. Specifically, the admission sheet must be completed; the Kardex must be set up; bed tags and allergy tags must be completed; the chart must be set up; admitting vital signs, height, and weight must be obtained; and a nursing history and physical examination must be taken. Furthermore, the patient must be introduced to the unit and nursing personnel must become acquainted with the patient's individual needs, mental condition, and family relationships. All of these "one-time" patient care elements require considerable nursing labor expenditures. It is also well known that the intensity of nursing care generally is much higher in the first few days following admission than during the tail end of the patient's stay. A reduction in the length-of-stay with a corresponding increase in admissions results in replacing patient days that require less nursing time with patient days that require more nursing time, thus adding substantially to the workload. Thus, although it is apparent that increasing admissions contribute substantially to the nursing workload, resources have not been available to quantitatively document the extent of this phenomenon at El Camino Hospital.

To deal with this situation, it is helpful to utilize the ratio of nursing hours per patient day. Under the conditions experienced in this study (viz., rising admissions and relatively stable patient days), nursing hours per patient day can be used as a lower bound in the measurement of changes in nursing productivity. This ratio errs on the conservative side in two respects: (1) it underestimates increases in productivity by entirely ignoring

increased workload due to increased admissions; and (2) it is likely to be biased on the high side under conditions of declining patient days (true for 1973 and 1974), since declines in nursing hours usually will not keep pace with the drop in patient days. Thus, the actual change in nursing labor productivity lies somewhere between the values measured by the two criteria, probably towards the nursing hours per admission end of the range.

However, the situation with respect to the measurement of productivity changes in ancillary labor is quite different. From research on the distribution of ancillary services across patient stay conducted by the Battelle-KMB team in 1971 and 1972,[1] it is known that roughly 75 percent of all ancillary services at El Camino Hospital are delivered before the fifth day of stay. More specifically, it was determined that approximately 35 percent of all ancillary services are delivered to the average patient on the first day of stay, while only 5 percent are delivered on Day 5. Thus, the intensity of the ancillary workload is seven times greater for a Day 1 patient than for a Day 5 patient. Hence, a reduction in length-of-stay will effectively replace patient days corresponding to Days 5 or 6 with new admissions who require seven times more ancillary services on this first day. Using the distribution of ancillary service by day of stay as developed by the Battelle-KMB team, it was estimated that the 5 to 6 percent increase in admissions experienced in the 1972-1974 period would produce an increase in the overall ancillary workload which exceeded the proportionate increase in admissions. That is, it was estimated that the ancillary workload increased more than the corresponding 5 to 6 percent increase in admissions. Because of this, it may be concluded that the ratio of ancillary hours per admission validly represents changes in ancillary productivity. Clearly, the measure ancillary hours per patient day would be inappropriate.

Lastly, it should also be pointed out that the *cost benefit* of a particular total hospital information system *cannot be indicated by a single discrete value, but rather is represented by a cost-benefits range.* Relative position within that range is a function of a number of variables including the service characteristics of the institution, the nurse staffing policy, top administration management style, the length of time the system has been operational, the attitudes of department heads and staff, system acceptance by physicians, the level of effort devoted to realizing benefits, and the methods used to measure benefits.

Before proceeding to a discussion of the models and accompanying results, it is important that the reader understand the nature of the labor savings and particularly the process whereby these labor savings are realized. It may be helpful in understanding the derivation and measurement of system labor savings to look at these potential benefits from another point of view. Labor benefits can be categorized into three classes: (1) those which "fall out" automatically; (2) those which require explicit effort (the "benefits realization process") on the part of management to convert potential benefits inherent in the system to actual realized savings; and (3) "spin-off" benefits which are made possible as a result of implementing the system, but which are not integral to the system.

Classification of benefits in this way provides a convenient mechanism for placing end points on the range of system cost benefits. The lower bound is represented by measurement of the set of "fall-out" cost benefits which are available with little or no management effort beyond completion of the implementation process. It should be noted parenthetically that the installation (excluding development) cost of a sophisticated total hospital information system likely will range from $100,000 to $300,000. These costs do not represent out-of-pocket expenditures but rather "opportunity costs" associated with time spent by employees to implement the system, evaluated at the cost of labor expended. An upper bound on cost benefits is provided by the sum of (1) "fall-out" benefits, (2) benefits which arise out of an explicit benefits realization process, and (3) implementation of "spin-off" cost-saving potential. This sum perhaps is better described as a goal rather than an upper bound.

Certain cost benefits fall out automatically with the physical implementation of the system and require little or no effort or involvement on the part of management to effect their realization. An obvious example is the elimination of keypunchers who formerly translated charge slip information into machine-readable format. Also included in this category are other labor savings which, while not involving the elimination of a full staff position, nevertheless constitute easily discernible and well-defined work reductions which can be converted to savings. Obvious examples are the work reduction associated with the admitting process and automatic production of a medications supply list for a pharmacy unit-dose system. On the nursing floors, if the implementation has been carried out capably and if the system has sufficient labor savings potential, a certain amount of savings should accrue in an implicit manner, even without an explicit benefits realization endeavor. This savings will show up more readily in a situation where close correspondence between workload demand and nursing staffing levels has already been achieved. Nursing labor savings which accrue naturally without the aid of an explicit realization effort will enable nursing more effectively to meet peak workload demands.

In the nonlabor area, cash flow improvement, late charge elimination, and lost charge reduction (for those who consider these results to be cost benefits attributable to the system) all arise with little realization effort. Material savings in terms of forms cost also fall out automatically.

The second class of potential benefits can be described as *those which entail explicit efforts* on the part of management *to convert the potential benefit to realized savings*. These potential time savings constitute the large reduction or bulk of labor savings on the nursing units. After implementation and stabilization of the system, work content reduction or displacement benefits are available to users as they become adequately familiar with the new operational procedures. However, these labor savings consist of bits and pieces spread among different skill levels (RN, Ward Clerk, and Aide) and across three shifts. In order to realize these savings in terms of reduced staffing requirements, they must be aggregated and released. The process whereby this is accomplished has been termed the "labor benefits realization process."

The labor benefits realization process is a unique endeavor, quite separate and distinct from the implementation process, but equal or greater in importance. It is this task which undertakes to translate potential labor savings spread piecemeal through several hundred employees across three shifts on the nursing stations into aggregate amounts amenable to release as partial or whole full-time equivalents (FTE's) for cost reduction or to release to other nursing unit uses for improved service. Thus, the actual realized savings which result from the benefits realization endeavor are a function of both the work content reduction potential inherent in the system itself and the success of the realization endeavor. The latter depends on the degree of imagination, effort, and sensitivity with which the program is conducted as well as on the attitude of department heads and administration toward change.

Another source of benefits which may be labeled "coincidental methods improvement" can be distinguished as also being associated with the benefits realization process. During the reorganization of the work content on the nursing units, there exists the opportunity to achieve work methods improvements in areas related in a peripheral way to the information system. These benefits are associated in the sense that the work content reorganization on the unit affords an opportunity for the recognition and introduction of work methods improvements which might otherwise have been difficult or impossible to detect and carry out, without the existence of either (1) the system or (2) the benefits realization process.

Because the results of the benefits realization process are so heavily dependent upon nonsystem parameters, attribution of cost benefits to the proper source represents a considerable challenge. The "coincidental methods improvements" mentioned above represent only part of the industrial engineering activity which may be involved in realizing the cost benefits inherent in the system. Other work method improvement efforts (1) may be *necessary* to realize certain benefits, or (2) may *facilitate* overall benefits realization. Thus, it becomes very difficult, when attempting to evaluate cost benefits arising out of the benefits realization program, to distinguish whether resulting savings are ascribable to the system or whether a good deal of them reflect industrial engineering methods improvements which could have been accomplished without the system. For example, in order to realize substantial nursing savings, it probably will be necessary to implement a dependency (acuity) staffing system to better mesh workload demands and nursing staffing. Such industrial engineering improvements tend to reduce inefficiencies inherent in the manual system.

The third category of cost benefits represents *spin-off labor savings developments which are enabled by, but not integral to, the system.* A prime example of this sort of cost reduction, which has been carried out at El Camino Hospital, is illustrated by the closing of the Admitting Department during the evening and night shifts. This achievement was made possible because the patient admission process can be accomplished at any one of the 50 some system access terminals scattered throughout the hospital. Another example is furnished by cost-avoidance savings associated with the implementation of a unit-dose system at the hospital. Implementation of a unit-dose system concurrent with MIS implementation can be accomplished without substantially increasing pharmacy staff. Under a manual unit-dose system, this

additional staffing requirement for a hospital such as ECH is estimated to be five FTE's. A third important example relates to potential savings from reorganizational changes which may be possible with such a system. As a substantial reduction in required clerical activities is realized for the head nurse, the possibility of enlarging the responsibilities of this position to cover perhaps more than one unit or shift can be considered.

The importance of the benefits realization phase cannot be overemphasized for this kind of system. Experience at El Camino Hospital demonstrated that after implementation, but *previous to inauguration of the benefits realization phase, the extent of clerical work actually increased* from its pre-implementation level. Nursing personnel had learned to use the system (i.e., to operate the system), but nursing work patterns and roles had not yet been reorganized so that the potential labor savings could be realized.

Potential Labor Savings: Theoretical MTM Model of Clerical Work Before and After Implementation

The potential labor savings model served to build up an estimate of savings using detailed data based primarily on Methods Time Measurements. The methodology separately estimated a number of elements of the total potential savings:

1. Potential nursing labor savings resulting from
   a. direct work content reduction, and
   b. associated work methods improvement;
2. Ancillary and support areas direct work content reduction; and
3. Other incidental labor savings in
   a. work content reduction in ICU/2 North, and
   b. additional unit-dose spin-off savings.

The development of potential cost savings estimates for each of these elements is detailed below.

Nursing - Predicted Potential Labor Savings. Development of the theoretical labor savings potential of the MIS system due to work displacement was based on Methods Time Measurement standards particularized for medical clerical activities. Master Clerical Data (MCD) aggregate time standards as published by Birn, Crossan, and Eastwood[2] and based on Methods Time Measurement (MTM) data were used as standard time building blocks. This work was carried out in 1971-1972, and developed potential labor savings projected over a 5-year period corresponding to the 5-year contract for the system.

The procedures followed in estimating the labor savings potential consisted of the following eight steps:

1. First, each information processing activity affected by MIS was described in detail as it was performed manually before implementation of the MIS system, and then as accomplished using the system. This step was executed by interview and observation and was subject to changes as the system was modified over the implementation period. Examples of the summary descriptions are presented in Table 3.

2. Then, for each affected activity identified, detailed descriptions were developed of the precise work motions involved under the manual method in the activity for each skill category (RN, LVN, Ward Clerk, and Aide). Discussion with nursing unit personnel provided a "model" or average description of the motions involved in each specific activity. These model descriptions then were modified accordingly for specific personnel (e.g., a clerk and a staff nurse might on occasion perform the same task but generally their "home work station" or starting location would be different). Such descriptions also were altered for variation in the physical configuration of nursing stations. The work motions were summarized on Standard Time Work Sheets such as the one shown in Figure 3.

3. Master Clerical Data time standards were applied to the detailed work motions listed on the Standard Time Work Sheets. The clerical time standards were applied to the descriptions by a qualified standard time analyst. These then were reviewed by persons familiar with the nursing procedure and frequently revised to assure that the standard time and motion data applied were appropriate to the movements. Time values were expressed in terms of Time Measurement Units (TMU's), where one TMU equals 0.006 minutes.

4. The data from the Standard Time Work Sheets were summarized for each function on Function Analysis Sheets as illustrated in Figure 4.

5. An occurrence factor was determined for each subactivity, which specifies the frequency with which the subactivity occurs within the work unit. Because a particular activity might be done by any of several capable personnel, occurrence factors by skill were developed based on sampling or aggregation of individual estimates where necessary. Data from which the required occurrence factors were developed came from the following general categories or a combination thereof: hospital statistics, department reports, counts of forms used, patient chart analysis, tallies, statistical samples, estimates, and surveys of stated practice. Patient chart analysis involved review of randomly drawn patient charts (cluster sampling) to

enumerate frequency of occurrence of information processing items such as, "the number of laboratory orders per order set" or "the number of medical orders per order set," and so forth. Estimates were used as little as possible and were based on numerous opinions. Surveys of stated practice were used primarily to develop an "average" method of a procedure where variation in information processing activity was prevalent. The product of the standard time and occurrence factor for each subactivity yielded the required time per unit of work for the subactivity. These figures were summed by skill classification to yield standard time per work unit for each job title. A 20 percent time allowance was built into each information processing function standard to cover personal time, rest periods, and minor unavoidable delays. In addition, a nursing labor productivity factor peculiar to that nursing unit was included in the development of the required standard times. For example, if the measured productivity factor for a given unit was 70 percent, a task requiring 1.0 standard minutes would normally require 1.43 minutes of labor on that unit. The measured labor productivity factors used were those calculated by the Commission for Administrative Services in Hospitals (C.A.S.H.) hospital labor productivity measurement system.

6. In addition to the actual time requirements per work unit, the calculation of total labor savings requires a measure of the number of times per year each affected function is performed. These estimates, denoted as "traffic," were developed separately for each nursing station and by shift for each affected function. Figure 5 is an example of one such Traffic Sheet. Determination of traffic data was accomplished by utilizing techniques similar to those used to develop occurrence factors.

7. All of the steps to this point were repeated for each affected function, with estimates under both the manual system and under MIS. The information was summarized at the bottom of the Function Analysis Sheet shown earlier in Figure 4.

8. To summarize data across functions and to translate the estimates into full-time equivalents by nursing station, by shift, and by skill, a work sheet such as that shown in Table 4 was prepared. In this work sheet, each affected function was listed, and estimates of time requirements and traffic were entered by nursing station, by shift, and by skill. Time savings were determined as the difference between the manual and MIS times, multiplied by the traffic and totaled over functions. These estimates then were converted to full-time equivalents as shown at the bottom of Table 4.

TABLE 3

ABBREVIATED DESCRIPTION OF COMPARABLE NURSING INFORMATION PROCESSING FUNCTIONS BEFORE AND AFTER MIS IMPLEMENTATION

FUNCTION NUMBER AND TITLE (NURSING)	
1.1 Initiate Chart and Rand File	
Manual Method	Get Addressograph plate and stamp eight forms; date nurse's notes, medication sheets, and graphic sheet, write name and room number on nursing history sheet; prepare chart and bed identification tabs; write headings and allergy data on Rand card.
1.1 Initiate Chart	
MIS Method	Receive typed list of patients to be admitted. Assemble four forms: graphic sheet, MD progress notes, nursing history sheet, valuables sheet. Remove admission notice from printer, print chart identification tabs. Label each form with preprinted gummed patient ID label. Enter nursing history data via VMT.
• • •	
3.2 Discontinue Medication Orders	
Manual Method	Write discontinued on medication sheet, cross through medication on Rand file, tear up card and discard.
3.2 Discontinue Medication Orders	
MIS Method	MIS system deletes order from Medications Due List. Pharmacy Department receives discontinuance order.
• • •	
11.0 Set Up, Give, and Chart Unscheduled Medications	
Manual Method	Check medication card against Rand file, check medication sheet in chart for last time given, prepare medication, administer medication, annotate medication sheet in chart, document nurse's notes.
11.0 Set Up, Give, and Chart Unscheduled Medications	
MIS Method	Check Patient Care Plan or check video retrieval for last dose and time given. Prepare medication at unit-dose cart. Administer medication, annotate Patient Care Plan. Chart given and observations at VMT.
• • •	
15.1 Process Discharges	
Manual Method	Stamp discharge form with patient's Addressograph plate, check discharge box, cross off name in Diet List and write "home"; record time when patient leaves and sign discharge form, call Admitting to advise them of discharges, write credit slip for unused supplies.
15.1 Process Discharges	
MIS Method	Admitting Department notified by discharge notice upon entry of discharge order. Ancillary departments receive discharge notice. Enter discharge nursing data into MIS.
• • •	
21.0 Handle Interim and Patient Data Summaries	
Manual Method	No comparable information processing function existed under the manual system.
21.0 Handle Interim and Patient Data Summaries	
MIS Method	Remove daily summary nursing records and nursing notes from printer; separate. Insert in chart under proper section. Remove interim summary from front of chart; discard.

STANDARD TIME WORK SHEET ☐ MIS-I

FUNCTION TITLE INITIATE CHART AND RAND FILE SHEET 1 OF 2

FUNCTION NO. 1.1 DATE 2/28/72 ISSUE PREPARED BY E. W. Bush

CONDITIONS:

STEP	ELEMENT CODE	DESCRIPTION	TMU		STD. MIN.
			ELEM.	STEP	
5		HAND WRITE HEADINGS ON RAND CARDS			
		(DOUBLE AND SINGLE)			
		RAND CARDS WITH FORMSET PRE MADE UP			
		AND ON DESK IN FRONT OF CLERK			
HGP	PA01	GET AND SET ASIDE PENCIL	46		
HGP	SS01	GET RAND CARDS INTO POSITION ON TABLE	19		
HGP	AS01	ADDITIONAL CARD	15		
		ON DOUBLE CARD			
		WRITE OCCUPATION			
		EXAMPLE: "ENGINEER, MECHANICAL"			
HWR	RLP02	2 CHARS. × 23	46		
HWR	LP01	16 CHARS. × 18	288		
		WRITE AGE			
HWR	WD01	2 CHARS. × 18	36		
		WRITE NAME			
		EXAMPLE: "PATIENT, MR. LARRY"			
HWR	LP02	3 CHARS. × 23	69		
HWR	LP01	11 CHARS. × 18	198		
HWR	WP01	3 CHARS. × 15	45		
		WRITE ROOM NUMBER			
		EXAMPLE: "203B"			
HWR	LP01	1 CHAR. × 23	23		
HWR	WD01	3 CHARS. × 18	54		

Figure 3. Standard Time Work Sheet.

INFORMATION PROCESSING FUNCTION: Process Discontinued Medication Orders

WORK UNIT DEFINITION: Single Discontinued Medication Order

DEPARTMENT: Nursing

FUNCTION NUMBER: N3.2

EXPECTED GROWTH RATE PER YEAR: 2.2 Percent

WORK STATION: All Nursing Stations

MANUAL METHOD

STEP	JOB TITLE	DESCRIPTION	TIME (MIN)	OCC. FACT	MIN/ UNIT
1	Ward Clerk	Get patient's chart, remove green flag and read order. Time included in N2.0. (Process Medical Orders)			
2	RN	Get patient's chart, remove green flag and read order. Time included in N2.0. (Process Medical Orders)			
3	Ward Clerk	Give chart to RN to write "discontinued" on medication sheet. Occ. Fact: (S.S.P.)	.25	.66	.17
4	RN	Open chart to medication sheet and write "discontinued."	.35	1.00	.35
5	Ward Clerk	Cross through discontinued drug on Rand. Occ. Fact: % of time done by WC (S.S.P.)	.96	.66	.63
6	RN	Cross through discontinued drug on Rand. Occ. Fact: % of time done by RN (S.S.P.)	.96	.34	.33
7	Ward Clerk	Tear up medication card. Occ. Fact: % of time done by WC (S.S.P.)	.74	.66	.49
8	RN	Tear up medication card. Occ. Fact: % of time done by RN (S.S.P.)	.74	.34	.25

SUMMARY - MANUAL METHOD

Standard Min./Work Unit Summary by Job Title		Nursing Unit Productivity Factor	Standard Min. Actually Required/Work Unit
Clerk	1.29	.73	1.77
RN	.93	.73	1.27

MIS METHOD

STEP	JOB TITLE	DESCRIPTION	TIME (MIN)	OCC. FACT	MIN/ UNIT
		DC of medications is handled through physicians ordering as in Function 2.0. No longer done by nursing unless entering orders for MD's. Delimiters on orders and finite schedules cause automatic DC of orders.			

SUMMARY - MIS METHOD

Standard Min./Work Unit Summary by Job Title		Nursing Unit Productivity Factor	Standard Min. Actually Required/Work Unit
Clerk	0	.73	0
RN	0	.73	0

Time Savings Std. Work	Time Savings Min/ Unit	Traffic = No. of Work Units/Shift 1st	2nd	3rd	1st Shift Time Savings Minutes/Shift (staff positions per shift) WC	RN/NA	Rel. Rank All Shfts	% of All Shft Savings	2nd Shift Time Savings Minutes/Shift (staff positions per shift) WC	RN/NA	Rel. Rank All Shfts	% of All Shft Savings	3rd Shift Time Savings Minutes/Shift (staff positions per shift) WC	RN/NA	Rel. Rank All Shfts	% of All Shft Savings	Total Time Savings Minutes/Shift (staff positions per shift) WC	RN/NA	Rel. Rank All Shfts	% of All Shft Savings
1.8	1.3	427	253	17	769 (.0068)	551 (.0049)			455 (.0040)	329 (.0029)			31 (.0003)	22 (.0002)			1,255 (.0111)	902 (.0080)		

NOTE: The net time savings in this example include a productivity factor applied to the individual function whereas Table 4 has the productivity factor applied to the sum of all functions.

Figure 4. An Example of Analysis of Work Content Reduction.

TRAFFIC N 11.0

Number of Administrations of Unscheduled Medications
by Nursing Station for the Base Year (Fiscal Year 1972)

Nursing Station	Shift 1	Shift 2	Shift 3
1 South	1,691	1,691	0
2 North	3,907	3,004	300
Maternity	25,076	19,282	1,928
Nursery	3,535	964	0
2 East	14,919	8,849	585
2 West	14,986	8,888	587
Pediatrics	4,999	3,326	1,105
3 West	16,694	9,902	655
4 West	16,739	9,929	2,340
ICU	3,390	3,048	677
CCU	2,988	2,687	596
TCU	4,559	4,099	910
5 East	20,555	12,192	806
5 West	14,631	8,678	574
6 East	14,381	8,530	564
6 West	12,270	7,278	481

Figure 5. Example of Traffic by Nursing Station and Shift.

TABLE 4

ANNUAL TIME SAVINGS (MANUAL VS. MIS METHOD) BY INFORMATION PROCESSING FUNCTION ON A TYPICAL "MSO" NURSING STATION (6 WEST)

	Manual Method Std. Min/ Work Unit		MIS Method Std. Min/ Work Unit		Time Savings Std. Min/ Work Unit		Traffic = No. of Work Units/Shift			1st Shift Time Savings Minutes/Shift (staff positions per shift)		Rel. Rank 1st Shift	% of 1st Shft Sav-ings	2nd Shift Time Savings Minutes/Shift (staff positions per shift)		Rel. Rank 2nd Shift	% of 2nd Shft Sav-ings	3rd Shift Time Savings Minutes/Shift (staff positions per shift)		Rel. Rank 3rd Shift	% of 3rd Shft Sav-ings	Total Time Savings Minutes/Shift (staff positions per shift)		Rel. Rank All Shfts	% of All Shft Sav-ings
	WC	RN/NA	WC	RN/NA	WC	RN/NA	1st Shift	2nd Shift	3rd Shift	WC	RN/NA			WC	RN/NA			WC	RN/NA			WC	RN/NA		
1.1 Init. Chart and Rand	10.5	0.00	4.9	2.19	5.6	(2.19)	736	328	238	4144 .04	(1612) (.01)	16	1.55	1847 .02	(718) (.01)		1.20		819 .01	16	1.12	5991 .05	(1511) (.01)	20	1.03
1.2 Add Blank Forms to Chart	0.0	1.87	0.0	1.34	0.0	.53	0	0	7744	0	0			0	0				4104 .04	5	8.84		4104 .04	17	1.35
1.3 Make Up New Patient Formset	0.0	1.95	0.0	0.00	0.0	1.95	0	0	1302	0	0			0	0				2539 .02	7	5.47		2539 .02	25	0.84
•																									
•																									
•																									
20.0 Process Incident Rpts.	0.0	8.25	0.0	7.56	0.0	0.00	19 13		19 13	0	59 0	26	0.04	0	59 0	26	0.06						176 0	32	0.06
20.0(c) Process Incident Rpts. (night)	0.0	8.28	0.0	7.59	0.0	0.00			19 13										58 0	23	0.13				
21.0 Handle Interim & Patient Data Summaries	0.0	0.00	0.6	0.00	(0.6)	0.00	7744			(4879) (.04)												(8674) (.08)	(4492) (.04)		
21.0(b) Handle Interim & Pt. Data Sum.(eve.)	0.0	0.00	0.5	0.00	(0.5)	0.00		7744						(3795) (.03)											
21.0(c) Handle Interim & Pt. Data Sum.(ngt.)	0.0	0.00	0.0	0.58	0.0	(0.58)			7744										(4492) (.04)						
TOTALS										66,964	96,466			28,312	65,683				57,332			95,276	219,481		
										163,430				93,995								314,757			

Footnotes: LVN's are included in RN/NA.

The upper figure in Traffic refers to pre-MIS, while the lower figure documents MIS traffic.

Parentheses indicate a negative time savings.

Net Minutes	314,757
Productive Minutes (Net Min. : .73)	431,173.97
Productive FTE (Prod. Min. : 60 Min./Hr.) ÷ (Hrs./Yr. - vacation, sick, holiday = 1872) =	3.84

The standard time descriptions of each information processing function represent an "average" of the variations in physical configuration and staffing patterns found across nursing stations. Thus, with the exception of the scheduled medication functions (10.1, 10.2, 10.3) and Initiation of Chart (and Rand file) function (1.1) in Maternity, standard time *per work unit* for a given function did not vary from unit to unit. Differences in the amount of time saved per function do vary, however, from one unit to another on the basis of different traffic counts. For instance, the 5 East day shift processes 13,100 new medical order sets per year while the 2 East day shift processes 9,508 in the same period of time. This difference accounts for approximately 14,000 more minutes saved per year on 5 East than on 2 East. Such differences in traffic count are greatest between unlike units and vary much less between units handling similar types of patients. Both 3 West and 4 West, for example, are medical nursing units. In one year, the 4 West day shift processes 10,669 new medical order sets whereas 3 West processes 10,639. Other differences in traffic count may exist because a function is not performed on a unit. Maternity, for instance, seldom prepares radiology requisitions.

For the scheduled medication functions, both the magnitude of their savings contribution and the degree of method variability between nursing stations (i.e., the number of nurses who administer medications on a particular unit) necessitated documentation by individual nursing station.

Total time savings for fiscal year 1972 of 47.4 full-time equivalents (FTE's) were estimated for all three shifts across all nursing stations as further described by Table 5. In terms of FTE's, 51 percent of this savings appeared in day shift activities, 29 percent on the evening shift, and 20 percent on the night shift. Ward Clerk savings constituted 31 percent while RN/LVN and Aide savings made up the remaining 69 percent. The full-time equivalent savings translate to FY72 dollar savings totaling $466,296, amounting to monthly savings of $38,858. In terms of dollars, the savings distribution changes only slightly to the following: Day - 48 percent, Evening - 30 percent, and Night - 22 percent; Ward Clerk - 24 percent, and RN/LVN and Aide - 76 percent.

Potential labor savings are the highest on the maternity unit because of several factors including a higher number of admissions, shorter patient stay, a higher number of new medication orders, and more frequent administration of unscheduled medications. Savings potential is also high on 5 East, a purely orthopedic unit, because the unit is approximately 25 percent larger than the average medical-surgical-orthopedic (MSO) unit. Savings potential would have been even higher on this unit if the efficient MIS method of team dispensing of scheduled medications were to be adopted. One South, a psychiatric unit, showed the lowest amount of labor savings potential attributable to a lower number of admissions, longer patient stay, and an overall lower level of new medication orders, medication administrations, and diagnostic procedures. Pediatrics also showed a relatively low level of savings potential ascribable to a low number of new medication orders and unscheduled medication administrations. Variations in the number of patient days on a unit accounted for the difference in labor savings potential between like units.

TABLE 5

PREDICTED POTENTIAL LABOR SAVINGS
DUE TO WORK CONTENT CHANGES
BY NURSING STATION, SHIFT, AND SKILL
(Full-Time Equivalents)

SHIFT / SKILL / STATION	Day Shift		Evening Shift		Night Shift	TOTAL
	Ward Clerk	RN/LVN/ Aide	Ward Clerk	RN/LVN/ Aide	RN/LVN/ Aide	
1 South	.46	.78	.23	.66	.51	2.64
Maternity	1.23	1.67	.40	1.00	1.66	5.96
2 East	1.04	1.37	.42	.93	.82	4.58
2 West	1.00	1.32	.44	.85	.81	4.42
Pediatrics	.80	.88	.33	.60	.76	3.37
3 West	.95	1.47	.40	1.00	.84	4.66
4 West	1.01	1.31	.44	.91	.88	4.55
5 East	1.20	1.66	.53	1.05	.94	5.38
5 West	.92	1.20	.43	.77	.76	4.08
6 East	.90	1.23	.38	.81	.73	4.05
6 West	.81	1.11	.34	.76	.69	3.71
*2 North, ICU, CCU, TCU, Labor and Delivery, Nursery, ER, and AKU	----	----	----	----	----	----
Total FTE	10.32	14.00	4.34	9.34	9.40	47.40
FTE Percentages	21.8%	29.5%	9.2%	19.7%	19.8%	100.0%
Total Dollar Savings	$78,490	$146,368	$33,747	$103,749	$103,942	$466,296
Dollar Saving Percentages	16.8%	31.4%	7.2%	22.2%	22.3%	100.0%

* Because savings in these areas were expected to be comparatively small on an individual basis, a less rigorous analysis of work content reduction was conducted. An aggregate estimate of savings potential is presented in this section under the heading Other Incidental Labor Savings.

The wage rates applied to the estimated work content reduction include fringe benefits at 22 percent allocated as follows:

Employer social security contribution, compensation insurance, health insurance, and pension plan	12%
Vacation, holiday, and sick time	10%

Associated Work Methods Improvements. The benefits realization process provides an opportunity to achieve work methods improvements in areas indirectly related to the information system. Because of the pervasiveness of the impact of the MIS system on nursing information processing, a large number of procedures and activities are affected by the reorganization of work content (the realization process necessary to aggregate MIS labor savings to achieve their release as partial or whole full-time equivalents). While restructuring and reorganizing these tasks, it usually is possible to introduce work methods improvements. It should be noted that a portion of such improvements *could* in theory be implemented independently of any automated information system development; however, the benefits realization process (1) prompts the identification of many such potential improvements which might otherwise remain hidden, and (2) the thorough reorganization of work which is being carried out presents a convenient opportunity to introduce these improvements. In fact, it is very likely that a substantial number of these work methods improvements would never be implemented on a piecemeal basis.

For example, the following potential methods improvement areas have been identified by the nursing team carrying out the benefits realization process:

1. Batching of certain work;
2. Better distribution of the workload across the shift;
3. Improved coordination between MIS and the unit-dose system to result in better use of the unit-dose system;
4. Standardization of procedural methods for supplies and their location on the floor;
5. Better utilization of personnel through the use of half shifts, staggered schedules, and so on;
6. Improvement in matching job requirements to personnel capabilities;
7. Charting by exception;
8. Optimization of MIS operational procedures;
9. Better definition of responsibility between nursing and other interacting departments such as housekeeping; and
10. Variable staff planning.

The magnitude of savings associated with such methods improvements, of course, can only be estimated. Industrial engineering experience indicates that when extensive work reorganization occurs, additional secondary cost reductions on the order of 10 to 20 percent of the primary savings can be accomplished. For the purpose of predicting total labor savings, it was estimated that the potential work content savings could be increased by 15 percent through appropriate work methods improvements, amounting to $69,944 for FY72 or monthly savings of $5,829.

Management Structure Reorganization. There appear to be certain labor benefits of an organizational nature attending the implementation of a MIS system. The impetus to examine existing nursing management structure in the context of the overall reorganization being carried out to realize MIS benefits probably was initiated by the observation that the impact of the predicted clerical work reduction was especially apparent upon head nurses. As a good deal of the "desk work" that frequently was borne by head nurses was expected to be assumed by the system, the suggestion was made to expand head nurse responsibility. Specifically, it was suggested that the resultant free time could allow the head nurse to manage her unit on a 24-hour-a-day, 7-day-a-week basis. This suggestion has been implemented by ECH nursing administration and a thorough review of the nursing organizational structure has been undertaken. As a result, a revised organizational structure has been adopted. Further details of these activities are described in Section 6 of this report. No estimate of the cost impact of management structure reorganization was made for this analysis.

Ancillary and Support Areas - Predicted Potential Labor Savings. Predictions of potential labor savings in ancillary and support areas other than the Pharmacy were based on preliminary studies undertaken previous to implementation and modified by additional studies made by the ECH management engineering staff. The preliminary estimates were developed by applying appropriate industrial engineering measurement techniques to the impacted elements of the manual system and comparing the results with corresponding measurements for the MIS system obtained by extrapolating data provided by test systems and by the "demonstration hospital system." The latter is a small-scale mock system which emulates the behavior of a full hospital system for demonstration purposes. The estimated savings in ancillary and support areas, summarized in Table 6, total $116,013 for FY72, amounting to potential monthly savings of $9,668. The fact that a substantial portion of these predicted labor savings has been realized is indicative of the relative accuracy of the estimates.

Admitting Department. Labor savings amounting to five FTE's were predicted for the Admitting Department. Proposed savings were based on the assumption of clerical duties by the MIS system, transfer of the pre-admit function to the Business Office, and transfer of the admitting function to the Emergency Room between 7 P.M. and 5 A.M. on the weekdays and for longer periods over the weekend. It should be noted that the ability to transfer such functions is assignable to the MIS system. The 5-FTE figure represents net savings, i.e., the result after subtracting the increase in the Business Office workload. To date, 3.1 FTE's have been realized in spite of increasing numbers of admissions.

TABLE 6

PREDICTED POTENTIAL LABOR SAVINGS:
ANCILLARY AND SUPPORT AREAS

Department	Predicted Net Reduction FTE's	Net Savings Fiscal 1972
Admitting	5.0 Clerks	$ 40,628
Business Office	1.0 Clerk	$ 7,822
	3.5 Keypunchers	$ 27,373
Central Service	1.0 Clerk	$ 7,146
Pharmacy	1.0 Pharmacist	$ 17,365
	1.0 Pharmacy Technician	$ 7,354
Radiology	1.0 Transcriptionist	$ 8,325
TOTAL	13.5 FTE's	$116,013

NOTE: Dollar values include fringe benefits of 22 percent broken down as follows: 12% - employer social security contribution, workmen's compensation insurance, health insurance, and pension plan; 10% - vacation, holiday, and sick time.

Business Office. Predicted savings in the Business Office constituted 4.5 full-time equivalents composed of 3.5 FTE's of keypunch labor and 1.0 FTE of cashier labor. Keypunch labor savings are a result of direct transfer of patient charges from the MIS system to the computerized Business Office System, obviating the need for keypunching charge slips. The cashier reduction represents labor savings due to automatic preparation of the check register. These savings have been realized.

Central Service. Labor savings of one clerk were predicted and have been realized for Central Service attributable mainly to automatic pricing of Central Service items.

Laboratory. No net savings occasioned by the MIS system were expected initially in the Laboratory and none have been realized yet; however, realization of existing potential labor savings has not been aggressively pursued to date.

Medical Records. No net savings ascribable to the MIS system were expected in Medical Records and none have been realized.

Pharmacy. A net savings of one pharmacist and one pharmacy technician were predicted for the Department of Pharmacy. These estimates were based on the results of a detailed MTM study combined with current operational experience.

Radiology. Predicted savings in Radiology are associated with reduction in transcriptionist labor and are partially dependent on radiologists' use of standard reporting statements. Savings of one FTE were predicted and have been realized.

Other Incidental Labor Savings. There were several other activities/functions on which MIS had an impact that were not studied in depth since highest priority was given to areas with the greatest expected savings. Two of these other areas are discussed below with corresponding estimated potential cost savings.

Less detailed analysis using the MTM standards developed for MSO units and for a smaller-sized unit were applied to the intensive care units and to 2 North (a short-term GYN unit) yielding the following savings (in FTE's) because of work content reduction: ICU - 1.78, CCU - 1.34, TCU - 2.37, and 2 North - 1.10. To correct for certain assumptions of the MSO functional analysis model, these figures were adjusted downward by a factor of 0.25. A conservative estimate of five FTE's resulting in average savings of $4,380 per month (over FY72 through FY76) in additional nursing work content reduction thus was predicted for these areas.

Although the hospital did not have a unit-dose system prior to implementing MIS, it should be noted that substantial cost avoidance can be achieved through the concurrent implementation of MIS and unit dose. The primary source of savings derives from the Medications Supply List produced by the MIS system for the Pharmacy which presents a real-time profile of all patients' current medications. Such a profile is required by the unit-dose system and demands substantial compilation labor. By comparison with a very similar manual unit-dose configuration in a nearby hospital having almost identical service characteristics and patient load, this clerical workload savings was estimated to be five FTE's of pharmacy technician time equaling $3,453 per month currently. Coupled with the estimated savings predicted for the Department of Pharmacy, the net effect of the concurrent implementation of MIS and unit dose should have been an increase of three FTE's. However, no additional pharmacy personnel were required to implement the unit-dose system in conjunction with the MIS system implementation; thus, a realized net cost benefit of three additional FTE's was achieved beyond the two FTE savings predicted for the Pharmacy and was added to the estimated savings. This additional spin-off benefit associated with unit-dose implementation provided an additional three FTE average savings of $2,184 per month (over FY72 through FY76).

Summary of Predicted Potential Labor Savings. The predicted potential labor savings detailed in the preceding subsections cumulate to a dollar total of $5,637,384 over the 5-year period from FY75 through FY79. This prediction results in an average potential savings of $93,955 per month. The distribution of these potential savings across fiscal years is shown in Table 7. The first three items in this table were estimated in FY72 dollars. The remaining items, estimated as average costs for FY72 through FY76, were assigned to FY74. These estimates were projected forward to obtain consistency with the subsequently developed models based on the actual established contract period FY75 through FY79. Years prior to FY74 were estimated to experience a growth rate of 7.5 percent in nursing and 5 percent in ancillary and support areas. A 15 percent adjustment was carried out in FY75 to reflect higher than anticipated wage increases, after which an 8.5 percent growth rate was used to extrapolate to FY79. This growth rate was compounded annually to reflect growth in wages as well as traffic growth and its resultant growth in information processing requirements.

Hospital Internal Labor Impact (Internal Labor Measurements Model)

Internal hospital labor changes were measured by determining the difference in *labor actually being expended* in nursing and ancillary areas after two years of operation under MIS with *the expected labor expenditure* for the same point in time had the hospital retained manual information processing. Because admissions data were not available by service for the full base-line period, the preferable measurement---hours per admission---could not be used. Thus, the model utilizes as its raw data productive labor hours and corresponding patient days computed biweekly for payroll accounting purposes over a period of six and one-half years (July 1968 through December 1974). The raw data were broken down by nursing service as follows: Medical-Surgical-Orthopedic (MSO), Maternity, Nursery, Labor and Delivery, Pediatrics, Psychiatry, and selected ancillary areas (Pharmacy, Laboratory [Inpatient], Radiology [Inpatient], Inhalation Therapy, and Central Service).

The model essentially has three components: (1) manual-system labor expenditures during the 4-year base-line period (July 1968 through June 1972*), (2) expected growth under the manual system, and (3) actual labor expenditures during the 2-year experimental period (January 1973 through December 1974). Actual labor expenditures at the end of the experimental period (December 1974) are compared with the expected labor expenditures for the manual system at the same time point and the difference calculated.

The first component involves establishment of a base-line model for hourly labor expenditures under the manual system. Using the *4-year period prior to system implementation*, the labor expenditures in terms of *paid hours* per patient day for a given service (e.g., MSO) were plotted for the 105 pay

* Although actual operation of the system was initiated in January of 1972 and by June of 1972 roughly half of the nursing units were using the system, no labor changes were made as a result of the system until the following December.

TABLE 7

PREDICTED POTENTIAL LABOR SAVINGS

	Estimated Monthly Savings								Last 5-Year Average
	FY72	FY73	FY74	FY75	FY76	FY77	FY78	FY79	
Nursing Department:									
Work Content Reduction	$38,858	$41,789	$44,966	$51,711	$56,106	$60,875	$66,050	$71,664	$61,281
ICU/2N Work Content Reduction	3,790	4,074	4,380	5,037	5,465	5,930	6,434	6,981	5,969
Associated Work Methods Improvement	5,829	6,268	6,745	7,757	8,416	9,131	9,908	10,750	9,192
Ancillary and Support Areas:									
Work Content Reduction	9,668	10,159	10,667	12,267	13,310	14,441	15,669	17,000	14,537
Total Predicted Potential Labor Savings	$58,145	$62,290	$66,758	$76,772	$83,297	$90,377	$98,061	$106,395	$90,979
Additional Unit-Dose Spin-Off (3 FTE's)	1,980	2,079	2,184	2,511	2,724	2,958	3,207	3,480	2,976
Total Predicted Labor Savings	$60,125	$64,369	$68,942	$79,283	$86,021	$93,335	$101,268	$109,875	$93,955

periods in the *base-line* period (see Figure 6). A best-fit straight line was determined using the least-squares regression technique. The resulting regression line represents the best estimate of the actual trend in MSO nursing unit labor expenditures under the pre-MIS manual system, without using any other predictor variables.

The second component of the model estimates the expected growth in labor expenditures during the post-MIS period, assuming that the hospital had continued to use a manual system. In Figure 6, this expected growth is depicted as the dotted line which represents the straight-line extrapolation of the pre-MIS regression line. The extrapolated value at the end of the post-MIS period is the expected labor expenditures at that point in time given the continued use of the manual system.

The third component of the model, actual labor expenditures during the 2-year experimental period, is determined from the regression line fitted to the data points in this period. This line is shown in Figure 6 as the solid line in the post-MIS period. At the end of the experimental period, the difference between the extrapolated regression line and the actual regression line estimates the labor savings under the MIS system.

Figures 7 through 10 present similar graphic summaries of the analysis for the other service areas where labor savings were estimated. In Figure 11, a similar approach was used for the selected ancillary services with the exception that labor hours per admission was the criterion variable used rather than labor hours per patient day. The rationale for using this measure was discussed earlier. For Labor and Delivery, the approach was slightly different. The criterion used was labor hours per delivery. Separate regressions were run on labor hours and on number of deliveries, after which trend lines of the rate were determined. Further details concerning all of the regression analyses are presented in Appendix B.

The regression results depicted in Figures 6 through 11 form the basis for the estimated savings summarized in Table 8. The regression model for the base-line period was extrapolated to the December 1974 time period to yield the estimates of *expected* nursing hours per patient day which would have been expended if the hospital had remained on the manual system. The regression line for the experimental period yielded the estimates of *actual* nursing hours per patient day under the MIS system. The difference between the *expected* labor expenditures and the *actual* labor expenditures provides an estimate of internal labor impact on the nursing units. In addition, separate regression lines were fitted to the data on patient days to yield an estimate of patient days per pay period by service area. The product of labor hour savings per patient day, number of patient days per pay period, number of pay periods per month, and hourly wage rates yields monthly cost savings.

The nursing wage rate used ($6.76 per hour) represents the average wage rate for all nursing unit personnel (Head Nurse, Assistant Head Nurse, Registered Nurses, LVN's, Aides, and Clerks) prevailing as of December 1974, and includes all fringe benefits, paid and unpaid, amounting to approximately 24 percent. An average wage rate of $6.80 per hour, including fringe benefits, for all ancillary personnel in the ancillary areas affected by MIS was used.

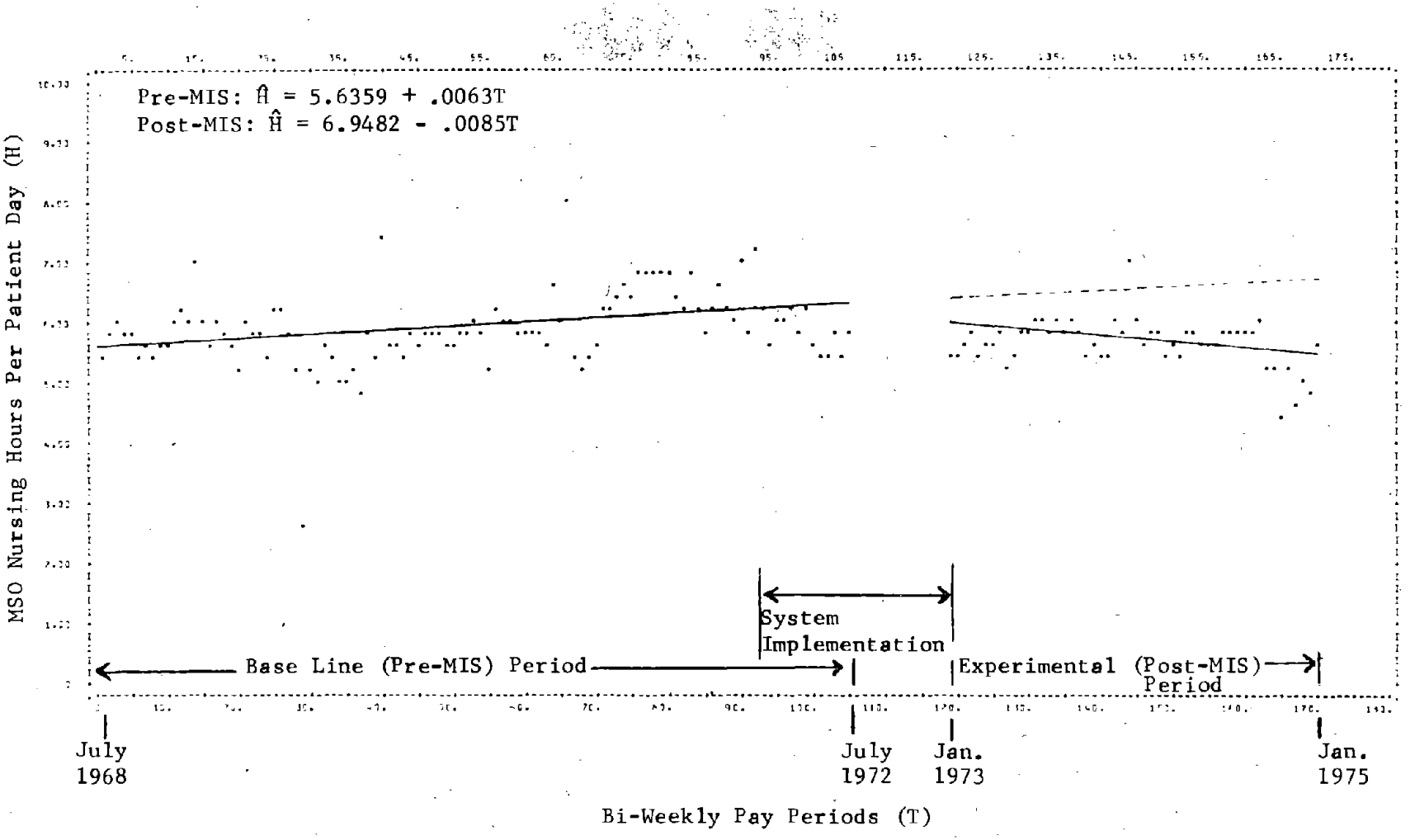

Figure 6. MSO Nursing Unit Labor Expenditures (Paid Hours per Patient Day) Scattergram and Regression Lines for Pre-MIS Manual System and for MIS.

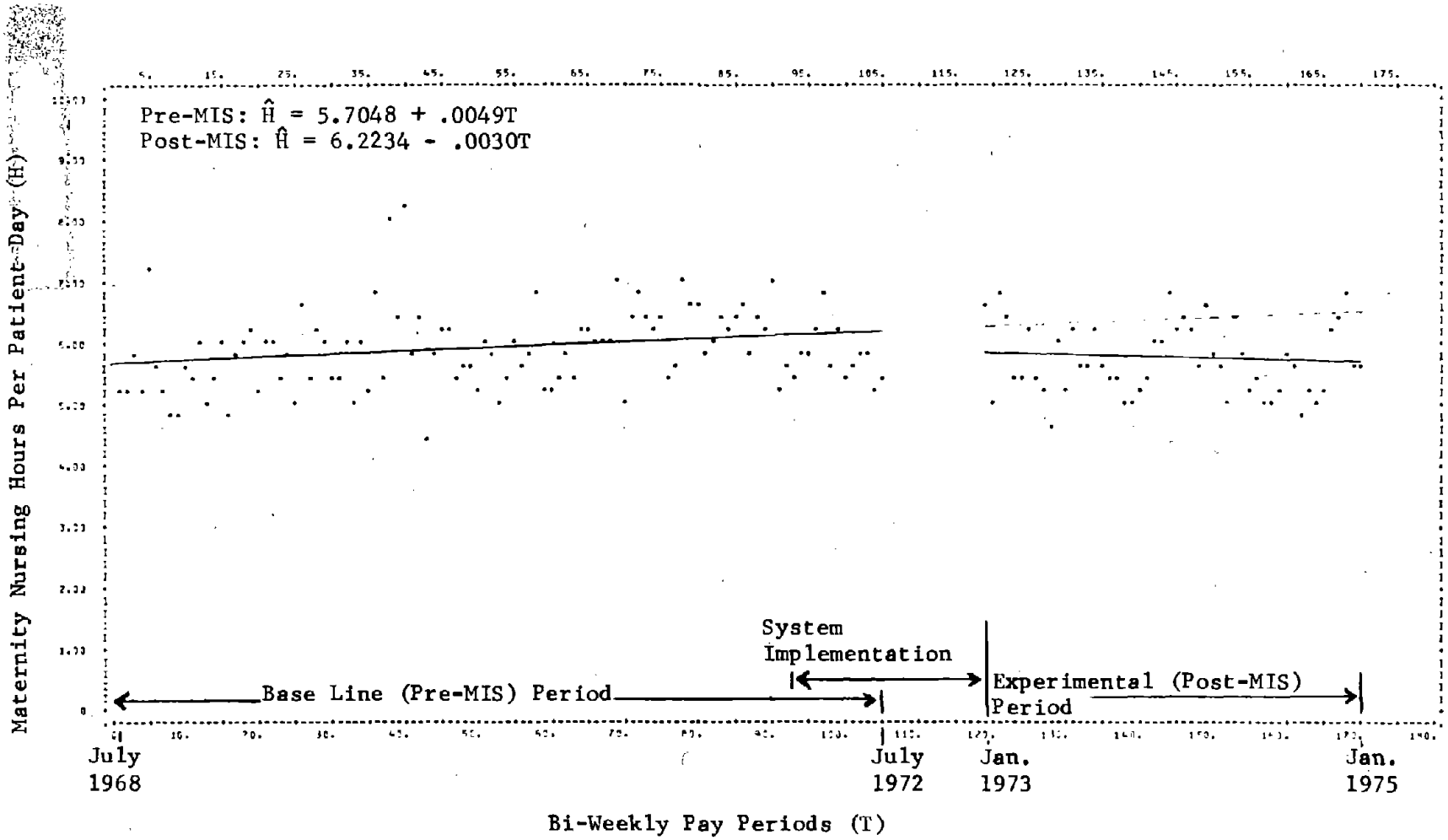

Figure 7. Maternity Nursing Unit Labor Expenditures (Paid Hours per Patient Day) Scattergram and Regression Lines for Pre-MIS Manual System and for MIS.

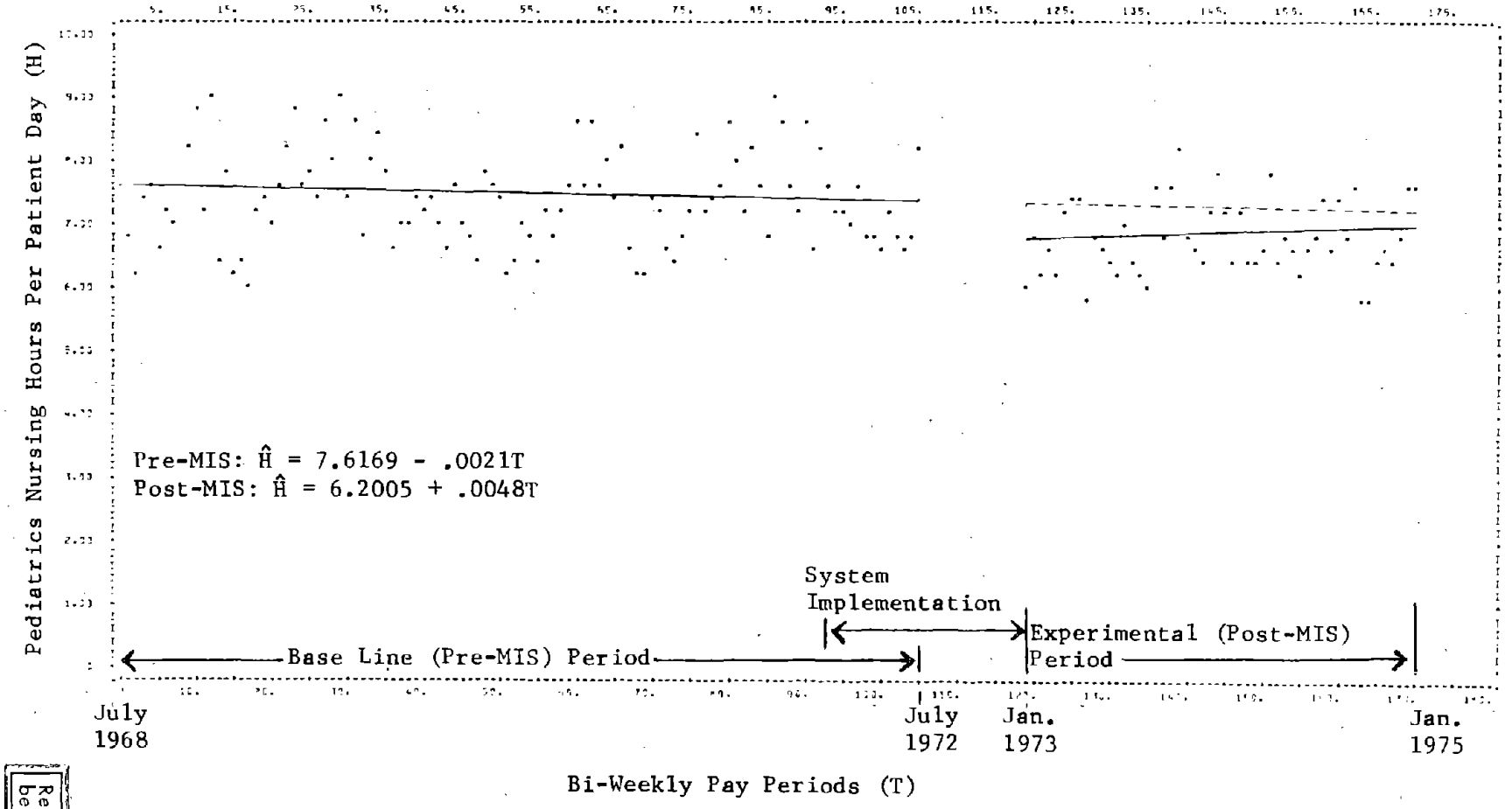

Figure 8. Pediatrics Nursing Unit Labor Expenditures (Paid Hours per Patient Day) Scattergram and Regression Lines for Pre-MIS Manual System and for MIS.

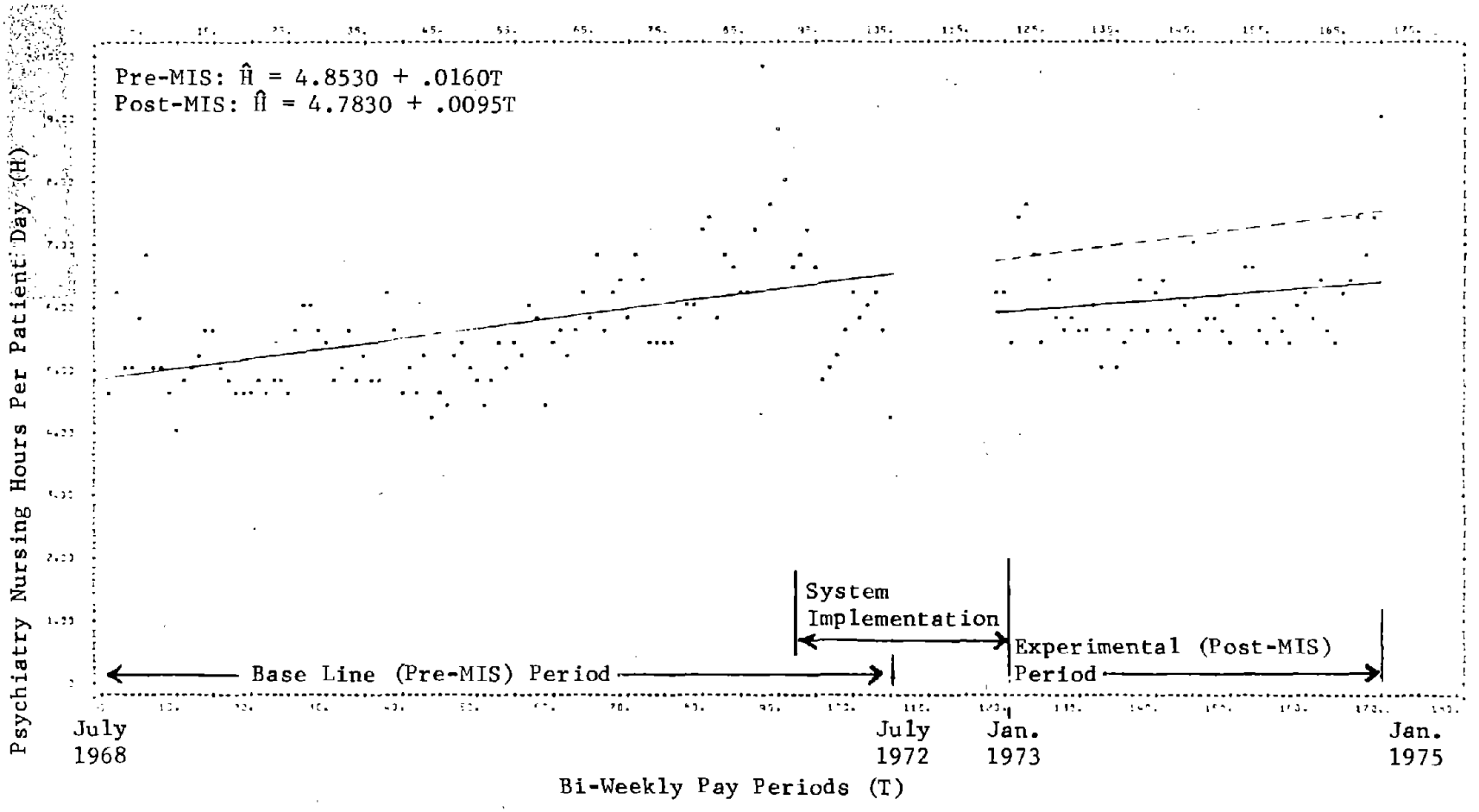

Figure 9. Psychiatry Nursing Unit Labor Expenditures (Paid Hours per Patient Day) Scattergram and Regression Lines for Pre-MIS Manual System and for MIS.

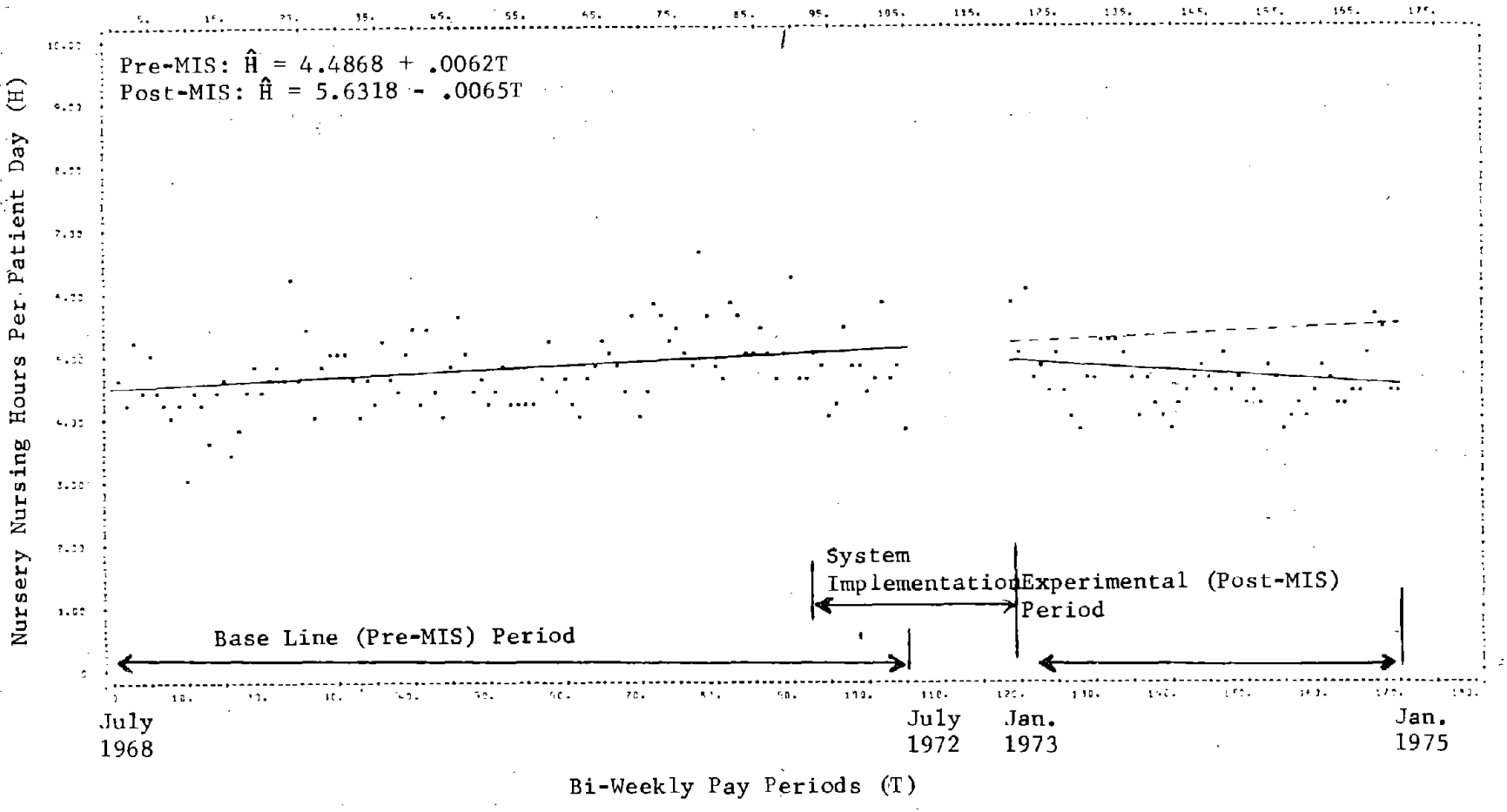

Figure 10. Nursery Nursing Unit Labor Expenditures (Paid Hours per Patient Day) Scattergram and Regression Lines for Pre-MIS Manual System and for MIS.

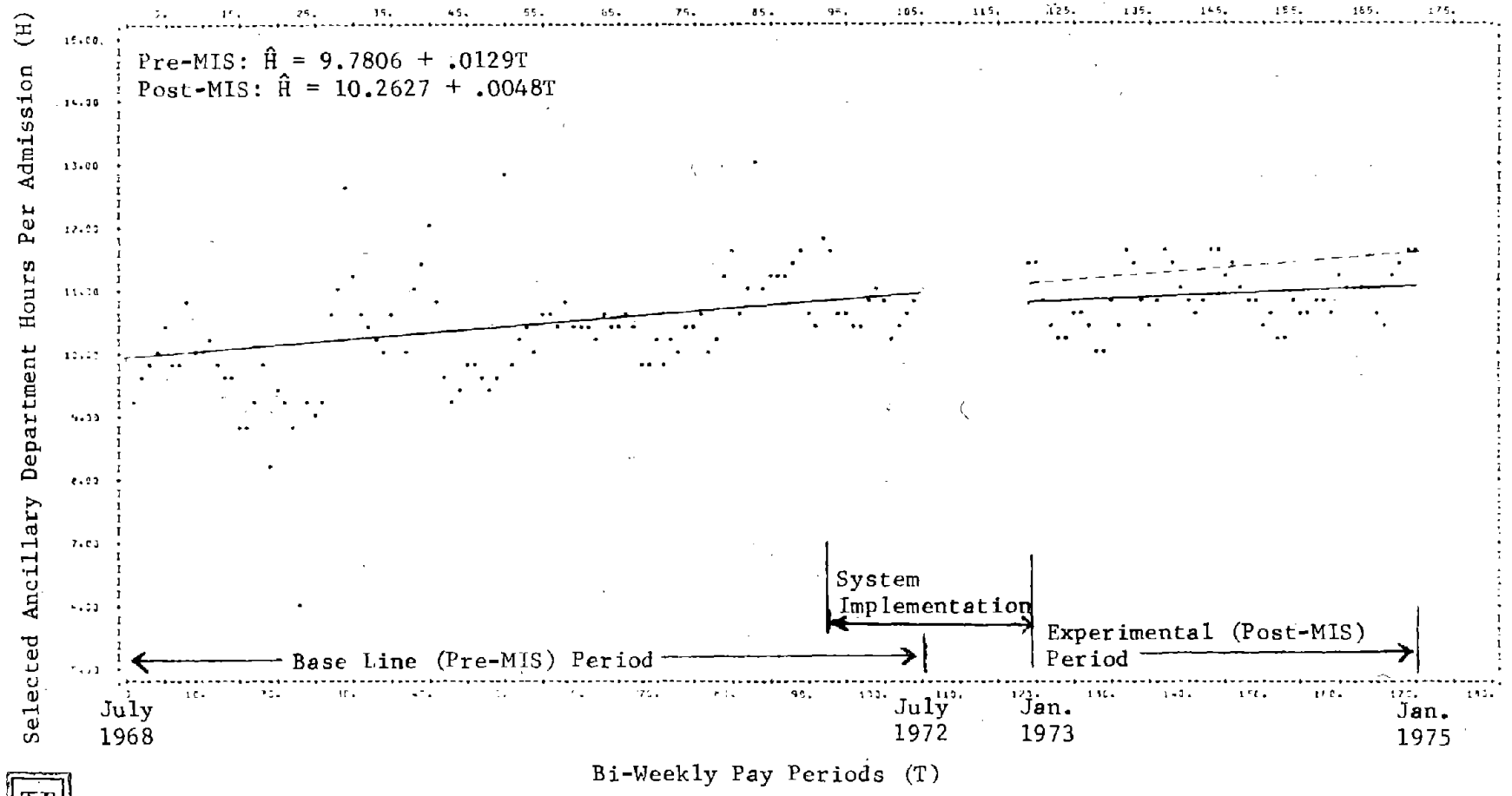

Figure 11. Selected Ancillary Department Labor Expenditures (Paid Hours per Admission) Scattergram and Regression Lines for Pre-MIS Manual System and for MIS.

TABLE 8

PAID LABOR EXPENDITURES *EXPECTED* UNDER MANUAL INFORMATION PROCESSING METHODS COMPARED WITH *ACTUAL* LABOR EXPENDITURES UNDER MIS SYSTEM OPERATION (AS OF DECEMBER 1974)

Nursing Area	Regressed *Expected* Labor Expenditures (Hrs/Pt. Day)	Regressed *Actual* Labor Expenditures (Hrs/Pt. Day)	Estimated Labor Savings (Hrs/Pt. Day)	Regressed Patient Days per Pay Period	Monthly Cost Savings[1]
MSO	6.7069	5.5032	1.2037	2,771.20	$48,320
Maternity	6.5378	5.7134	0.8244	313.98	3,750
Pediatrics	7.2599	7.0165	0.2434	238.93	843
Labor and Delivery[2]	5.0961[2]	4.0505[2]	1.0456[2]	231.03[2]	3,500
Psychiatry	7.5730	6.3980	1.1750	376.58	6,410
Nursery	5.5408	4.5268	1.0140	351.92	5,169
Total Nursing (excluding CCU, ICU, and TCU)					$67,992
Selected Ancillary Departments[3]	11.9736[3]	11.0787[3]	0.8949[3]	976.76[3]	$12,737

1 Monthly Cost Savings are calculated as the product of Estimated Labor Hours Saved per Patient Day, Estimated Patient Days per Pay Period, $6.76 per Hour (Average Nursing Wage, December 1974), and conversion factor from pay periods to months (60 pay periods = 28 months).

2 Labor and Delivery estimates were calculated using nursing hours per delivery rather than patient day.

3 Selected ancillary department estimates were calculated using ancillary department hours per admission rather than per patient day.

TABLE 9

COMPARISON OF BASE-LINE AND EXPERIMENTAL PERIODS

Variable	Base-line Period		Experimental Period	
	Midpoint	Annual Growth Rate	Midpoint	Annual Growth Rate
Admissions	1,821/mo.	3.28%	2,037/mo.	2.74%
Patient Days	9,728/mo.	0.90%	10,031/mo.	-4.16%
Length-of-Stay	5.34		4.92	
	Growth *Within* Base-line Period		Growth *Between* Base-line and Experimental Periods	
Admissions	3.28%/yr.		3.38%/yr.	
Total Patient Days	0.95%/yr.		0.88%/yr.	

The validity of conclusions drawn from this model depends on the extent and kind of change taking place between base-line and experimental periods. Although the rate of admissions growth was slightly lower during the experimental period than it was for the base line, in both cases it was positive (see Table 9). The volume of admissions rose by almost 12 percent (1,821 per month to 2,037 per month) from the midpoint of the base-line period to the experimental period midpoint, a span of three and one-half years. Patient days, on the other hand, rose only 3.1 percent over the same period. Accordingly, length-of-stay was reduced by 7.8 percent. Length-of-stay compression was particularly strong during the experimental period wherein patient days declined by 5.4 percent while admissions rose by 8.32 percent. As discussed earlier in this section under *Labor Impact Measurements*, this compression of stay should increase the information processing requirements on a per-patient-day basis. Thus, it would be expected that the daily information processing demands would be greater in the experimental period than they were in the base-line period.

Of particular importance for the validity of extrapolation of the base-line conditions to the experimental period is a comparison of change *within* the base-line period as contrasted with change *between* the base-line and experimental periods. The respective growth rates for admissions and patient days as shown in Table 9 suggests that this correspondence is quite good.

Table 10 summarizes the labor cost impact as estimated by the Internal Labor Measurements Model. It should be noted that because of two major organizational changes during the base-line and experimental periods, respectively, regression analysis of the critical care complex (ICU, CCU, and TCU care units) could not be carried out. Detailed observations on these three units by ECH's Management Engineering staff during the benefits realization process indicate a savings at least as great as other acute nursing units on a per-patient-day basis. Since this area represented approximately ten percent of the 1975 census, savings are commensurately adjusted upward on a patient-day basis by an additional $7,555 per month. Labor savings in the support areas of Admitting and the Business Office for the most part reflect actual elimination of positions.

Inter-Hospital Labor Trend Comparison Model

Because potential cost containment effects might be missed by studies focused solely within the hospital, a comparative analysis of labor trends and diagnostic patterns was undertaken in six similarly sized hospitals within a radius of 20 miles of El Camino Hospital. The objective of the study was threefold: (1) to determine whether labor expenditures tended to trend together at the other six hospitals (i.e., did labor expenditures tend to rise and fall together over time?); (2) to analyze whether ECH followed the labor trend pattern exhibited by the other hospitals before the system was implemented; and (3) to determine how the trend of labor expenditures at El Camino Hospital shifted before and after the implementation of the system compared with any trend shifts at the other hospitals.

Monthly values of economic and diagnostic mix data were collected from two 18-month time periods reflecting experience before (July 1970 through December 1971) and after (July 1972 through December 1973) implementation of the system. The 6-month gap (January 1972 through June 1972) represents the period during which implementation of the MIS system took place at El Camino Hospital, and thus is omitted as being not representative of normal operation.

The following economic and operational variables were analyzed: admissions, patient days, occupancy, capacity, paid nursing hours (excluding nursing administration and in-service education), and paid man-hours (Pharmacy, Central Service, Inhalation Therapy, Laboratory, and Radiology). Percentage figures for inpatient volume also were collected for Radiology and the Laboratory. Monthly diagnostic mix data were collected from Professional Activities Study (PAS) reports or similar sources, with the principal objective being to describe a diagnostic category and patient age profile for each hospital over the 4-year period 1970 through 1973. These profiles then were compared between hospitals, and the change in the profiles was analyzed over time to assess the impact of potential changes in diagnostic mix or patient age on hospital labor cost.

Labor hours were chosen as the labor cost indicator rather than dollar costs in order to avoid wage rate differentials and similar incompatibilities. "Nursing Hours" represent cumulative paid service hours expended by *nursing unit* personnel per month on the following types of units: medical, surgical, orthopedic, intensive care, and pediatric (obstetric, psychiatric, and

TABLE 10

SUMMARY OF LABOR COST IMPACT AS MEASURED
BY THE INTERNAL LABOR MEASUREMENTS MODEL

Cost Element	AVERAGE MONTHLY SAVINGS					5-Year Average (4)
	FY75	FY76	FY77	FY78	FY79	
Nursing Labor Savings (1)	$ 67,992	$ 73,771	$ 80,042	$ 86,845	$ 94,227	$ 80,575
Critical Care Areas	7,555	8,197	8,894	9,650	10,470	8,953
Selected Ancillary Labor Savings (2)	12,737	13,820	14,994	16,269	17,652	15,094
Support Labor Savings (3)	3,910	4,242	4,603	4,994	5,419	4,634
Total Labor Savings	$ 92,194	$100,030	$108.533	$117,758	$127,768	$109,256

(1) Excludes Critical Care Areas.

(2) Includes Pharmacy, Laboratory, Radiology, Inhalation Therapy, and Central Service.

(3) Admitting and Business Office.

(4) The average monthly savings for the 5-year period FY75 to FY79 is assumed to experience an 8.5 percent annual increase to reflect growth in wage rates and growth in information processing traffic rates.

extended care facilities are excluded). "Total hours" represent total productive man-hours for the hospital. Obstetric, psychiatric, and extended care facility figures were excluded in order to achieve comparability of data across hospitals since not all of the hospitals in the study provided all of these service units.

Selected ancillary man-hours represent the summation of monthly productive man-hours expended in Pharmacy, Radiology, Laboratory, Central Service, and Inhalation Therapy. These departments constitute those most significantly affected by the MIS system.

Analysis of Inter-Hospital Data. Using regression analysis, a best-fit straight line was plotted for each economic or operational variable through the data points to obtain trend lines for before and after periods. Other statistical techniques, such as moving averages and nonlinear regression, were examined and found to be inferior for purposes of describing the trend of the data points. Trend lines thus were developed for each of the economic and operational parameters noted above, as well as for ratios such as length-of-stay for each hospital. Aggregate trend lines also were developed for the variables in question by averaging the data from all six comparison hospitals. Figures 12 through 15 present summaries of the trend lines of selected variables for individual hospitals and for the aggregate of comparison hospitals (dashed line). Tables 11 and 12 present further details of the before and after period trend analysis comparing El Camino Hospital with the average experience of the other six hospitals. Results are presented for regression models using data for three time intervals. One model used the first 12 months of data in the experimental periods to determine trend. Another used the last 12 months of the data collection periods. A third used the entire 18-month data collection periods. All three sets of results are presented to counter possible objections to using periods other than multiples of a full year which might lead to unequal weighting of seasonal effects. The variation in results provides a range within which the estimates may be presumed to lie. For each variable studied, the beginning, midpoint, and end-point values of the trend lines are given in Tables 11 and 12 as well as the percentage change (positive or negative) over the period in question. Additional details of the regression analyses are presented in Appendix B.

A substantial difference in the behavior of El Camino Hospital and the comparison hospitals, both individually and in the aggregate, is suggested by the trend lines. In Figure 12, comparisons of medical-surgical nursing hours per patient day are presented. The trend lines are especially sensitive to the time interval used for the regression analysis. Nevertheless, the relative differences between El Camino Hospital and the comparison hospitals persisted. The 18 months' regression models indicate El Camino Hospital experienced a higher growth rate in medical-surgical nursing hours per patient day during the base-line period, with a decreasing rate during the experimental period. The first 12 months' models (July to July) suggest that El Camino Hospital went from an increasing rate during the base-line period to a decreasing rate during the experimental period, below the aggregate trend line. The last 12 months' regression models (December to December) show all trend lines increasing, but the experimental period trend line for El Camino Hospital has a lesser slope than the aggregate. The data indicate that some

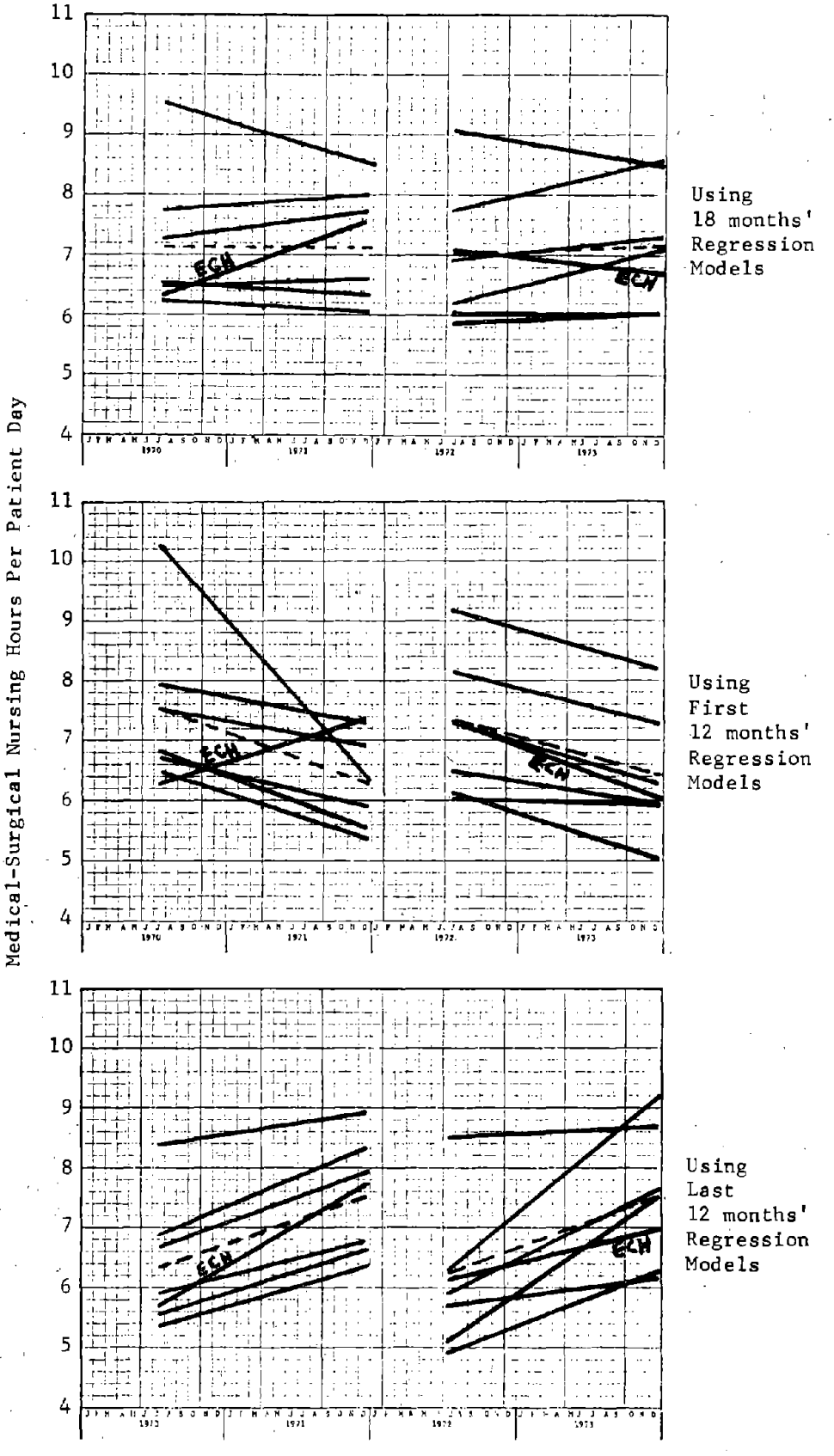

Figure 12. Trends in Medical-Surgical Nursing Hours per Patient Day Before and After Implementation of MIS at ECH versus Other Local Hospitals.

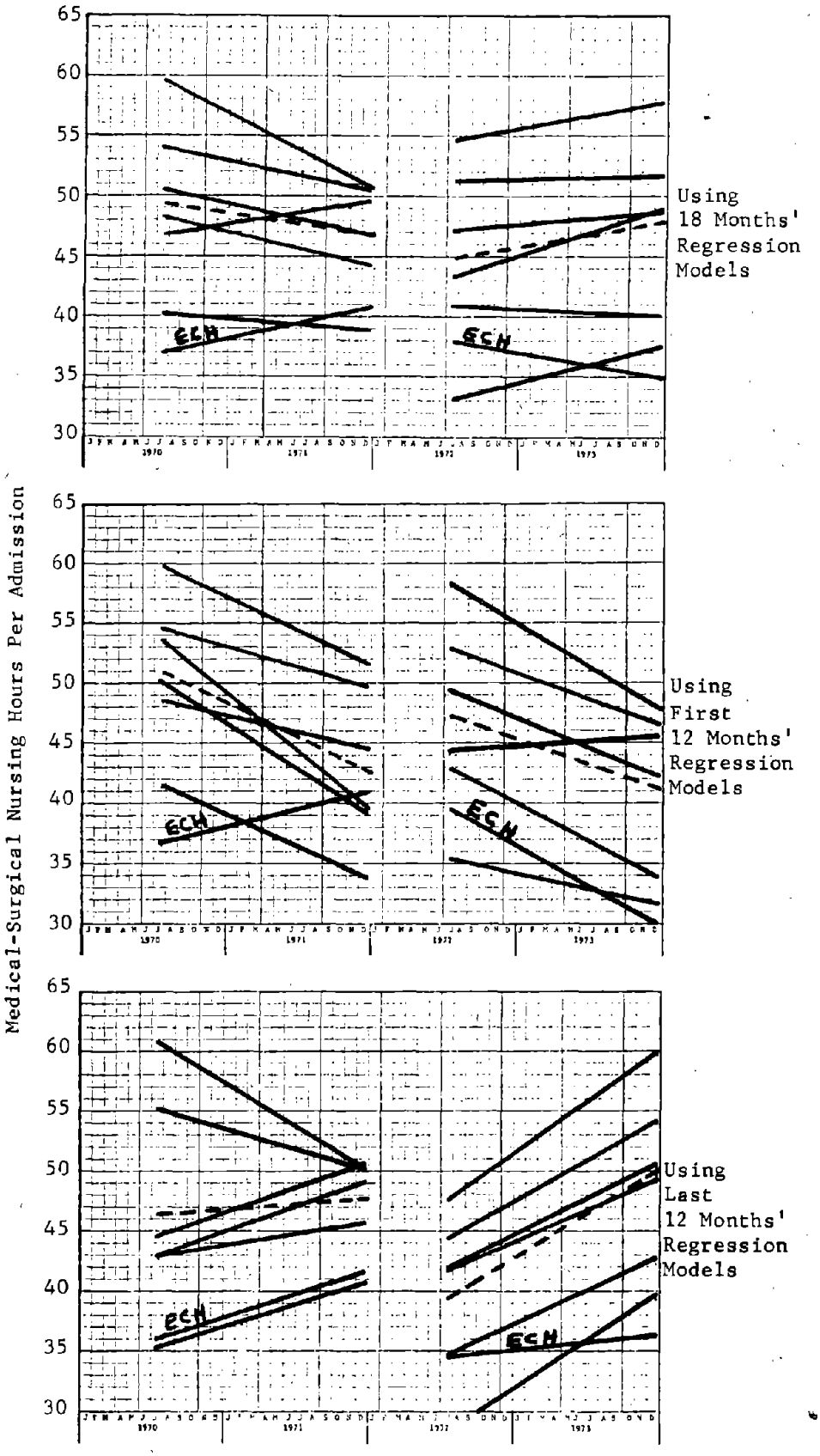

Figure 13. Trends in Medical-Surgical Nursing Hours per Admission Before and After Implementation of MIS at ECH versus Other Local Hospitals.

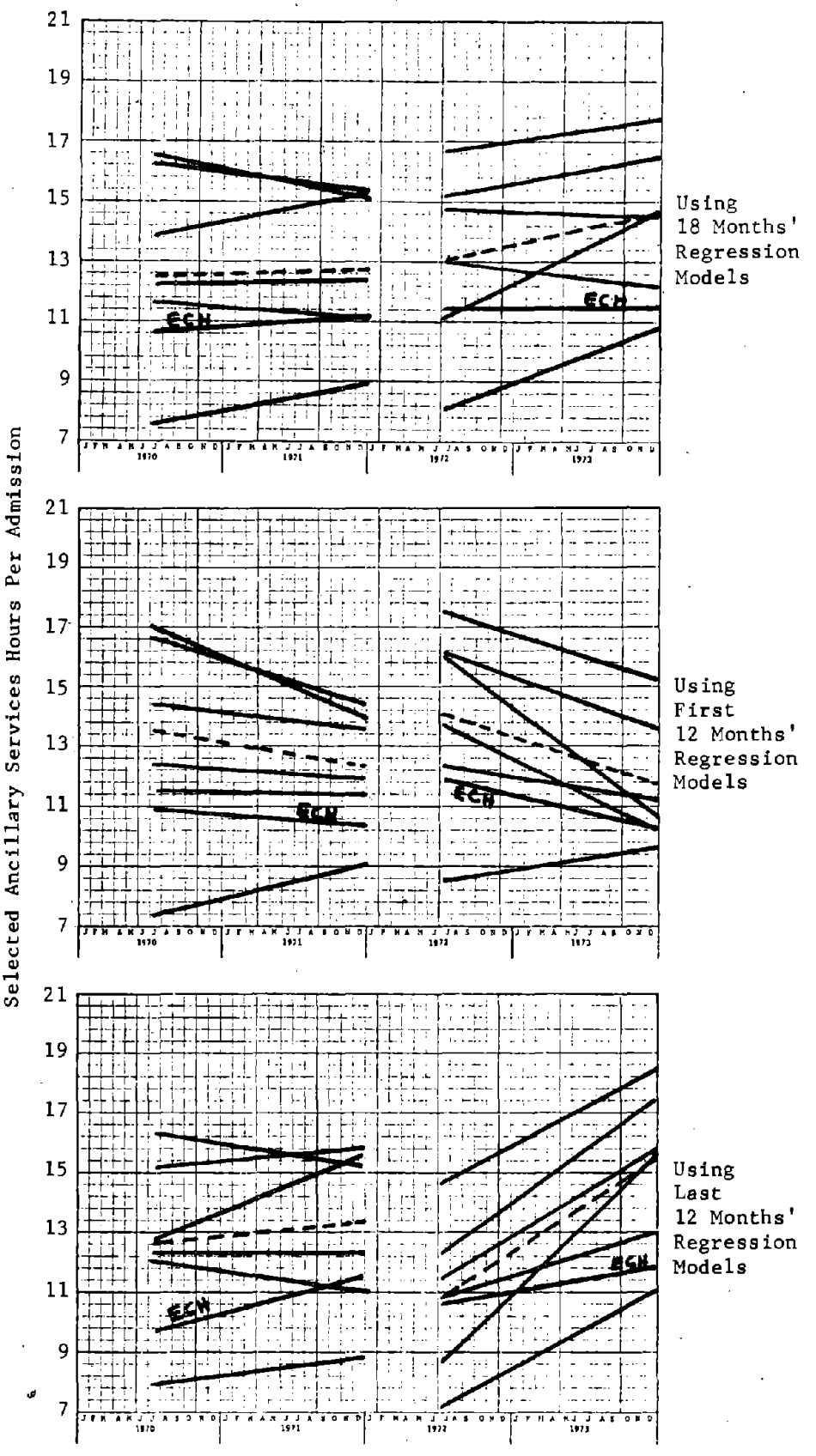

Figure 14. Trends in Selected Ancillary Services Hours per Admission Before and After Implementation of MIS at ECH versus Other Local Hospitals.

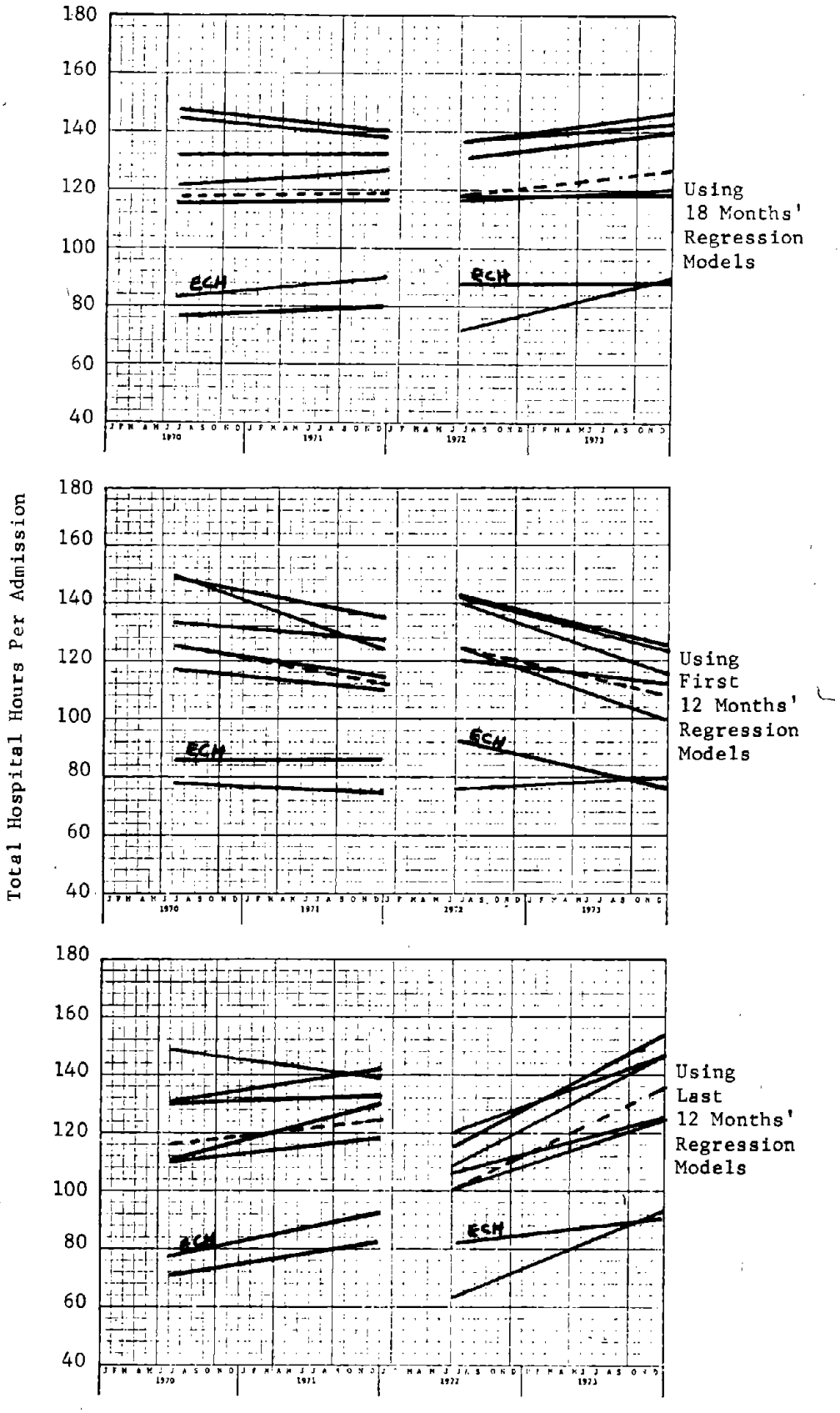

Figure 15. Trends in Total Hospital Hours per Admission Before and After Implementation of MIS at ECH versus Other Local Hospitals.

TABLE 11

COMPARISON OF SELECTED ECONOMIC AND OPERATIONAL PARAMETERS
ON MEDICAL-SURGICAL UNITS BEFORE IMPLEMENTATION OF MIS

Criterion	Hospital(s)	Regressions Using First 12 Months' Data[1] Beginning Point[4]	Mid-point	Ending Point	% Change	Regressions Using Last 12 Months' Data[2] Beginning Point	Mid-point	Ending Point	% Change	Regressions Using 18 Months' Data[3] Beginning Point	Mid-point	Ending Point	% Change
Admissions/ Month (Med-Surg)	ECH	1277	1343	1410	10.41	1402	1367	1331	5.03	1296	1329	1361	4.97
	6 Others	914	957	1000	9.45	1023	954	885	-13.46	943	926	910	- 3.56
Patient Days/ Month (Med-Surg)	ECH	7416	7666	7915	6.73	8738	7927	7117	-18.56	7592	7524	7455	- 1.79
	6 Others	6275	6549	6822	8.72	7341	6532	5722	-22.05	6540	6261	5981	- 8.54
Average Length of Stay (Days: Med-Surg)	ECH	5.80	5.70	5.61	- 3.28	6.26	5.80	5.35	-14.54	5.85	5.66	5.47	- 6.46
	6 Others	6.92	6.90	6.89	- 0.50	7.31	6.91	6.51	-10.92	7.00	6.81	6.62	- 5.38
Occupancy Percent (Med-Surg)	ECH	64.96	66.00	67.04	3.20	76.04	67.69	59.34	-21.96	66.61	64.40	62.19	- 6.65
	6 Others	76.94	74.75	72.56	- 5.69	80.18	75.14	70.11	-12.56	77.55	74.20	70.85	- 8.63
Nursing Hours/Patient Day (Med-Surg)	ECH	6.33	6.82	7.31	15.48	5.67	6.70	7.73	36.33	6.30	6.93	7.56	19.97
	6 Others	7.49	6.87	6.26	-16.36	6.35	6.90	7.45	17.34	7.11	7.10	7.09	- 0.36
Nursing Hours/ Admission (Med-Surg)	ECH	36.74	38.81	40.88	11.27	35.94	38.77	41.61	15.78	36.88	39.15	41.42	12.31
	6 Others	50.76	46.79	42.81	-15.67	46.20	46.94	47.69	3.21	49.34	48.08	46.83	- 5.08
Ancillary Hours/ Admission (Total)	ECH	10.92	10.67	10.42	- 4.58	9.66	10.59	11.51	19.15	10.64	10.92	11.20	5.28
	6 Others	13.26	12.80	12.35	- 6.88	12.71	12.93	13.16	3.57	12.50	12.60	12.70	1.55
Hospital Hours (Total)/ Admissions (Total)	ECH	84.55	85.44	86.32	2.09	77.55	84.58	91.61	18.13	83.32	86.56	89.80	7.77
	6 Others	124.60	119.17	113.74	- 8.72	115.83	119.88	123.93	6.99	117.92	118.33	118.74	0.70

(1) ECH Data: 6/21/70 to 6/19/71; Six Other Hospitals' Data: 7/1/70 to 6/30/71.

(2) ECH Data: 1/3/71 to 1/1/72; Six Other Hospitals' Data: 1/1/71 to 12/31/71.

(3) ECH Data: 6/21/70 to 1/1/72; Six Other Hospitals' Data: 7/1/70 to 12/31/71.

(4) The beginning point is estimated for July 1970; the midpoint is estimated for March/April 1971; and the end point is estimated for December 1971.

TABLE 12

COMPARISON OF SELECTED ECONOMIC AND OPERATIONAL PARAMETERS
ON MEDICAL-SURGICAL UNITS AFTER IMPLEMENTATION OF MIS

Criterion	Hospital(s)	Regressions Using First 12 Months' Data(1) Beginning Point(4)	Mid-point	Ending Point	% Change	Regressions Using Last 12 Months' Data(2) Beginning Point	Mid-point	Ending Point	% Change	Regressions Using 18 Months' Data(3) Beginning Point	Mid-point	Ending Point	% Change
Admissions/ Month (Med-Surg)	ECH	1334	1532	1731	29.72	1593	1519	1445	- 9.32	1411	1457	1503	6.52
	6 Others	879	972	1064	21.00	1048	971	893	-14.82	924	930	935	1.10
Patient Days/ Month (Med-Surg)	ECH	7281	8024	8766	20.40	8782	8127	7472	-17.53	7585	7718	7851	3.51
	6 Others	5763	6321	6880	18.38	6836	6370	5905	-13.62	5974	6085	6195	3.70
Average Length of Stay (Days: Med-Surg)	ECH	5.44	5.24	5.05	- 7.17	5.54	5.36	5.18	- 6.50	5.38	5.31	5.23	- 2.69
	6 Others	6.61	6.56	6.51	- 1.55	6.48	6.60	6.73	3.94	6.51	6.61	6.72	3.32
Occupancy Percent (Med-Surg)	ECH	67.95	68.52	69.09	1.68	73.85	69.52	65.19	-11.73	68.74	67.80	66.86	- 2.74
	6 Others	72.29	78.48	84.67	17.13	85.25	79.16	73.07	-14.29	74.91	75.70	76.49	2.11
Nursing Hours/Patient Day (Med-Surg)	ECH	7.30	6.62	5.95	-18.49	6.18	6.57	6.97	12.78	7.05	6.87	6.68	- 5.22
	6 Others	7.21	6.81	6.40	-11.17	6.19	6.82	7.46	20.55	6.98	7.08	7.18	2.95
Nursing Hours/ Admission (Med-Surg)	ECH	39.64	34.70	29.77	-24.90	34.34	35.23	36.11	4.90	37.89	36.41	34.92	- 7.84
	6 Others	47.11	44.16	41.22	-12.50	39.39	44.53	49.66	26.07	44.83	46.30	47.76	6.52
Ancillary Hours/ Admission (Total)	ECH	11.75	11.01	10.27	-14.41	10.57	11.16	11.75	11.16	11.35	11.42	11.49	1.20
	6 Others	13.96	12.89	11.82	-15.32	10.57	13.03	15.48	46.38	13.03	13.82	14.61	12.10
Hospital Hours (Total)/ Admissions (Total)	ECH	92.00	83.89	75.79	-17.62	80.57	85.47	90.37	12.16	87.99	87.92	87.85	- 0.16
	6 Others	123.71	116.54	109.36	-11.60	100.60	117.09	133.58	32.78	117.52	122.60	127.67	8.63

(1) ECH Data: 6/18/72 to 6/16/73; Six Other Hospitals' Data: 7/1/72 to 6/30/73.

(2) ECH Data: 12/31/72 to 12/29/73; Six Other Hospitals' Data: 1/1/73 to 12/31/73.

(3) ECH Data: 6/18/72 to 12/29/73; Six Other Hospitals' Data: 7/1/72 to 12/31/73.

(4) The beginning point is estimated for July 1972; the midpoint is estimated for March/April 1973; and the end point is estimated for December 1973.

of the hospitals experienced more favorable trends than ECH during both periods, while others did not. However, in the aggregate El Camino Hospital experienced more favorable trends during the experimental period than the average of the other comparison hospitals. Figures 13 through 15 indicate similar results for other variables.

In addition to variable-by-variable comparison, an analysis was carried out to quantitatively summarize the impact of cost trend differences between ECH and the other hospitals during the experimental period. Table 13 summarizes these estimated cost impacts. The idea underlying this analysis was to apply the cost *trend* experience of the comparison hospitals *during* the experimental period to the cost *levels* that existed at El Camino Hospital at the beginning of the experimental period in order to predict what El Camino Hospital cost levels might have been at the end of the experimental period, *if El Camino Hospital had followed the same behavior as the comparison hospitals.* These predicted costs then could be compared with actual cost levels existing at El Camino Hospital at the end of the experimental period and the difference calculated. The analysis was predicated on the assumption that the natural forces which produce changes in hospital cost trends would be similar for hospitals of similar size, locale, and service characteristics. It also was assumed that although the diagnostic profiles of the hospitals might differ, the trends in changing diagnostic mix would be similar among the seven hospitals.

The calculation of these estimated cost savings is illustrated by the example in Figure 16. Based on the assumptions above, the predicted cost level in terms of ancillary hours per admission for the 18-month period is shown in Figure 16. The difference between predicted and actual labor cost is determined by projecting the beginning value for ECH along the same increase experienced by the average of the six other hospitals, measuring the difference between this projection and the regressed actual value, and then converting to dollars by multiplying by the regressed estimate of admissions for ECH at the end point and by the proper wage rate.

A range for the total labor savings predicted by this model is presented in Table 14. The extension of the labor cost savings to the maternity complex and psychiatric unit was carried out by proration based on patient-day volume. The rationale underlying calculation of predicted savings, both on a per-admission basis and on a per-patient-day basis is discussed earlier in this section under *Labor Impact Measurements.* In Table 14, Ancillary Labor Savings were calculated on a per-admission basis in both parts of the table. Savings reported under the category of Support Labor represent accomplished internal labor reductions rather than calculated reductions. Because of the sensitivity of the model to the time interval upon which the regression models are based, the range of savings is very broad, with potential monthly savings averaging from $52,563 to $169,001 over the 5-year period from FY75 to FY79.

Monthly diagnostic mix data (patient days by diagnosis) were aggregated into 17 major diagnostic categories corresponding to major H-ICDA[3] classifications and into three age groups. Because of incompleteness of the available data at some hospitals, one of the comparison hospitals was not included in the comparative analysis and the first year (1970) of the analysis was dropped.

TABLE 13

ESTIMATION OF THE IMPACT OF COST TREND DIFFERENCES BETWEEN
EL CAMINO HOSPITAL AND THE COMPARISON HOSPITALS

	Percent Change Six Hospitals	ECH Beginning Point (July 1972)	As of December 1973				
			Projected ECH End Point	Regressed ECH End Point	Estimated Savings NHPPD or NHPA	Regressed ECH End Point Patient Days/ Admissions	Monthly Cost Savings
Nursing Unit Savings[1]							
First 12 Months' Regression	-11.17	7.30	6.48	5.95	0.53	8766	$31,407
Last 12 Months' Regression	+20.55	6.18	7.45	6.97	0.48	7472	24,245
18 Months' Regression	+ 2.95	7.05	7.26	6.68	0.58	7851	30,782
Nursing Unit Savings[2]							
First 12 Months' Regression	-12.50	39.64	34.68	29.77	4.91	1731	57,455
Last 12 Months' Regression	+26.07	34.34	43.29	36.11	7.18	1445	70,136
18 Months' Regression	+ 6.52	37.89	40.36	34.92	5.44	1503	55,272
Ancillary Labor Savings[3]							
First 12 Months' Regression	-15.32	11.75	9.95	10.27	-0.32	1731	- 3,769
Last 12 Months' Regression	+46.38	10.57	15.47	11.75	3.72	1445	36,553
18 Months' Regression	+12.10	11.35	12.72	11.49	1.23	1503	12,571

(1) Savings based on Medical-Surgical nursing hours per patient day, using $6.76/hour as wage rate.

(2) Savings based on Medical-Surgical nursing hours per admission, using $6.76/hour as wage rate.

(3) Savings based on Ancillary hours per admission, using $6.80/hour as wage rate.

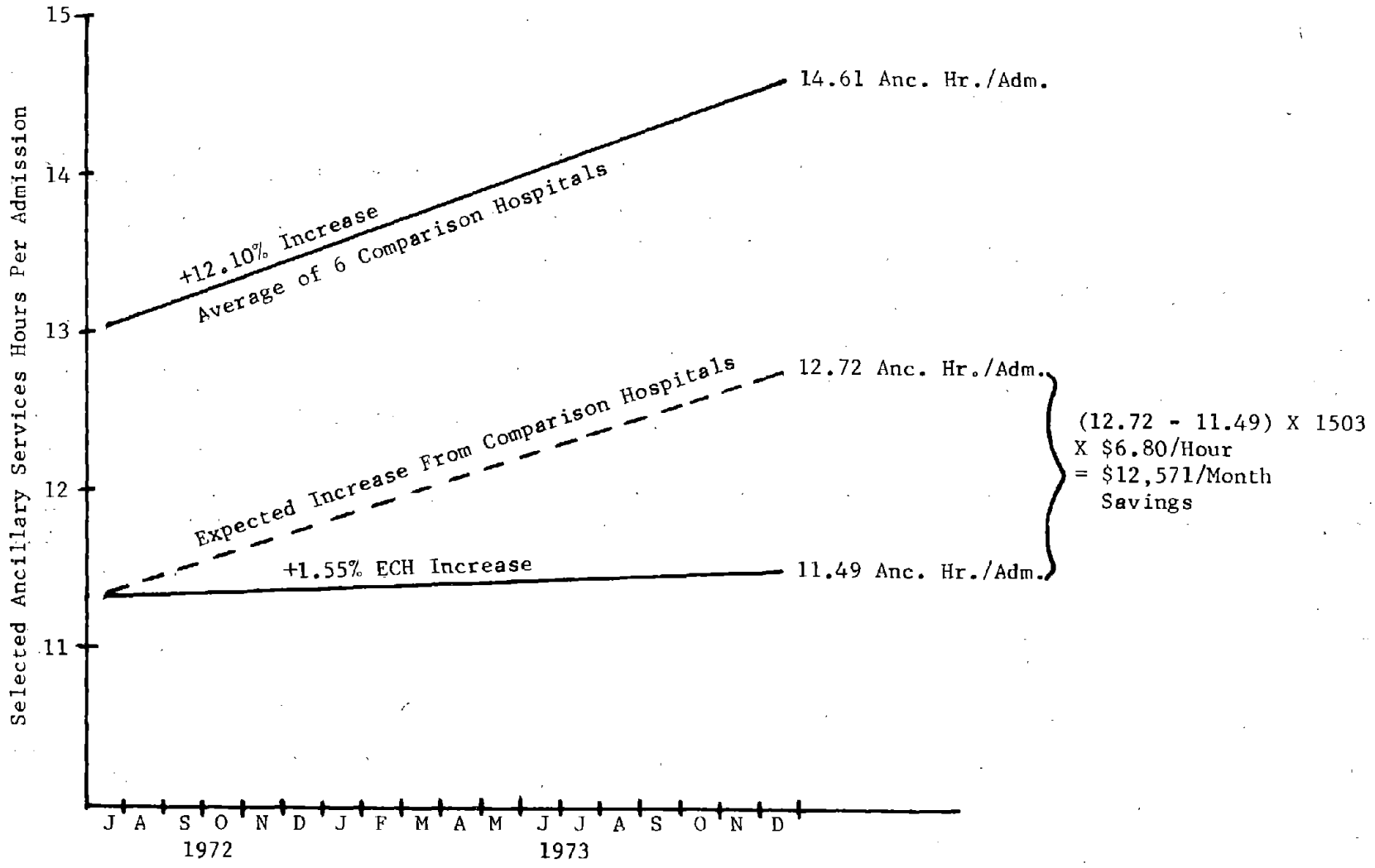

Figure 16. Illustration of the Method for Estimating Savings by the Inter-Hospital Labor Trend Comparison Model.

TABLE 14

LABOR COST SAVINGS AS PREDICTED BY THE INTER-HOSPITAL LABOR TREND COMPARISON MODEL

	Per Admission Basis			Per Patient Day Basis		
	Regression First 12 Months	Regression Last 12 Months	Regression 18 Months	Regression First 12 Months	Regression Last 12 Months	Regression 18 Months
Nursing Unit Labor Savings:						
Nursing [Excluding Psychiatric Unit and Maternity Complex]	$ 57,455	$ 70,136	$ 55,272	$ 31,407	$ 24,245	$ 30,782
Psychiatric Unit and Maternity Complex [Prorated on Patient Days]	17,070	20,837	16,421	9,331	7,203	9,145
Nursing Unit Labor Savings Totals	$ 74,525	$ 90,973	$ 71,693	$ 40,738	$ 31,448	$ 39,927
Ancillary Labor Savings [Laboratory Pharmacy, Central Service, Radiology, and Inhalation Therapy]	- 3,769	36,553	12,571	- 3,769	36,553	12,571
Support Labor Savings(1) [Admitting, Business Office, Medical Records]	3,910	3,910	3,910	3,910	3,910	3,910
Total Monthly Labor Reduction Savings(2)						
FY74	$ 74,666	$131,436	$ 88,174	$ 40,879	$ 71,911	$ 56,408
FY75	81,013	142,608	95,669	44,354	78,023	61,203
FY76	87,899	154,730	103,801	48,124	84,655	66,405
FY77	95,370	167,882	112,624	52,214	91,851	72,049
FY78	103,477	182,152	122,197	56,653	99,658	78,174
FY79	112,272	197,635	132,583	61,468	108,129	84,818
Average (FY75 to FY79)	$ 96,006	$169,001	$113,375	$ 52,563	$ 92,464	$ 72,530

(1) Cost savings measured internally, not through inter-hospital comparison.

(2) The average monthly savings for the 5-year period, FY75 to FY79, is assumed to experience an 8.5 percent annual increase, to reflect growth in wage rates and in information processing resulting from increased traffic.

By calculating the number of patient days in each of the 17 diagnostic categories for a given hospital for a given year, a profile of the diagnostic mix at the hospital in question could be obtained. Such profiles were developed for each of the hospitals for each year of the study (see, for example, Figure 17). Similar profiles were developed for the age groupings. By comparing these profiles over time, the change in diagnostic mix and age groups could be analyzed between hospitals. By summing the absolute value of the differences between the percentage of patient days in each diagnostic category at one hospital from the corresponding percentages at another hospital for a given year, a measure of the difference in the diagnostic profiles can be developed. Thus, diagnostic profile differences could be studied both across hospitals and over time. Table 15 shows the distribution of patient days by diagnostic category across the six hospitals for 1973. The difference in diagnostic profiles also is shown for several hospital combinations for the 1973 data. For all possible hospital combinations in any given year, this difference index ranged from a low of about 15 to a high of about 40. The analysis indicated that while the diagnostic profiles were broadly similar (e.g., the largest category in each hospital was Diseases of the Circulatory System), they differed one from another when considered in detail. The most significant finding was that the profiles and the difference indexes did not change substantially over time. Thus, although El Camino Hospital differed in varying extent from the other hospitals, as did the comparison hospitals among themselves, this difference tended to remain quite constant over time.

Because El Camino Hospital's economic and operating parameters were compared on a before and after basis with the same variables aggregated across the comparison hospitals, an analogous study was carried out for the diagnostic and age data. Table 16 presents the results of this comparison. The average diagnostic profile of the five comparison hospitals was compared with that of El Camino Hospital and the difference analyzed over the 3-year period. The difference between ECH and the aggregate profile of the five comparison hospitals, while perhaps significant in extent, does not vary considerably over the time period. Additionally, changes within diagnostic categories do not seem to be considerable. With the exception of the Supplementary class and the class Signs, Symptoms, and Ill-Defined Conditions (both of which might be expected to vary more significantly than well-defined classes), deviation in opposing directions over time was less than one percent. In summary, it is felt that while the diagnostic profiles for each hospital were different, this difference remained constant over the 3-year time period studied. Therefore, changing diagnostic mix is an unlikely explanation for changes in the economic and operational parameters reviewed.

An entirely analogous procedure was carried out with respect to the age category data yielding similar findings. These results are also shown in Table 16.

Interpretation of the Inter-Hospital Labor Trend Data and Extrapolation to El Camino Hospital. Although the diagnostic mix and patient age data suggest that the five local comparison hospitals and El Camino Hospital seem to trend together, certain key labor and operating variables (notably nursing hours and admissions) in some cases trended in opposite directions in the 18-month *before* or control period. The prediction of cost savings by means of the inter-hospital labor trend comparison model assumes, however, that labor

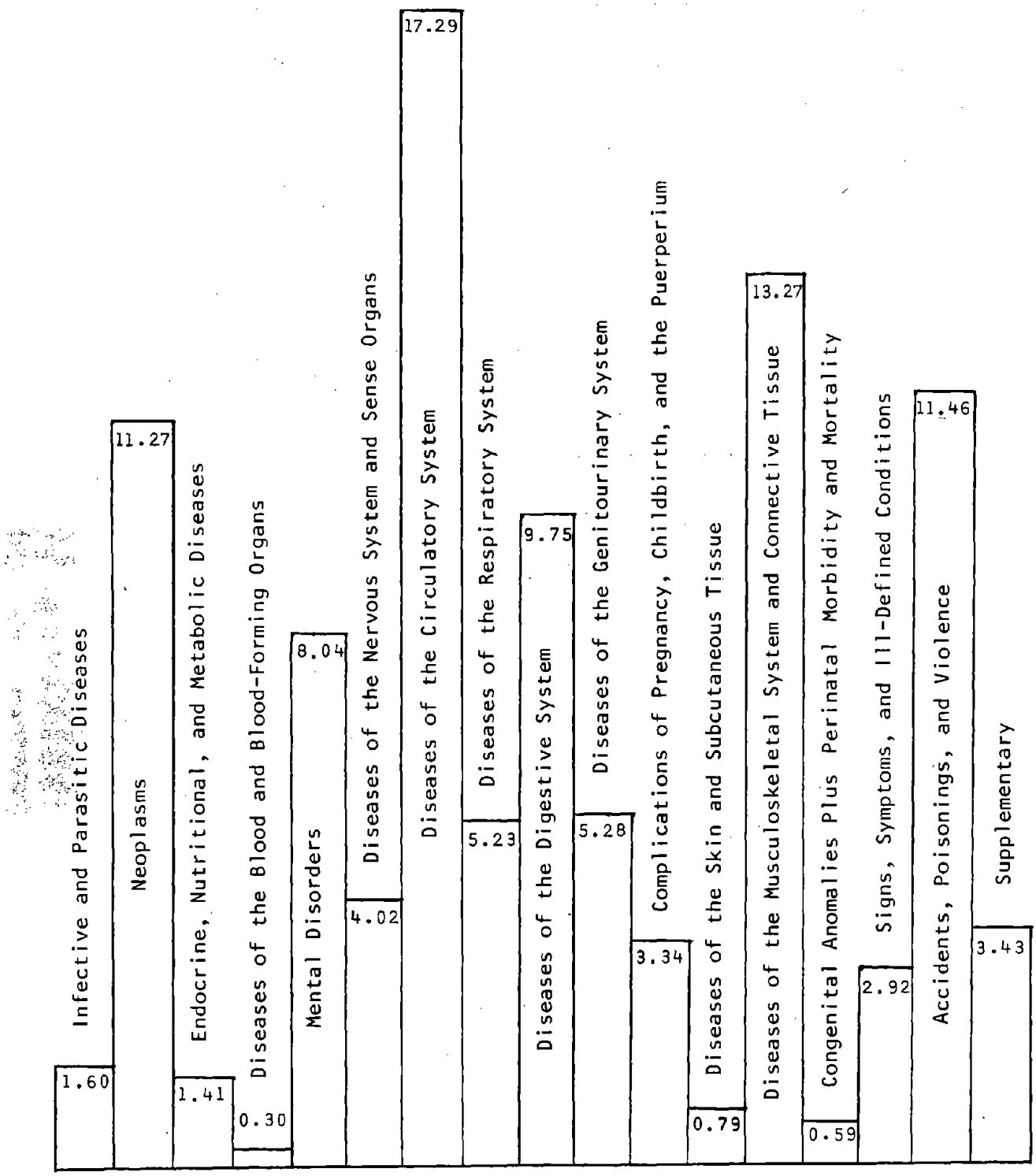

Figure 17. Diagnostic Profile for Hospital B - 1971 (Percentage of Patient Days by Diagnostic Category).

TABLE 15

COMPARISON OF DIAGNOSTIC PROFILES BETWEEN HOSPITALS AND OVER TIME

Distribution of Patient Days by Diagnostic Categories - ECH and Comparison Hospitals

1973

Disease Category	HOSPITAL E	B	A	C	F	ECH
Infective/Parasitic	1.49	1.04	1.66	1.46	.95	1.57
Neoplasms	10.54	10.91	8.99	12.90	10.04	8.65
Endocrine, Nutritional-Metabolic	1.16	1.12	1.12	1.72	1.25	1.10
Diseases of the Blood	.40	.41	.38	.53	.41	.28
Mental Disorders	.66	8.48	6.18	.28	11.26	8.44
Nervous System and Senses	3.70	3.42	3.76	5.55	1.40	2.76
Circulatory System	19.17	16.42	18.85	19.82	18.60	13.88
Respiratory System	7.32	5.66	6.63	7.81	5.74	6.05
Digestive System	10.82	9.58	10.17	10.98	8.33	10.27
Genitourinary System	7.09	5.94	6.64	7.48	6.32	8.55
Complicated Pregnancy	3.56	2.61	3.27	4.22	4.30	7.47
Skin	.91	.85	.78	1.21	1.48	.76
Musculoskeletal/Connective Tissue	11.40	13.79	10.96	9.09	5.29	8.35
Congenital Anomalies	.51	1.19	.53	1.27	.52	1.03
Signs and Symptoms	3.62	4.04	3.79	3.57	3.60	2.55
Injuries and Adverse Effects	13.62	11.27	12.59	8.89	16.22	10.93
Supplementary	4.37	3.26	3.60	3.20	4.30	7.34

Inter-Hospital Comparison - 1973 Data

Hospital Combination	Diagnostic Profile Difference Index
A/B	16.03
C/E	16.62
A/F	24.59
B/E	23.37
ECH/B	26.33
ECH/A	25.40
ECH/E	33.30

Inter-Hospital Comparison Over Time (1970 to 1973)

ECH/B - 1970	30.62
ECH/B - 1971	31.73
ECH/B - 1972	27.49
ECH/B - 1973	26.33

TABLE 16

ANALYSIS OF THE DISTRIBUTION OF PATIENT DAYS BY DIAGNOSTIC CATEGORY AND BY AGE GROUP FOR ECH VERSUS FIVE LOCAL COMPARISON HOSPITALS

DISEASE CATEGORY	1971			1972			1973			Change Between ECH & 5 Other Hospitals 1971-1973 (%)	5 Hospitals Greatest Variation	Net 5 Hospitals Change 1971-1973	Net ECH Change 1971-1973
	Average 5 Hosps.	ECH	5 Hosps. -ECH	Average 5 Hosps.	ECH	5 Hosps. -ECH	Average 5 Hosps.	ECH	5 Hosps. -ECH				
Infective/Parasitic	1.49%	1.84%	- .35%	1.37%	1.51%	- .14%	1.32%	1.57%	- .25%	.10%	.17%	- .17%	- .28%
Neoplasms	10.69	8.83	1.86	9.48	8.93	.55	10.68	8.65	2.03	.17	1.21	- .01	- .18
Endocrine, Nutritional-Metabolic	1.50	1.09	.41	1.21	1.28	- .07	1.27	1.10	.17	- .24	.29	- .23	+ .01
Diseases of the Blood	.42	.38	.04	.54	.39	.15	.43	.28	.15	.11	.12	+ .01	- .10
Mental Disorders	4.24	7.40	- 3.16	4.52	8.60	- 4.08	5.37	8.44	- 3.07	.09	1.13	+1.13	+1.04
Nervous System and Senses	3.54	2.99	.55	3.62	3.28	.34	3.57	2.76	.81	.26	.08	+ .03	- .23
Circulatory System	17.03	13.08	3.95	17.37	13.60	3.77	18.57	13.88	4.69	.74	1.54	+1.54	+ .80
Respiratory System	7.22	5.75	1.47	5.80	5.78	.02	6.63	6.05	.58	- .89	1.42	- .59	+ .30
Digestive System	10.23	10.62	- .39	10.32	9.78	.54	9.98	10.27	- .29	.10	.34	- .25	- .45
Genitourinary System	6.65	9.44	- 2.79	6.49	8.53	- 2.04	6.71	8.55	- 1.84	.95	.22	+ .06	- .89
Complicated Pregnancy	4.43	8.70	- 4.27	3.97	8.14	- 4.17	3.59	7.47	- 3.88	.39	.84	- .84	- .33
Skin	.78	.69	.09	.84	.68	.16	1.05	.76	.29	.20	.27	+ .27	+ .07
Musculoskeletal/Connective Tissue	9.65	7.90	1.75	9.89	8.22	1.67	10.11	8.35	1.76	.01	.46	+ .46	+ .45
Congenital Anomalies	.74	1.05	- .31	.67	.94	- .27	.80	1.03	- .23	.08	.13	+ .06	- .02
Signs and Symptoms	2.64	2.88	- .24	2.95	2.75	.20	3.72	2.55	1.17	1.41	1.08	+1.08	- .33
Injuries and Adverse Effects	10.84	9.85	.99	13.07	10.00	3.07	12.45	10.93	1.52	.53	2.23	+1.61	+1.08
Supplementary	7.85	7.51	.34	7.88	7.58	.30	3.75	7.34	- 3.59	- 3.93	4.13	-3.10	- .17
TOTAL	99.94	100.00	- .06	99.99	99.99	.00	100.00	99.98	.02	.08			
Diagnostic Profile Difference Index			22.96			21.54			26.32	10.20	15.66		
AGE CATEGORY													
Younger 13-	8.74%	11.92%	- 3.18%	8.24%	11.44%	- 3.20%	7.38%	11.26%	- 3.88%	- .70%	[illegible]	[illegible]	- .06%
Middle 14 - 64	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Older 65+	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	- .16	[illegible]	+1.84	+1.00
TOTAL	[illegible]	[illegible]	- .01	[illegible]	[illegible]	.00	[illegible]	[illegible]	- .02	- .06			
Age Category Difference Index			[illegible]			[illegible]			[illegible]	[illegible]	[illegible]		

trends at ECH would be similar to those in the other six hospitals during the experimental period had the MIS system not been installed. Because El Camino Hospital labor trends did not always follow those of the other hospitals during the *before* period, the conclusion that ECH would have followed the other hospitals in the experimental period may be disputed. Rather, it may be concluded that conditions differed between El Camino Hospital and the other six hospitals both before and in the period after ECH had installed the MIS system.

Furthermore, using the 18-month regression results shown in Table 12, the rise in length-of-stay experienced by the comparison hospitals in the experimental period (3.32%) explains roughly half of the increase in nursing hours per admission experienced by the other hospitals (6.52%). El Camino Hospital continued to experience a downward trend in length-of-stay, it might be argued, as a result of the MIS system. Two aspects of this argument may be distinguished: (1) reduction of length-of-stay because of faster return of diagnostic results which promotes earlier discharge of the patient; and (2) significantly improved level of utilization review achieved as a result of computer assistance. The first argument is somewhat tenuous and also is discussed under *Nonlabor Cost Benefits*. The second argument merits consideration and further analysis, since largely as a result of computer assistance to the utilization review process at El Camino Hospital, the proportion of patients reviewed has doubled from 50 percent to nearly 100 percent. Approximately 90 percent of the reviews can be accomplished at the VMT using data in the system.

Lastly, to further confound the results, it can be argued that there may be a phase difference between ECH and the other hospitals with respect to the variables studied (labor and operating parameters). If El Camino Hospital and the other hospitals were out of phase for some reason, the trend analysis technique used to analyze the data could be comparing different portions of the cycle. Length-of-stay data present some possible evidence to this effect. In the experimental period, an upturn in length-of-stay was noted for the comparison hospitals, ending a several-year downward trend. ECH's length-of-stay continued to trend downward during the experimental period; however, it recently has begun to rise slightly.

In summary, without further research and analysis, it is difficult to arrive at a definitive conclusion regarding the role that the MIS system played in comparative differences between El Camino Hospital and the other six local hospitals that were analyzed.

Nonlabor Cost Benefits

The analysis of nonlabor cost benefits falls into three basic categories. The first of these is the impact of the MIS system on such revenue sources as lost charges, late charge write-offs, cash-flow changes, and volume changes in ancillary service orders. The second category which may experience an impact is that of material costs, primarily changes in the need for preprinted forms. Other miscellaneous incidental savings comprise the third category, covering items such as equipment needs and their maintenance, and personnel supplies. Each of these three categories is discussed further below.

Revenue Impacts

Suggested potentially beneficial revenue impacts were considered in the areas of lost charges, late charge write-offs, cash flow improvements, and volume changes in ancillary service orders. The following conclusions were reached concerning potential revenue impacts for each of these areas.

Lost Charges. Hospital audits in years previous to the implementation of the MIS system indicated that "lost" charges were not a significant problem at ECH. Nevertheless, analyses were conducted under the auspices of the evaluation study to determine the impact of the new information system on the lost charge phenomenon. These analyses essentially confirmed the fact that ECH would benefit little from improved charge capture. Lost charges were not a significant problem at El Camino Hospital before implementation of the system, nor were they afterward.

Late Charge Write-Offs. Before the implementation of MIS, late charges of amounts under $50 were "written off" as it was found that the average cost of re-billing and collection exceeded that amount. Because there are no "late charges" under MIS system operation, an average monthly savings of $900 has been achieved.

Cash Flow. A second source of increased revenue from accounts receivable was expected because of the existing ability to move the billing date one day forward, thus realizing a one-time cash flow increase in the amount of one day's receivables (valued at $50,000) and ongoing savings equal to the interest on that amount (about $250 per month). Because certain areas of charge collection still involve input of charges via separate light-pen selection (e.g., Operating Room, EKG, Blood Gases, and Clinical Pathology) and acceleration of billing would require input of all charges within 24 hours of discharge, this option was not considered financially attractive and thus was not implemented.

Inventory reduction in the Pharmacy associated with conversion to the unit-dose system was accomplished in the amount of approximately $10,000. Interest costs on this amount yield savings of roughly $50 per month, given a six percent annual interest rate. Since it is cost beneficial to implement unit dose with the MIS system, unit-dose savings can properly be included as a part of total system cost benefits.

Ancillary Service Volume. For systems in which the physician interacts directly with the computer, it has been hypothesized that increased ordering of ancillary services, particularly diagnostic tests, would take place because of the existence of a complete "shopping list" of all tests which is readily available as a part of the ordering process. Since the ancillary services in the hospital generally are profit-making centers, increased revenue would result.

This hypothesis was tested in the first year of system operation (1972) with negative results. Although further studies for the years 1973 and

1974 have not been carried out, neither have abnormally large growth rates been observed by ancillary services. The 1972 investigation of this effect was focused on the Laboratory. Study of other ancillary departments was planned if positive findings were discovered. The analysis was accomplished by tracking the growth rates per patient day of various categories of tests over the last four years via least squares regression fits.

The raw data consisted of the monthly values of the following variables: The number of total laboratory tests per patient day, the number of total tests excluding new tests (new tests which became available over the 4-year period) per patient day, new tests (tests added over the 4-year period) per patient day, common tests (the set of tests which constituted approximately 90% of the volume) per patient day, and uncommon tests (those comprising about 10% of the total volume) per patient day. These values then were plotted by year and the average growth rate was determined by fitting linear or exponential curves to the data by the least squares regression process. Curves (linear vs. exponential) with the lowest standard error then were selected to represent the growth for particular categories. Growth in total tests per patient day varied from a negative 9.25 percent per year in 1969 to 21.3 percent per year in 1970.

Beginning in January of 1972, MIS was sequentially implemented over a 9-month period. The period October through December represented fairly stable operation; yet, total tests per patient day dropped from an annual growth rate of 4.9 percent in 1971 to 3.65 percent in 1972. Exogenous variables such as admissions, patient days, length-of-stay, diagnostic mix, and so forth were essentially unchanged during the period. Total tests minus new tests introduced since 1969 also experienced a decline in growth from 0.7 percent per month in 1971 to 0.15 percent per month on a per-patient-day basis. The growth rate of the common tests fell similarly. These declines were countered by a significant rise in the growth rate for new tests and uncommon tests which included the set of new tests. It is possible that the increased popularity of the new tests set was increased by the expanded selection list so readily available; however, normal experience would predict their increasing popularity over time. In addition, a shift from the SMA-12 chemistry panel to an SMA-6/SMA-18 combination in November of 1972 contributed substantially to the rise in uncommon and new test growth rates.

The conclusion of this investigation is consistent with findings in the study of changes in ancillary service volume conducted by Battelle/KMB and discussed in their reporting. Thus, as of the date of this report, the occurrence of this phenomenon has not been discernable as a separate and identifiable influence at ECH. If such an influence is in fact operating, its magnitude appears to be well below that of other exogenous variables such as introduction of new tests, change in physician ordering patterns, and normal growth. Although such an effect might be more likely to be observed at a teaching institution, our experience suggests that its magnitude is not as significant as predicted.

Material Costs

The majority of the preprinted forms used in the course of patient care now are printed by the computer printers. Attendant forms savings currently constitute $3,900 per month.

Small savings ($100 per month) in the reduction of wasted patient meals appear to be possible, but have not yet been realized.

Cost Avoidance

A reduction in pneumatic tube maintenance costs has resulted in a time savings of 20 hours per week or approximately $500 per month.

A reduction in flat work printing was accomplished since many flat work forms are replaced by MIS. It is expected that over ten man-hours a week may be available if properly utilized. The monthly savings is estimated to be about $200 per month.

The automatic interface between MIS and BOS provides for automatic charging which in turn obviates the need for two keypunch machines. A hospital leasing such machines would save $160 per month. At ECH, these were provided by Technicon and included in the price of the contract.

Direct variable overhead savings were not measured. However, one can expect some savings even though not directly measurable in the area of personnel supplies, costs of payroll, costs of personnel services, equipment, and so on.

Potential Changes in Length-of-Stay

Another cost benefit occasionally advertised by vendors of hospital information systems is reduction in patient length-of-stay (LOS). Two aspects of this claim merit consideration. First, reduction in patient length-of-stay (if it can be proven to result from implementation of the system) must be matched with excess demand in order to effect improved utilization. Many hospitals in the United States do not enjoy excess demand except in certain patient categories (e.g., elective surgeries). Secondly, it is difficult or impossible to rigorously demonstrate the causal link between introduction of the system and reduced length-of-stay. The usual rationale made for this argument revolves around faster turn-around time for ancillary orders (particularly diagnostic tests). Faster turn-around time, so the argument goes, returns results to physicians sooner, allowing them to discharge patients sooner. The introduction of the automated interface for certain laboratory tests, when combined with MIS, has resulted in some physicians entering laboratory orders in the early morning, retrieving results shortly after noon, writing additional orders, and obtaining test results in the late afternoon. This achievement of two turn-arounds a day provides the potential for reducing patient length-of-stay in some cases.

There are, of course, some other quality improvements in information processing which may have an impact on length-of-stay (e.g., linkage between Dietary and Nursing which prevents the supposedly fasting patient from receiving a meal, which may result in another day of stay). However, it is almost impossible (except by correlative inference) to tie changes in length-of-stay to introduction of a total hospital information system. The impact of the utilization review process being widely introduced in the United States probably overshadows the information system effect. Nevertheless, the hospital administration is convinced that MIS is a significant factor in the reduced length-of-patient-stay. The data presented in Table 17 show a gradual downward trend for both pre-MIS and post-MIS implementation years, with a sharp decrease in 1972---the year that MIS was implemented.

TABLE 17

AVERAGE LENGTH-OF-PATIENT-STAY
AT EL CAMINO HOSPITAL
OVER THE PERIOD 1969 THROUGH 1974

Year	Length-of-Patient-Stay (in Days)
1969	5.67
1970	5.50
1971	5.38
1972	5.02
1973	5.08
1974	4.87

Summary

At El Camino Hospital, cost savings grouped under the nonlabor category include material cost savings (mainly multi-part forms), small revenue increases, and other incidental cost avoidances achieved through reduction of pharmacy inventory, printing volume, and service needs of the pneumatic tube system. For the 5-year period from FY75 through FY79, these monthly nonlabor cost savings are summarized in Table 18. In the aggregate, these savings represent in the neighborhood of five percent of total cost savings.

TABLE 18

MONTHLY NONLABOR COST SAVINGS BY SOURCE

Nonlabor Cost Savings Source	Average Monthly Savings					5-Year Average
	FY75	FY76	FY77	FY78	FY79	
Preprinted Forms Savings	$3,900	$4,212	$4,549	$4,913	$5,306	$4,576
Late Charge Capture	900	972	1,050	1,134	1,224	1,056
Flat Work Forms Printing Reduction	200	216	233	252	272	235
Pneumatic Tube Maintenance	500	540	583	630	680	587
Pharmacy Inventory Reduction Interest	50	54	58	63	68	59
TOTAL	$5,550	$5,994	$6,473	$6,992	$7,550	$6,513

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6. REALIZATION OF ECONOMIC BENEFITS

Nursing Cost-Benefits Realization

The realization of potential labor savings in nursing was approached in three phases. Phase One, an initial pilot project on one nursing unit, was undertaken by one ECH management engineer and one nurse to determine the extent of potential labor saving benefits achievable. Phase Two involved a 25-week program wherein a team of two management engineers and three nurses evaluated the *potential* labor savings and developed the methodology required to achieve this level of labor savings throughout nursing. This second phase was patterned after the experiences of the pilot unit. The third phase represented the continued implementation, refinement, and extension of the programs started or recommended by the evaluation team in Phase Two.

Pilot Project

After system installation had been completed in October of 1972, one nursing unit---a 32-bed GYN surgical unit, was chosen for the pilot cost-benefits realization project. Objectives were twofold. The first objective concentrated on realization of actual savings---the time that was formerly spent in information processing, now made available with the implementation of MIS. This realization of labor savings was accomplished in two stages. In the first stage, each type of job category on a nursing unit (RN, clerk, aide, etc.) was analyzed, paying particular attention (1) to those activities with flexible accomplishment times, that is, the performance of the task could be moved about within the shift or transferred to other shifts, and (2) to information processing tasks. The second step involved restructuring these tasks and smoothing the fluctuations in the workload throughout the shift in order to arrive at the lowest possible staffing level, utilizing most advantageously the time available of each job category. The second objective sought to plan a stabilized staffing level on the basis of re-allocated work content and normal workloads that would realize the labor savings available through MIS. It was necessary to do this on the basis of the average or slightly above average workload. If changes were made based on the less-than-normal workload or on an unusually high workload, a severe distortion in the staff's workload and staffing patterns would be created. The staffing plan so developed was to be reviewed on an ongoing basis by the head nurse, charge nurses, and their supervisor to insure its appropriateness.

The project was conducted using the following methodology:

1. Observation of the unit on all three shifts, to document nursing activity and its rationale.

   The observation period was one of noninvolvement in the unit's activity, used to gather information and to develop understanding of the unit's pattern of operation and the reasons for this pattern.

2. Analysis of the observations, formulation of recommendations, and development of a plan to implement the recommendations.

   Analysis involved documenting and placing in time sequence, when possible, the routine activities of each job on a nursing station. Tasks then can be reassigned among the staff to consolidate related tasks and to even the workload over the shift.

3. Meetings with the head nurse, charge nurses, and the supervisor to discuss the analysis and recommendations. Modification of recommendations and finalizations of plans for implementation.

4. Meetings with all staff on each shift and discussion of the analysis, recommendations, and implementation plans for that shift.

5. Training and scheduling of staff required to implement the recommendations.

6. Implementation of recommendations with close support to avoid problems and to refine the recommended changes as needed.

7. Evaluation of the changes after a suitable test period with input from all staff members.

Because this was a pilot project and because neither the Nursing Service nor the Management Engineering Department had any experience in this type of program, Steps 2 through 7 above represented an iterative process involving trial and error until the staff was able to assimilate a feasible work routine at a staffing level acceptable to both the management engineering team and to the nursing staff on the unit. The result of the effort was a reduction of 3.2 FTE's from a potential of 3.84 FTE's for the unit. The details of the staffing changes are presented in Table 19.

The major change required to accomplish these staff reductions involved the redistribution of and assignment of priorities to the time-flexible tasks or tasks constrained to an interval of time in a way which would reduce the workload peaks to the lowest possible level during each shift. In some cases, this meant redistributing tasks from one shift to another. For example, preparation of the discharged patient's chart by the ward clerk for Medical Records was moved to the evening shift instead of being done at the time of discharge. Head nurse and charge nurse roles were affected most dramatically by MIS, followed by ward clerks and thirdly by RN's and LVN's. The least affected job role was that of the nursing assistants.

TABLE 19

COST-BENEFITS REALIZATION TABLE OF PILOT UNIT STAFFING PATTERN BASED ON AVERAGE CENSUS

Before Analysis		After Analysis	
Week	Weekend	Week	Weekend
DAY SHIFT			
Head Nurse	Head Nurse	Head Nurse	Head Nurse
Asst. Head Nurse	2 RN's	Ward Clerk	2 RN's
Ward Clerk	2 Aides	3 RN's	2 Aides
3 RN's		3 Aides	
3 Aides			
Total = 11.0 FTE's		Total = 10.0 FTE's	
EVENING SHIFT			
Asst. Head Nurse	Asst. Head Nurse	Asst. Head Nurse	Asst. Head Nurse
Ward Clerk	1 RN	Ward Clerk	1 RN
2-3 RN's	2 Aides	2 RN's	2 Aides
3 Aides		3 Aides	
Total = 9.4 FTE's		Total = 8.6 FTE's	
NIGHT SHIFT			
Asst. Head Nurse	Asst. Head Nurse	Asst. Head Nurse	Asst. Head Nurse
1 RN	1 RN	1 RN	1 RN
2 Aides	1-2 Aides	1 Aide	0-1 Aide
Total = 5.6 FTE's		Total = 4.2 FTE's	
3-Shift Total = 26 FTE's		3-Shift Total = 22.8 FTE's	

NET REDUCTION = 3.2 FTE's

The actual process of achieving the realization of economic benefits from MIS was an iterative one. Different modes of operation were tested by the staff utilizing both their own ideas and those of the cost-benefits realization team in order to even the workload over each shift, to discontinue redundant or unnecessary tasks, and to change an internal organization so as to improve the overall efficiency of the unit. It was necessary to change the working atmosphere from one in which members of the staff were very reluctant to try new ways of doing things to one in which they would experiment with ideas of their own. The historical method of work assignments and work patterns had to be modified drastically before economic benefits could be realized.

The first change that needed to be made involved redefinition of the ward clerk's role. Her role was to be the center of information processing. Using MIS, it was determined that all nonprofessional information-processing tasks on the unit could be consolidated and carried out by the ward clerk. When such tasks were properly scheduled and assigned appropriate priorities, the resulting workload represented less than a full-time job. At times it was found that the information processing would back up, and it was very natural for a nurse to want to step in and help out. It was discovered that this practice could be avoided except in emergency circumstances. The ward clerk also had time to improve the efficiency of telephone communication to other hospital departments and physicians.

The charge nurse or head nurse, who formerly assisted the ward clerk in her duties much of the time, now had time for more appropriate duties such as involvement in direct patient care activities as well as unit management activities. These role changes involving the ward clerk, head nurse, assistant head nurses, and charge nurses applied to both day and evening shifts. In both cases the information-processing and communication functions were assigned to the ward clerk, thus relieving the nurses of these functions as much as possible. The charge nurses then took on more patient care duties or direct support of staff RN's in patient care situations. One of the secondary goals of this reorganization involved training all nurses to be able to take charge of the unit. The expansion of the communication patterns on the nursing unit brought about by the implementation of MIS enables the nurse to handle a wider spectrum of patient care and physician situations. This increase in job scope obviously could be accomplished without MIS, but would require additional staff rather than less staff to implement. Under the new organization, charge nurses could assume definite patient care assignments or be available on a regular basis to support the staff when a situation developed requiring additional help. This adjunctive role could be taken on as part of the regular assignment without postponing information-processing tasks as happened before the implementation of MIS when the patient workload exceeded existing staffing.

The changes made on the night shift are easier to describe and discuss. The cause and effect relationships are more evident because of the small number of staff and the greatly reduced level of patient, nurse, physician, and other hospital department interaction on this shift. The staffing on the

night shift changed from two RN's and one to two nursing assistants to two RN's and one or no nursing assistants. These changes could be made because MIS removed the clerical duties such as preparation of tomorrow's X-ray and laboratory requisitions, reordering of medications, and updating of patient Kardexes. With these tasks eliminated, the staff's efforts could be focused more on patient care activities. One of the major obstacles that had to be overcome was the traditional hierarchy of work categorized into "RN" and "non-RN" duties. Traditionally, each RN and aide team took all the patients on one hall and the other RN and aide team took the patients on the other hall. Therefore, the staffing requirement for that unit was two RN's and two nursing assistants. It took some time and effort before the nursing staff was able to assimilate the idea of flexible roles and patient assignments depending on the patient's needs as assessed by the nurses. The traditional method had been typified by very functional, rigidly adhered-to roles. Under the new method, flexible roles and patient assignments were determined at the beginning of each shift, dependent on the staff size and needs of the patients.

The results of the pilot study showed that most of the labor savings potentially available through MIS could be realized. Current labor statistics for this unit indicate that an additional 0.4 FTE is being realized, bringing the total staff reduction on the unit to 3.6 FTE's.

Accelerated Cost-Benefits Realization Program

At the conclusion of the pilot project, the hospital recognized that it needed to substantially increase its effort in cost-benefits realization programs in order to garner the labor savings available through MIS. This increased effort took the form of a 25-week program involving an additional management engineering consultant, a Technicon management engineer, and two nursing consultants to assist the existing ECH management engineering and nurse realization team.

As evidenced by the results of the pilot unit project, it was felt that a major portion of the potential labor savings was realizable. Consequently, the objective of the accelerated cost-benefits realization program in nursing was to (1) determine if comparable cost savings could be achieved in other areas of nursing (i.e., could the experience of the pilot unit be translated to the rest of nursing and similar labor savings be achieved?); (2) refine and develop the pilot project methodology, technology, and management tools needed to produce sustained economic benefits in nursing, and (3) facilitate the transition of staff levels from pre-MIS to post-MIS levels.

The methodology for the accelerated realization program was very similar to that of the pilot project. It involved an observation period where the team looked for (1) areas where work was eliminated or added because of MIS; (2) tasks having variable performance time which could be used to even the workload distribution; (3) methods and procedures that should be changed for better utilization of personnel; and (4) problems that kept the nursing staff from operating at its optimum level.

The analysis of these observations was discussed with unit personnel to elicit feedback from the staff. This forum allowed them the opportunity to participate in the decision process and to understand the rationale used in recommending staff reductions. As the first step in realizing improvements, an implementation and trial period was undertaken. During the trial period, experimentation with the suggested improvements as well as with ideas generated by the staff themselves was encouraged and supported by the realization team. These personnel usually worked in pairs consisting of an engineer and a nurse observing each shift of a nursing unit for several days. Later in the project, specific days of the week were chosen to observe on a certain shift in order to increase the probability of observing particular types of workloads. The pattern of observation of like nursing units at the same time was followed to foster the beginning of standardization on similar units. Thus, surgical units would receive similar feedback and recommendations from the team. The team needed to spend enough time on the units to observe the spectrum of activity and workloads and also enough time to establish a level of credibility with the staff, which engendered acceptance of the realization team's recommendations.

The results and recommendations of the accelerated economic benefits realization program were parallel to those of the pilot project. The potential labor savings possible because of MIS were judged to be attainable by the evaluation team. Recommended changes involved (1) job role redefinition for all positions in the Nursing Department, (2) changes to improve and standardize various methods and procedures in nursing, and (3) the formulation of methods to quantify staffing requirements and implementation of procedures to use these data to determine near-term staffing requirements.

The accelerated program produced a wider scope of recommended and accomplished changes than the pilot project because it encompassed the total nursing department. A project such as this one has an impact on all the nursing staff and the way they organize themselves to take care of patients as well as their communication within the unit, with other nursing units, and with other hospital departments. Because of its depth, the study also identified other problems that interfered with the realization of the economic benefits from the system. To cope with many of these problems, a Nursing Standardization Committee composed of four head nurses, one supervisor/coordinator, and a management engineer was formed to facilitate the implementation of the proper methods and procedures for all aspects of nursing unit operation. The committee worked on both MIS and non-MIS methods and procedures. Some of the areas that have been worked on by the committee are the implementation of the correct unit-dose medication dispensing procedures (especially those dealing with proper use of the computer printouts and proper use of and stocking of supplies on the medication cart); location of supplies on the units; standardization of nursing unit service requirements for Housekeeping, General Stores, and Central Service; change in the timing of some nursing procedures to make the workload more even within and across the shifts on the nursing units; and implementation of the recommended MIS information-handling procedures and the standardization of the order and contents of the patient charts throughout Nursing and with the Medical Records Department. The committee also served as the vehicle for implementation of these types of changes.

By the end of the evaluation program, all nursing units on all shifts had been observed. The impact of MIS on information processing was evident and similar on all units. With the reorganization of work and job roles in the nursing units, it was recognized that the assumption of clerical work by the computer system had removed a portion of work which was time-flexible in performance. This flexibility was important in assisting staff in the accommodation of fluctuations in the patient care workload. Before MIS, there were enough nursing staff on each unit each shift to handle the usual patient care requirements and the corresponding information-processing tasks. If the nursing workload rose because of increased census or patient care requirements, people naturally worked faster and harder to handle the increased needs. If the increase in work exceeded their increased pace, the information-processing tasks could be put off until there was time or until after their shift was over. Thus, much of the manual information processing was time-variable and acted to cushion peaks in patient care demands. To compensate for the removal of these time-variable tasks, the remaining work content, a major portion of which was now patient care, was rescheduled as much as possible to reduce the workload peaks. Also, a near-term staffing allocation system was designed to adjust the staffing level of each nursing unit to correspond to the projected workload. The scheduling and allocation segments of this system were implemented on two medical and two surgical units during the 25-week evaluation program. This implementation included the introduction of a reporting and control system which is required to maintain the newly achieved reduced staffing levels. This system represented a definite improvement over the methodology used in the pilot project which utilized a very subjective review of staffing requirements by the head nurse. The new methodology gave much greater flexibility to staffing and documented the staffing requirement through the reporting system.

By the middle of the 25-week program, it became evident that the necessary changes in job roles, work patterns, assignments, nursing organizational structure, and training requirements could not be carried out on all nursing units by the end of the program. Also, the normal attrition rate of personnel would not allow the recommended level of reductions in this time frame. Realizing this, the evaluation team then made it a point to observe all the areas of nursing and to document these observations in a report which could be used as a guide in the continuing cost-benefits realization effort.

Although some of the areas studied may appear to be outside the realm of the MIS system, the problems existing in these areas prevented optimum usage of the time saved by the Medical Information System. Once the MIS system was operating smoothly, it seemed that the direct work time saved was being utilized to obscure problems existing in the other areas, thus necessitating the evaluation team's involvement in these areas. Examples of these areas with problems addressed by the evaluation team include the standardization program in nursing, recommendations concerning an ongoing in-service education plan for MIS as well as in-service education for clinical and management aspects of nursing, and recommendations regarding admission and transfer of patients to various nursing units, visitors' rules, and the admitting process for the various categories of patients served by the hospital.

Continued Cost-Benefits Realization

As part of the continued cost-benefits realization program, the staffing methodologies were extended to the rest of medical-surgical-orthopedic units, and modifications to the staffing system were made to make it appropriate for use by the maternal and child health and the critical care areas. Through the staffing mechanism and the corresponding management reports, the process of cost-benefits realization was continued.

The benefits realization process revolved around the head nurse, her ability to assimilate change, and her ability to organize and manage this change. The modifications in the role of the unit secretary (ward clerk), the new role of the charge nurse, new information-processing methods, and the new methods and procedures to even the nursing workload all must be supported, understood, and implemented on a sustained basis by the head nurse. To this end, the head nurse's role was changed to give her 24-hour responsibility and authority on her unit. All staffing decisions were now her responsibility. Along with this new authority, of course, came accountability. To provide the head nurse and management with the data necessary to monitor the effects of the cost-benefits realization efforts, "nursing utilization" reports were developed which documented actual staff used by shift on each unit as compared with staff required. These reports were reviewed regularly with the head nurse and her supervisor. This review process was used to validate that the required staff, as identified through the staffing system, was reasonable and to discuss with the head nurse and her supervisor the correspondence of the actual staffing to the required staffing. This review of actual versus required staff offered an excellent opportunity for discovery of unit problems which always seemed to manifest themselves in an excess of actual staff over required staff.

Also at this time, an extensive analysis of the historical census patterns by day of the week was done to help the head nurses set up the "best" scheduling pattern by shift and by day of the week. This procedure helped reduce the need to float personnel from one unit to another to meet varying patient care requirements. Census levels by 4-week periods were predicted to help the Nursing Department anticipate the upcoming staffing requirement level. The goal for the census forecasting model was to forecast the census for each day of the week for each nursing unit within the equivalent of one staff member. This tool could then greatly reduce the problem of staff allocation before each shift. The forecasting model has been in use for approximately one year. Although the results in predicting the total patient days by 4-week period have been quite good (usually ± 3-5%), the day of the week census prediction has not been close enough to be useful in scheduling the individual units' staff. As a result, the current workload forecasting methodology involves review of patient reservations for the next three weeks on a weekly basis to determine the expected level of hospital census.

Reorganization of the Nursing Department

Nursing organization changes have been very extensive following the implementation of MIS. The original nursing organization was characterized by

its hierarchical structure (see Figure 18). Each shift had line responsibility for nursing activity on each unit for that shift. This practice created three separate nursing organizational hierarchies within the department. The nursing unit personnel were reporting to three separate organizations that were coordinated two levels above. This reporting structure resulted in decision-making discrepancies among the three shifts at the unit level.

The reorganization of the Nursing Department was motivated by the desire to place as much of the decision making as possible at the unit level where patient care is given. Also, it was thought desirable to give the unit one line of supervision and direction through the head nurse who is responsible only to the Director of Nursing. These changes were greatly facilitated by MIS because the system enabled the head nurse and charge nurses to assume the additional management activity necessary without increasing the unit's staffing. This change brought increased solidarity to the nursing units across shifts by giving them a single line of supervision to the nursing director.

The nursing units have been grouped into three complexes---Maternal and Child Health, Medical-Surgical-Orthopedic, and Critical Care (see Figure 19). The head nurses work together within each group to manage their unit. Each complex has a rotating leadership position which includes responsibility for coordinating management activities which cross complex lines. An Educational Resource Group and an Administrative Resource Group were created and staffed by individuals who formerly held nursing supervisor jobs. These groups were formed to provide the expertise required to support the head nurses in managing their units and the staff in carrying out their patient care assignments. Labor savings as measured by the Internal Labor Measurements Model can be seen in Table 10 on page 100.

Summary of Nursing Cost-Benefits Realization

In summary, implementation of a total hospital information system (itself a new technology) focused on "cost-benefits realization" as an explicit phase critically necessary to the introduction of a viable cost-effective computer technology in the hospital. At the project's inception, it was assumed that many cost benefits would generally drop out once stable operation had been attained.

Because of the complexity and pervasiveness of the system at the nursing level, there was a distinct and explicit implementation phase necessary to convert *potential* cost benefits to *actual* gains in productivity. After the system had been physically installed and had attained fairly stable operation, it was necessary to teach nurses how to utilize the computer technology most effectively in handling medical orders, nursing orders, and other information-processing tasks on the unit. It also was necessary to teach nurses how to reallocate their time among the new set of activities and to assume new roles in a substantially modified organizational setting. This process of change has existed over the last two and one-half years and continues, seemingly, at an increasing tempo.

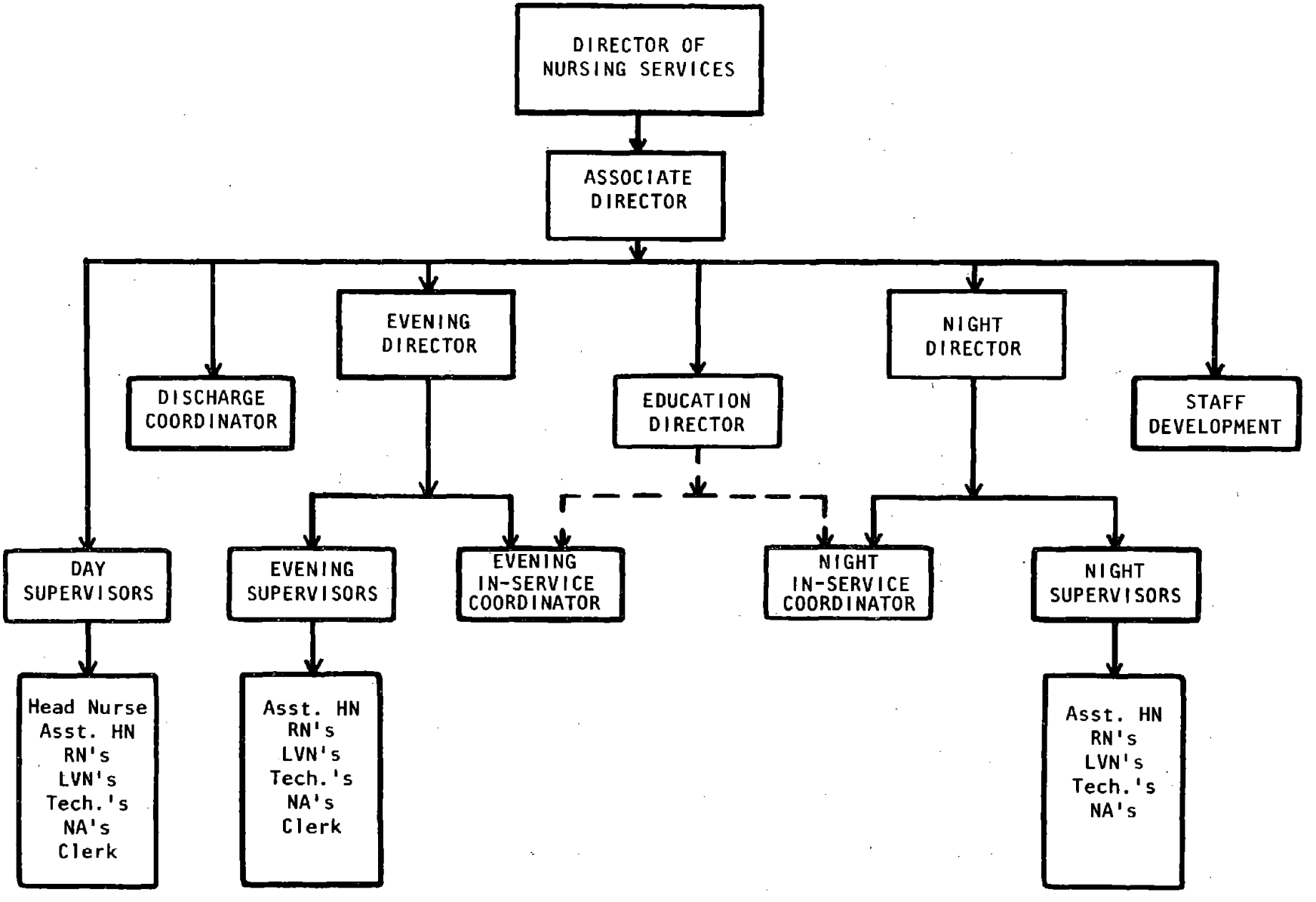


Figure 18. Old Nursing Organizational Structure.

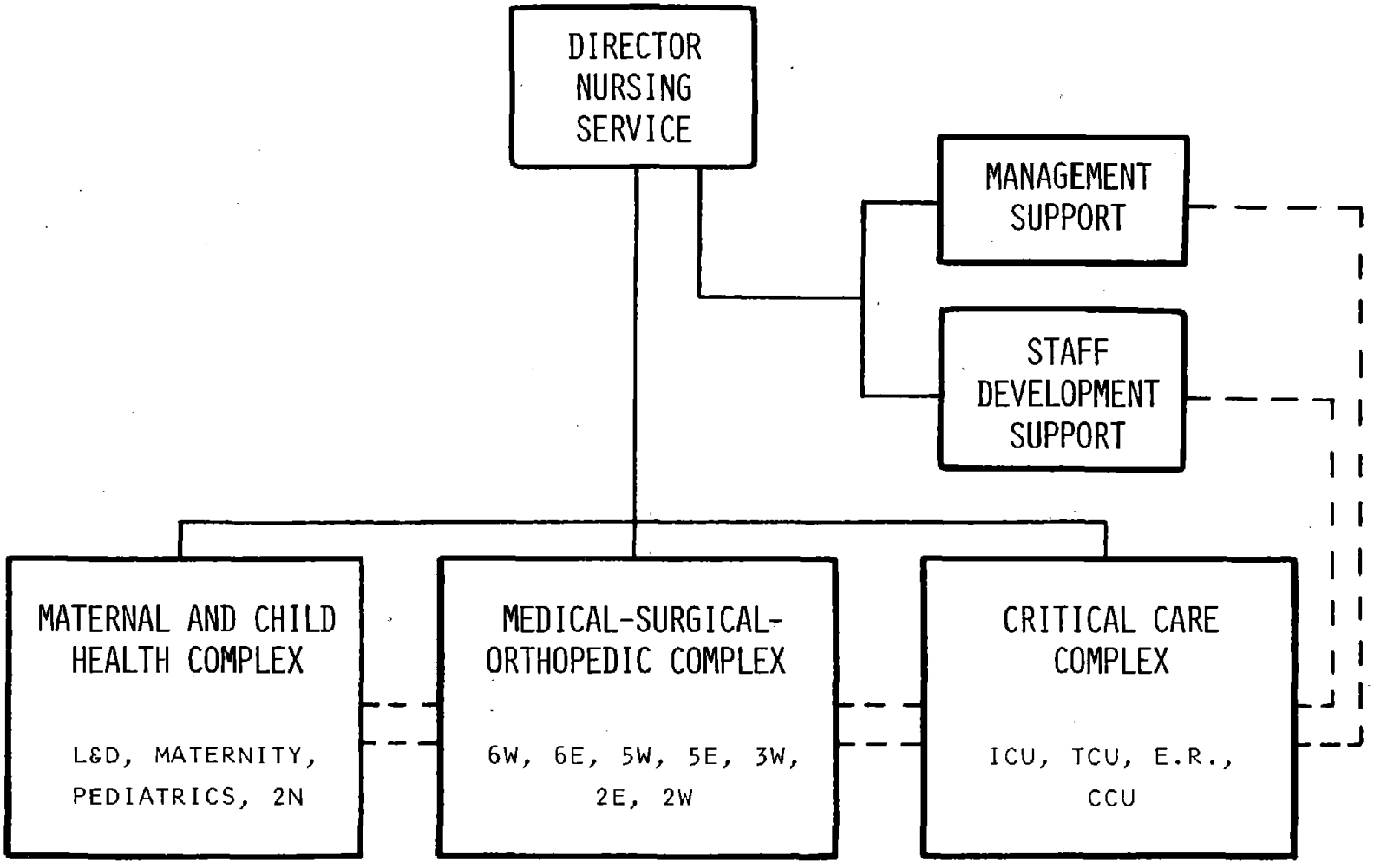


Figure 19. New Nursing Organizational Structure.

These changes had to be supported with both close management involvement and new management tools which measure and evaluate the impact of cost-benefits realization efforts. Only under these circumstances was it possible to reap the potential labor savings by redirecting the time savings into new nursing activities or releasing it to reduce labor cost.

Ancillary Cost-Benefits Realization

The cost-benefits realization effort in the ancillary service departments at El Camino Hospital can be categorized into three time periods. The first time period included initial benefits which were derived directly from the implementation of MIS. These benefits were preplanned and achieved with minimal effort at the time of implementation. Secondly, benefits were achieved as a result of an accelerated ancillary realization program. This program was undertaken after implementation from March through July of 1973 by analyzing the cost impacts of the MIS system in the ancillary areas and by developing work methods to convert potential cost benefits to actual savings. A team consisting of two ECH management engineers and one Technicon system analyst performed studies in Clinical Pathology, Radiology, the Pharmacy, EKG-EEG, the Emergency Room, Central Service, Admitting, and the Business Office. This team in the first phase of operation identified and realized all of the cost benefits that were a direct result of implementation of the system. In a second phase, they sought additional cost benefits through hospital methods improvements oriented toward best utilization of MIS in intra- and inter-departmental activities. The third period is an open-ended one involving realization of economic benefits developed in the period following July 1973, resulting from further development and refinement of the MIS system and continuing management engineering efforts. The ancillary cost-benefits realization process is discussed further by department.

Admitting Department

Initial cost benefits in the Admitting Department involved the reduction of patient registration time, substitution of MIS labels in place of the Addressograph patient identification plate, and the elimination of the distribution of admit notices throughout the hospital. Since 60 percent of all patients are pre-admitted in MIS, including almost all elective surgeries, registration can be achieved in as little as five minutes.

The first task undertaken during the accelerated ancillary realization program involved documentation of all manual operation procedures and a comprehensive study of all workload factors and requirements using MIS. A new set of job procedures eliminated many previous tasks that were now redundant or not necessary with MIS. New products developed to improve MIS utilization included a pre-admit list, an elective surgery list, daily admission reports, daily discharge reports, and a real-time bed census.

With the basic MIS configuration and these added features, MIS directly replaced two FTE's of admitting labor. Additionally, because there was little work during certain time periods, the Admitting Department was closed from 9 P.M. to 5 A.M. during the week and from 9 P.M. to 8 A.M. on weekends for a

trial evaluation period. During these periods, the Emergency Department handled unscheduled admissions to the hospital. After a 1-month test, the hospital decided to close Admitting only from 11 P.M. to 5:30 A.M. Friday and Saturday nights and made a plan to close the department every night from 11 P.M. to 5:30 A.M. when the department moved to its new location in 1975. By implementing this program, an additional savings in the Admitting Department of 1.1 FTE clerks has been realized for a total of 3.1 FTE's, in spite of an increased number of admissions.

An analysis of all hospital registration procedures was made and new procedures for the registration of outpatients and Emergency Room patients were written. An analysis of work content was made in both departments which concluded that with MIS, all registration procedures could be consolidated under one department. This reorganization would consolidate registration of patients and thus ensure the best conditions for proper patient identification and location and the correct retrieval of patient and guarantor data. In addition, new services would be provided by extending outpatient registrations to all times of the day and to all days of the week. This plan has saved the hospital 1.1 FTE clerks (as noted above) and has a potential of saving one additional clerk when both inpatient and outpatient registrations are physically merged in the summer of 1975.

Emergency Department

MIS benefits in this department consist of direct labor savings, improved revenue capture, and faster turn-around time on tests. Improved revenue capture comes about by positive registration, insurance verification, and real-time generation of account identification and charges in the BOS system. Because physician orders are entered directly into MIS and routed to proper departments, nurses do not have to prepare test requisitions and tube them to the correct departments. This procedure speeds test requests and saves labor.

Central Service

Savings in this department have resulted from automatic pricing of Central Service items. Comparative analysis of itemized charging disclosed actual savings in excess of eight hours per day and a reduction of one FTE.

EEG and EKG

Savings in this department consist of labor saved due to automatic billing, utilization of "work-completed" lists, "work-pending" lists, and work sheet printouts. Clerical task time reduction is approximately two hours per day.

Business Office

The following cost-saving benefits have been implemented in the Business Office: (1) The automatic interface between MIS and BOS has eliminated keypunching and, as a consequence, keypunch labor has been reduced by 3 FTE's. (2) The Business Office communicates through MIS to the nursing station to reduce the flow of patients who must visit the cashier at time of discharge.

Cashier labor has been reduced by one FTE. (3) The clerk that enters charges and receipts into the MIS terminal is entering surgical procedures at the same time that she enters Operating Room charges. This practice provides the physician, Medical Records, and the Business Office with timely data necessary for both billing and the permanent medical record. Fewer phone calls are placed to the Business Office billing clerks, attributable to better recording of personal data and charges on patient statements. (4) Labor savings also occur because each day labels are printed for all Emergency Room and outpatient visits for the prior day for use on billing folders. This feature saves one to three hours of labor per day depending on the number of Emergency Room and outpatient visits. (5) Insurance data are transferred automatically to the billing system for the different types of outpatient and Emergency Room patient insurance billed.

Inhalation Therapy and Pulmonary Function

These departments did not show labor savings but rather an increase in labor. This phenomenon is a prime example of an outside variable that had an impact on the hospital's analysis of labor reduction. These were new departments, opened just before the implementation of MIS, and they experienced normal growth as their services became known and utilized. Their workload and staffing increased approximately 100 percent. There has been a slight increase in productivity in these departments during this period of expansion.

Laboratory

The Laboratory at this time has not realized any labor savings. This outcome is a consequence of the original system design. As originally designed, laboratory results had to be entered into MIS by means of a clerk rather than being captured when generated. This added function turned out to be much more time-consuming than anticipated; consequently, the system had to be redesigned to substantially eliminate this added function. The redesign is being accomplished by automatically interfacing the SMA 18 and by providing the capability to input data from other tests using mark-sense cards. Also, an automatic interface with the Coulter-S equipment is being developed. After these changes have been completed, a benefits realization program will be instituted in the Laboratory as has been done in other departments following MIS implementation.

Medical Records

Analysis in this area began with the view maintained by Medical Records personnel that MIS had caused or increased workload in the department and that charts had become unwieldy and were missing important data. Initial analysis showed that the physical layout of the department was inefficient and that poor work flow caused many extra steps. A total reorganization of the department layout greatly improved the flow. Analysis also revealed that a new requirement for an abstract implemented two months prior to MIS caused a chart backlog to build up. This build-up was compounded by the initial MIS configuration that required all MD's to sign the discharge order in Medical Records. The first problem was reduced over a period of time; the MIS problem was corrected in late 1972.

A problem of chart bulk developed during the first year of MIS use, but this volume was reduced by substantially improving the chart format. These initial problems resulted in an increase in staff of three FTE's. As the MIS problems were reduced, the department acquired additional tasks such as medical audit and utilization review support. At the same time, the increase in admissions has resulted in a 14 percent increase in the number of charts that this department processes.

Final results of analysis in this area have led to the conclusion that there were no staff reductions in Medical Records. The system does benefit the department because they can do a much more complete check on the accuracy and completeness of charts with the audit trails provided by MIS. With further planned developments in MIS of long-term record retention and inclusion of more data, there will be some resultant cost savings.

Pharmacy

The benefits available in the Pharmacy were a hybrid result of MIS and the unit-dose medication system, since both were implemented at the same time. There were benefits that could be attributed to MIS in the areas of direct labor savings, turn-around time, and revenue capture.

The direct labor savings were attributable to the elimination of the manual charging procedure, the elimination of medication labels typed by the pharmacist (now MIS-generated), and the elimination of M.D. order sheets handled by the Pharmacy, which resulted in the reduction of one pharmacist and the replacement of a pharmacist with a pharmacy technician. There also was a cost avoidance assignable to MIS with the implementation of unit dose because the computer handles all of the clerical work needed to maintain the patient medication profile lists. This cost avoidance amounts to three personnel based on the experience of other similar hospitals that have implemented a unit-dose medication system. The total cost avoidance and reduction then amounted to four pharmacists and the replacement of a pharmacist by a technician.

The improved turn-around time results from a more timely transmission of the medication orders to the Pharmacy. With regard to revenue capture, as medications are administered and charted by the nurse into the patient's record, the charge for each medication also is made. This practice results in the patient being more accurately charged for the medication received.

Radiology

Typing of reports directly into the VMT has eliminated the need to type patient name and identification and physician name on X-ray interpretations. Carbons are not involved, saving the time required to separate copies and dispose of carbon paper. Corrections no longer require erasures on multiple copies. A portion of the workload is facilitated by predeveloped standard radiographic interpretive statements, and approximately 15 percent of the radiology reports generated use these statements. An analysis of multi-part forms used in this department disclosed a 10 percent waste factor potential savings caused by ease of retyping versus correcting multiple copies.

Prior to MIS, a backlog of dictated reports existed. MIS has eliminated the backlog. In addition, the number of typed reports has increased, additional tasks have been assumed by the secretaries, and secretarial overtime has been reduced while at the same time the number of secretaries has decreased by 0.5 FTE.

After a technician completes an examination, he is required to status the radiology order in MIS. This procedure requires retrieving the order at the video matrix terminal and recording the status of the examination. This statusing process requires from one and a half hours to two hours per day and partially offsets the savings in other areas. Although statusing is not an economic advantage to Radiology, it does assist other areas of the hospital. It provides the nursing units with the status of radiology requests, reduces the number of phone calls to Radiology, and improves the accuracy of the nursing care plans.

The availability of radiographic results through the video matrix terminal at the clerk's work station eliminates the need to pull and replace some reports. MIS has transferred from Radiology to the Mail Room the function of mailing radiographic reports without increasing the Mail Room's staff. This task previously consumed one to one and a half hours per day of file clerk time in Radiology.

7. FUTURE EXTENSIONS

To this point, research and development with the MIS system has largely been oriented towards making the system work not only to design specifications, but as a valuable, if silent, assistant to health care practitioners of all levels in the hospital. Premised on the successful operation of the system in a cost-effective manner in terms of its basic design specifications and its extensions, plans have been made to undertake further research emphasizing the quality improvement aspects of computer-assisted patient care delivery.

The objective of this future research is to design, implement, and evaluate a computer-assisted Patient Care Quality Assurance System (PACQAS) which can be overlayed on the existing total hospital Medical Information System. Because the existing total hospital information system is operational and cost effective, it is expected that the Patient Care Quality Assurance System (PACQAS) can be operated at a very low marginal cost utilizing the existing data base and the computer power supported by the existing fundamental MIS applications.

The Patient Care Quality Assurance System would be composed of four subsystems:

(1) A computer-assisted, diagnosis-particular, outcome-oriented Nursing Care Planning Subsystem.

(2) A computer-assisted Patient Care Audit Subsystem which integrates both concurrent and retrospective aspects of nursing audit, medical audit, and utilization review into a coordinated patient care audit.

(3) A computerized Patient-Care-Plan-Based Staffing Requirements Subsystem.

(4) A computerized Services Coordination Subsystem for patient scheduling/services coordination from pre-admission through discharge.

The rationale underlying future extensions of the total hospital information system along these lines is presented below. The hub of health care delivery in the general acute-care, short-term facility is the nursing unit. Not only is this component important as the largest single user of hospital manpower, it also represents the center of the information-processing network which coordinates the care delivery process. Ancillary resources represent a close second.

Appropriate organization and efficacious utilization of nursing and ancillary resources thus is critical to the welfare of the community hospital sector. As students of management have long reiterated, *planning* plays a key role not only in the effectivenss with which resources are used, but also in the efficiency of their use. These two parameters obviously relate to the quality of health care services delivered and their associated cost.

From a theoretical viewpoint, patient care planning (particularly nursing care planning) has not been neglected. Numerous forms and formats exist; however, in the reality of day-to-day nursing this devotion turns largely to lip service because the theoretical tenets of nursing care planning have not been made operational. The failure to do so stems primarily from the problem of data management, particularly for the more sophisticated nursing care planning systems. Nurses generally regard care planning as yet another task ---one with little associated reward for the amount of time required. Realizing that nursing care planning is key to the improvement of nursing quality and containment of its cost, we have sought to overcome the traditional barriers associated with making operational sophisticated patient care planning by building on our successful total hospital information system experience. In particular, we are drawing upon our success with a less sophisticated form of computer-assisted nursing care planning which is operational throughout the hospital.

In extending our efforts, we have implemented and successfully tested on a pilot basis a computer-based form of diagnosis-particular, outcome-oriented nursing care planning. It is the initial subobjective of the future research to further refine, thoroughly evaluate, and then install throughout the hospital this computer-based patient care planning system.

A great deal of our interest in this particular form of care planning revolves around its *outcome-oriented* nature. Not only does this focus make good sense from a nursing management perspective, it also provides a vehicle for integrating the management mechanisms of nursing labor resource allocation and quality control. The measurement of the attainment of expected patient care outcomes provides a mechanism for the appraisal of nursing care quality which is both appropriate as a measure of quality, and, importantly, integral as a part of the planning process.

Secondly, the medical tasks, nursing problems, expected outcomes, and planning deadlines specified provide an obvious framework for determining near-term nurse staffing requirements. Again, the use of these elements for staffing is both appropriate from a staff prediction standpoint and integral to the care planning process. Thus, through the implementation of the specified form of nursing care planning we obtain as spin-offs a Patient Care Audit Subsystem and a Patient-Care-Plan-Based Staffing Requirements Subsystem, both of which offer assurance of significant improvements in quality.

By adding a fourth subsystem (Services Coordination Subsystem), we obtain what is essentially a hospital-wide Patient Care Quality Assurance System. The total PACQAS system has a particularly unique quality. It is anticipated to operate at little or no increase in cost as a part of the existing system which has been previously shown to be cost beneficial. Once having the total hospital information system, we thus obtain the operation of the Patient Care Quality Assurance System for little additional overhead.

The significance of PACQAS is that it will draw together and coordinate various quality assurance programs (viz., medical audit, utilization review, appropriate staffing, hospital quality control, nursing quality control, and nursing audit) into a single hospital-wide patient care quality assurance system. It is suggested that such a coordinated approach to quality assurance will have a synergistic effect which will produce a net quality improvement greater than the sum of its parts.

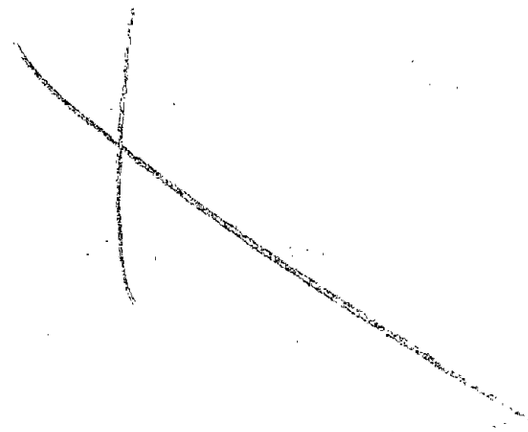
Three of the subsystems utilize a common focus (nursing care problems and their associated expected outcomes) in a unique, mutually complementary way. Resource allocation is based on production of the expected product (instead of process), and it is this product that is measured for quality. The results of quality measurement then feed back to affect resource allocation.

The data base and computer power supported in a cost-effective manner by the existing operational total hospital information system provide the capability for realizing significant quality improvements at very low marginal cost. The demonstration of this substantial quality payoff associated with implementation of a hospital information system will significantly enhance the climate of acceptance for such systems.

It is the general conclusion of the Project To Demonstrate and Evaluate a Total Hospital Information System in a Community Hospital that operation of such a system in a community hospital is not only *feasible*, but also can be *cost effective*. Furthermore, it can bring about many improvements in the quality of health care delivery and play an instrumental role in the achievement of many more. In arriving at such a conclusion, the project documents an acceptance of computer technology as a viable means for dealing with some of the significant problems facing the health care field today.

The extensions of this technology envisioned in this concluding section are technologically close at hand and represent a second, higher plateau of computer applications wherein computer involvement is extended from assumption of clerical work to provision of information for enhanced decision making and manipulation of data to provide information heretofore unavailable.

The material presented in this report thus represents only a tip of the iceberg in terms of the potential ability to be gained by further extensions of automated information-processing capabilities in the health care arena.



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APPENDIX A

DESCRIPTION OF THE TECHNICON MEDICAL INFORMATION SYSTEM (MIS) AT EL CAMINO HOSPITAL

Introduction

Introduction of the specific form of computer technology described in this report into the community hospital sector was originally proposed as a technological means for contending with the growing impact of three widely acknowledged problem areas: burgeoning clerical workload, sharply rising labor rates, and under-utilization of professional nursing skills. By transferring to the computer a major portion of the clerical work which is necessary to the delivery and documentation of care in an acute care setting, such a system, it was postulated, could (1) reduce the amount of clerical work and consequently staffing levels, (2) provide a hedge against inflation by replacing rising labor costs by fixed-price capital equipment, (3) improve resource utilization by freeing nurses for more duties commensurate with their professional skills, and (4) enhance quality by reducing errors, improving communication, and expanding the informational data base available to staff.

More specifically, the hospital information system which forms the focus of this report was designed to assume the substantial clerical burden spanning the originating point of medical directives (the doctors' orders) to the documentation of their completion (e.g., medications given or test result values). The system also would take over the amplification of such orders into nursing care plans and supplemental communication necessary to carry out orders, to document patient status, and to communicate patient information. In plain words, it was designed to take over the bulk of paperwork that nursing and ancillary staff traditionally have had to assume. In order to perform these functions, this system would have to do three basic things: (1) provide a means for capturing information at its source, (2) provide a means for computer processing and storage of these data, and (3) provide a means for display and printout of these data.

An Overview of MIS

This is a description of the Technicon Medical Information System (MIS) as it actually operated at El Camino Hospital in 1975. System operation in other Technicon client hospitals varies somewhat from this description. MIS is a hospital-wide system which uses a computer to store data and to send it, automatically or upon request, to the people who need to act upon it. The computer adds speed and accuracy to the transmission of information throughout the hospital and also performs many data processing tasks such as sorting, copying, filing, summarizing, checking for abnormal data, pricing, and a variety of other functions which are usually done by physicians, nurses, technologists, clerks, and other hospital personnel. A broad range of *medical* data (physicians' orders, test results, etc.) and *administrative* data (responsible party, insurance coverage, etc.) are processed by the computer.

Hospital personnel communicate with the computer by means of two devices: the Technicon Video Matrix Terminal (VMT) and the Technicon Multiprinter. The VMT consists of a television screen, a light pen, and a keyboard (see Figure A-1). VMT's are located throughout the hospital and are used to record (send) new information to the computer, or to retrieve information such as laboratory results, the time of the last dose of medication, and so forth. Each person who is authorized to use the VMT has a unique identification code. This code limits the capability to send and receive information, based upon the individ-

Figure A-1. Technicon Video Matrix Terminal (VMT) of the Type Installed at El Camino Hospital.

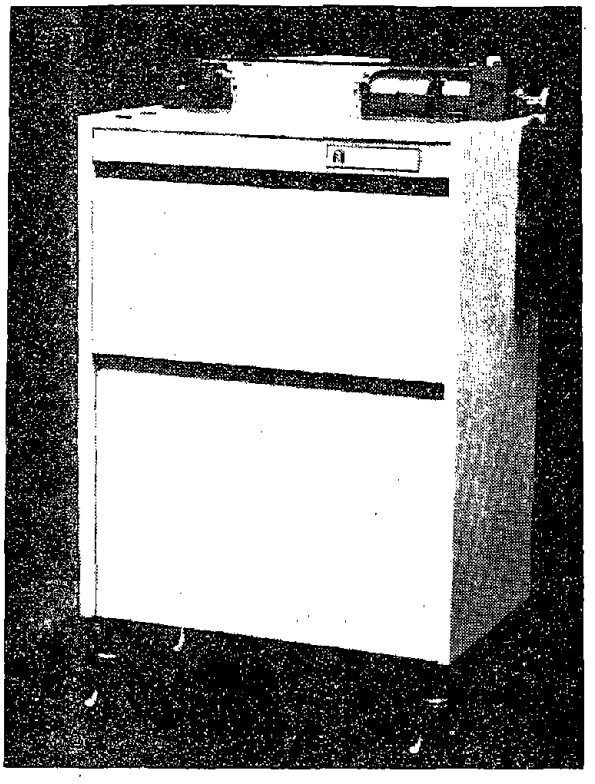


Figure A-2. Technicon Ink Jet Printer of the Type Installed at El Camino Hospital.

ual's position and the hospital's policies concerning data access control. Use of the VMT is based on the elementary communication technique of pointing. The television screen is used to display lists of items, for example, laboratory tests. A specific item is selected by pointing the light pen at the desired word (or phrase) and pressing a switch on the barrel of the pen. Using the light pen, a physician can select the specific patient, and then "write" a full set of medical orders (laboratory work, medications, X-rays, diet, activity, vital signs, etc.). The computer then stores the orders and sends appropriate documents (e.g., laboratory requisitions, pharmacy labels, and X-ray requisitions) to the proper hospital departments.

The keyboard on the VMT is used to supplement the light pen. In departments such as Admitting, the keyboard is used extensively to record the patient's name, address, responsible party, and other such information which cannot be written using the light-pen technique. Physicians, nurses, and other hospital personnel use the light-pen technique extensively and employ the keyboard only occasionally. The keyboard permits complete freedom to write special instructions or unique orders that are not available for light-pen selection.

The Technicon Multiprinter is a quiet, high-speed, computer-driven, ink jet printer (see Figure A-2). These printers are located throughout the hospital so that each document prints where it is needed. Computer-produced printouts, in addition to those referred to previously, include the following: Patient Care Plans, Medications Due Lists, Laboratory Specimen Pickup Lists, Cumulative Test Results Summaries, Radiology Reports, Discharge Summaries, and more than one hundred documents.

In summary, MIS is a comprehensive data system for patient care and hospital management functions. It uses a large-scale computer and advanced input/output devices to record information at its source and to make this information available throughout the hospital when and where it is needed. Its basic objective is to provide better patient care and more efficient hospital operations through an improved communication system. MIS substitutes computer processing for manual data processing, thus gaining advantages in terms of speed, accuracy, cost, legibility, and completeness and consistency of data.

MIS Scenario - Admission to Discharge

A patient's computer record originates when he is admitted or pre-admitted. Using special VMT displays which are similar in content to conventional Admitting forms, the admission clerk assembles the patient's basic record, consisting of name, age, sex, address, insurance coverage, and so forth. The computer stores this information and makes it available for use by physicians, nurses, and other hospital personnel.

The physician, upon identifying himself by typing in his code at any VMT keyboard, receives a list of his patients on the VMT screen. He selects a particular patient and then can either write new orders for the patient, or review any previous orders or test results. When the physician writes new orders or renews or discontinues previous orders, a New Orders sheet is immediately printed at the patient's nursing station. In addition, all orders

are automatically printed as service requisitions in the appropriate hospital departments. Each requisition is uniquely formated to minimize handling. For example, a laboratory requisition prints in the form of a work sheet for the specific test ordered, including spaces for all results to be filled in. In addition, the computer periodically prints Specimen Pickup Lists presorted in bed number sequence. For each drug order, the computer automatically prints appropriate documents in the Pharmacy---a prescription record, a gummed label for the medication bottle, an allergy alert notice, and a patient medication profile for use in pharmacies employing "unit-dose" dispensing. Dietary orders print in the form of a consolidated Diet Orders List, generated just prior to each meal. This Dietary Department printout is in bed number sequence with a separate page for each nursing station.

The computer also generates many follow-on documents as a result of medical orders. These include the following: Medications Due Lists printed at each nursing station for each hour of the day, Daily Orders Summaries which show both newly written orders and all current orders, and Reminder Notices for overdue laboratory work, medications, and so on. For all orders which are to be accomplished on a future date, the computer automatically schedules these requisitions to print in the appropriate departments on the correct dates.

When the Laboratory, Radiology, or other service department has completed a diagnostic test or examination, the results are entered into MIS by light pen, by specialized keyboard, or by direct hardware interface, depending upon which method is most efficient and accurate. As test results are entered into the computer, they immediately become available for screen retrieval by authorized personnel at any VMT. In addition, the computer summarizes and prints all laboratory results for each patient periodically at the nursing station. Stat. tests receive special immediate processing throughout the system, and the Laboratory also has the capability to assign "RUSH" (immediate) processing to any unusual test result.

Just prior to the start of each shift, the computer prints a Patient Care Plan for each patient. This document combines diet and fluid balance orders, medications to be given, laboratory work, nursing instructions, and patient data such as "wears dentures" or "speaks Spanish." The care plan is used for the shift change report and for giving (and annotating) care throughout the shift. Nurse reporting of medications given, intake and output, and other patient data is done by VMT using special video displays and the light pen.

Every night the computer reviews each patient's record to determine the charges that have accrued for the day (e.g., daily hospital service charge, medications given, and laboratory tests). The appropriate charges for each item are looked up by the computer and the billing file is updated.

After the patient is discharged, the computer goes through the complete patient file and prepares a series of documents, including a Test Results Summary, insurance forms, the patient's bill, and a Medical Record Abstract. Throughout the patient's stay in the hospital, and at discharge time, the computer has printed a series of documents which now become a part of the chart to be filed in Medical Records. In addition, the patient's complete computer record is retained on magnetic tape at the computer center.

A Detailed Description of How MIS Functions
(by Departments and User Groups)

Admitting, Outpatient Department, and Emergency Room

Admitting clerks use VMT's to generate, review, and modify patient admission records. Data are typed directly onto "video forms" on the VMT screen rather than on paper (see Figure A-3). The computer stores admission data, assists in bed assignment, and automatically prints admission records and notices at various locations in the hospital. The following paragraphs describe the MIS system as it impacts upon the following functions:

- Pre-Admission Records
- Admission Records
- Case Number Assignment
- Bed Assignment
- Transfer/Discharge/Expiration Data
- Outpatient Processing
- Emergency Room Patient Processing

Pre-Admission Records. For elective admissions, a Pre-Admission Record is established in the computer prior to admission. This record is generated by typing onto video forms and may be retrieved on the screen as frequently as necessary to add data or revise data prior to admission. Physicians can use the patient's Pre-Admission Record as a basis for writing medical orders to be accomplished either before or at admission time. It generally is not necessary to maintain any paper record for patients in pre-admission status.

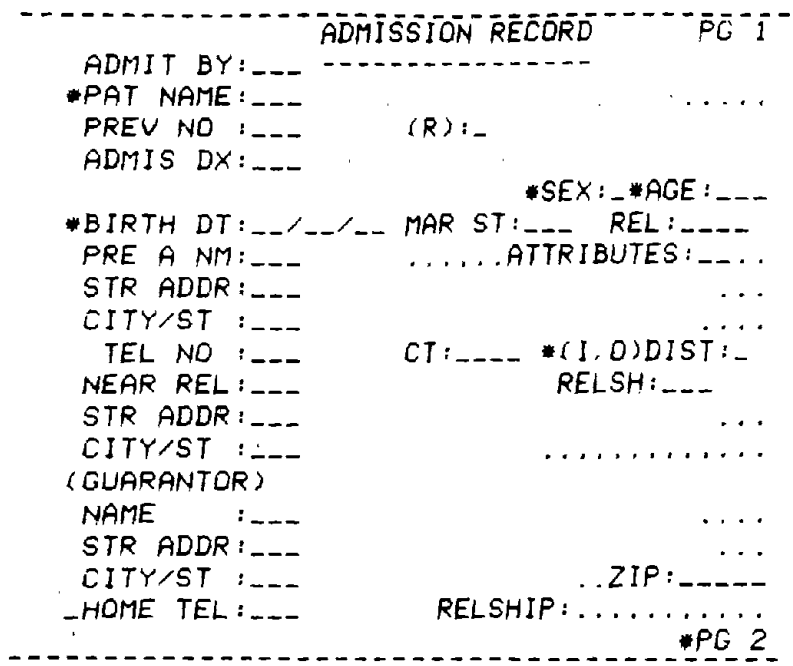
Admission Records. When a patient is admitted, the admitting clerk either completes a Pre-Admission Record, or, if the patient is nonelective, generates a complete admission record using the video form. A new long-term storage file currently is being added to MIS. This file will contain a permanent on-line record of all inpatients and outpatients including case numbers, full name, previous name(s), last address, and so forth. This file will simplify the re-registration process.

The video form technique of generating admission records differs from paper records in several respects:

1. Video forms are limited to 800 characters per page on the video screen. However, the computer can consolidate several screen pages into one printed form.

2. Typing errors can be corrected on the screen without erasure by simply backspacing and over-typing. This feature saves both time and spoiled forms.

3. Tabbing from one type-in area to the next is more convenient on the video form, as the computer-controlled tab key moves to the next area, regardless of its position on the page.



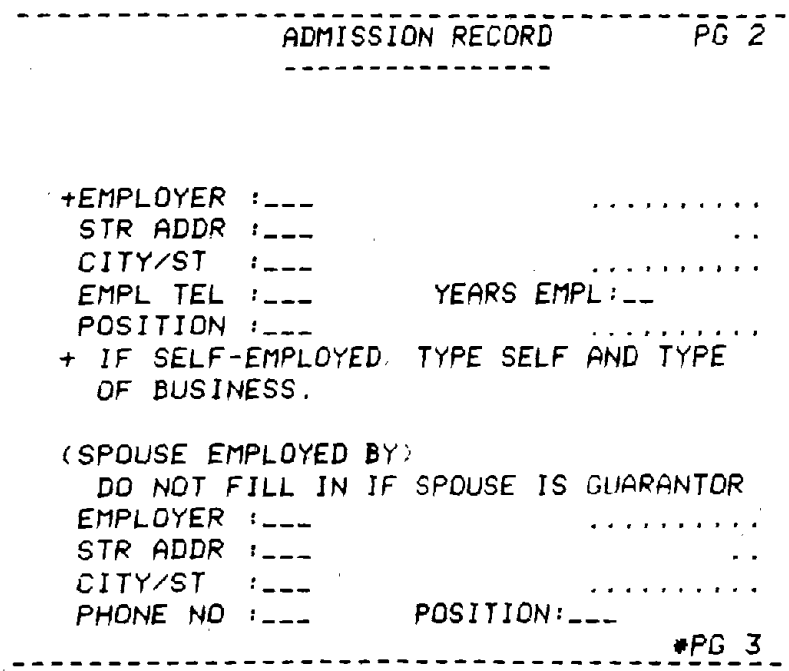


Figure A-3. Admission Video Forms.

On admission the computer automatically sends printed admission notices to various hospital departments as designated by hospital policy. For example, these records might be sent to the patient's nursing station, the Business Office, and the Information Desk in addition to the Admitting Department itself. The patient's admission record is available for VMT screen retrieval throughout the hospital by any authorized person.

Case Number Assignment. A hospital may elect to have the computer automatically assign case numbers to inpatients, outpatients, and Emergency Room patients with separate patient number logs being maintained in the computer for each category, or at the hospital's option a manual case number assignment may be made. MIS can accommodate any type of hospital-unique alphanumeric case numbering system, or can use the social security number as the hospital case number.

Bed Assignment. The Admitting Department receives two kinds of computer assistance in assignment of beds. First, the computer periodically prints a total hospital Bed Status Report. This report shows all available beds and includes age, sex, diagnosis, and attending physician for each patient. Secondly, as patients are admitted, the admission clerk can view an up-to-the-minute list of available beds at each nursing station on the VMT together with information about roommates (e.g., age, sex, diagnosis, smokes). For some nursing care areas (e.g., Psychiatry and Pediatrics) the Admitting Department may assign the patient only to a nursing unit. The unit then assigns the specific bed number. Once the patient's bed assignment has been entered into the computer, it is immediately available for retrieval by any authorized person in the hospital. The computer also periodically prints Patient Locator Lists which are used by many hospital departments.

Transfer/Discharge/Expiration Data. When a patient is transferred from one bed to another, this information is entered into MIS at the nursing station. MIS automatically makes all the necessary record changes and immediately notifies affected departments.

MIS discharge/expiration processing is as follows:

1. The physician uses the VMT to write a discharge authorization or an expiration statement.

2. The nurse uses the VMT record to record the discharge time and notes, or the expiration notes.

3. The computer stores this information and immediately notifies all affected hospital departments.

Upon receipt of discharge or expiration data for a patient, the computer sets a series of actions in motion which will continue over the next two to four days. These include the following:

1. Preparation of the last Daily Summary for the patient.
2. Preparation of a complete Test Results Summary for the hospital stay.
3. Preparation of a Medical Record Abstract.
4. Preparation of the patient's bill.
5. Movement of patient data from active computer storage to inactive storage. This action is under the control of the Medical Records Department.

Outpatient Processing. MIS recognizes two kinds of outpatients: *one-time* and *recurring*. When the patient is expected to have only one outpatient visit for X-rays or laboratory work, for example, his record is retained in the computer for two days or for any other time span stipulated by the hospital. Recurring patients, on the other hand, are likely to have repeated visits (e.g., for physical therapy). For such patients the computer records are maintained indefinitely, as long as there is activity at least once per month. This feature obviates re-registering the patient for each visit. Outpatient registration is accomplished by video form. Entry of medical orders for outpatients is also done by VMT---optionally at the Outpatient Desk, or by the department doing the work. The computer prints requisitions for laboratory tests, X-rays, electrocardiograms, and so on at the appropriate departments. Test results are recorded into MIS, along with the applicable procedure number(s), and printed in the hospital and at the physician's office. A new capability is now being added to MIS which will enable the Outpatient Department to use the VMT to look up the case number of an outpatient regardless of the time lapse since the last visit.

Emergency Room Patient Processing. Emergency Room patients are registered using the video form technique. The computer immediately prints a label in three copies. A label is attached to each part of a 3-part Emergency Room Record form. This method enables the Emergency Room Record to be available for immediate use in recording patient care before the patient is registered in MIS. Medical orders for laboratory tests, X-rays, medications, and so forth for Emergency Room patients are recorded into MIS by VMT. The computer automatically codes all Emergency Room orders for stat. processing. Emergency Room test results are entered through VMT's in the laboratories, Radiology, and other service departments, and these results are automatically printed in the Emergency Room immediately. Emergency Room charges are entered by VMT, and billing is done by the computer. Since the Emergency Room records are maintained in the same computer memory system with inpatient records, a consolidated Emergency Room/Inpatient Record is available when an Emergency Room patient is converted to inpatient status.

Medical Staff

The medical staff interacts directly with the computer by means of VMT's and by using a variety of computer-produced documents. However, the personal use of the terminal by physicians is not mandatory. An individual physician may choose to write his medical orders in the conventional manner and have the nursing staff enter them into MIS in his behalf. The major areas of physician interface are as follows:

- Patient lists and locators
- Patient data retrieval (by VMT)
- Medical information retrieval (by VMT)
- Medical order writing
- MIS documents

Patient Lists and Locators. Upon entering his identification code at any VMT in the hospital, the physician immediately receives a display of all patients for whom he is either an attending or consulting physician. This patient list is up to the minute and shows patients' names, case numbers, and bed locations (see Figure A-4). In addition, the physician can obtain the patient list of a colleague for whom he may be seeing patients. Physicians can add patients to their list whenever this action is appropriate. Many physicians request the computer to print their patient list, and they carry this list as they make rounds. The list is date and time stamped by the computer and is used by some physicians for billing purposes.

Patient Data Retrieval (by VMT). Physicians can quickly retrieve patient data at any VMT in the hospital. Retrieval is accomplished by selecting the desired type of information from the Retrieval Guide. The retrieval categories include the following:

- Admissions data
- Laboratory test results
- X-ray reports
- Medications given
- Current orders
- All orders since admission
- Nursing notes
- Diagnoses
- Allergies

Each category can be broken down more specifically to isolate the desired data. For example, laboratory results can be retrieved by department and/or by date(s). VMT retrieval reflects all information that has been entered from any point in the hospital up to the moment of the retrieval request.

Medical Information Retrieval (by VMT). MIS has a generalized storage and video retrieval capability which can be used for a wide variety of medical data. Its present usages include abstracts of current articles from surgical journals, antibiotic sensitivities and drug of choice information, laboratory test results interpretation aids, hyperlipemia work-up information, and several other subjects of interest to physicians in hospitals now using the MIS system.

Medical Order Writing. In using the VMT to write medical orders, the physician receives a number of computer assists. These include the following:

- Medical information retrieval capabilities as described above.
- An order-writing Master Guide which helps remind the physician to "touch all bases"---laboratory work, medications, vital signs, diet, fluid balance, activity (see Figure A-5).
- Specialized VMT displays which show hospital or departmental guidelines for treating particular types of patients. These may include coronary care, hemodialysis, psychiatry, pediatrics, maternity, and so on.
- A VMT display showing all orders now in effect for the patient. This display also permits the physician to discontinue or to renew any order.
- The capability to store personal order sets in the computer. The physician can generate a personal order set for any preoperative or postoperative condition or for any diagnosis. He then can write the complete order set for any patient with a single light-pen selection. He also has the capability to use any part of a personal order set and to modify, delete, or add other orders. (See Figure A-6.)
- The terminology used in the VMT order-writing displays (laboratory test names, radiological procedures, etc.) is coordinated with all hospital departments when the displays are originally created and each time that they are modified. This coordination means that standard, well-understood terminology is used.
- The VMT displays are designed to insure complete orders. Two examples of this feature are as follows: vital signs must be stated specifically as temperature, pulse, respiration (TPR), and medication orders must contain the drug, dose, route, and frequency.
- The computer generates a printed copy of new orders immediately after they are entered. This procedure eliminates the common problem of illegibility of the physician's handwriting.
- The computer automatically routes all orders to the appropriate hospital departments without the need for manual transcription onto requisition forms. This practice ensures that the orders go to the proper department, are worded precisely as stated by the physician, and are received immediately. For orders to be accomplished on a future date (fasting laboratory work, etc.), the computer holds the order until the proper time and then releases it to the appropriate department.
- The computer follows up to ensure that the physician's orders are carried out on a timely basis. If they are not, a Reminder Notice is printed at the appropriate location.

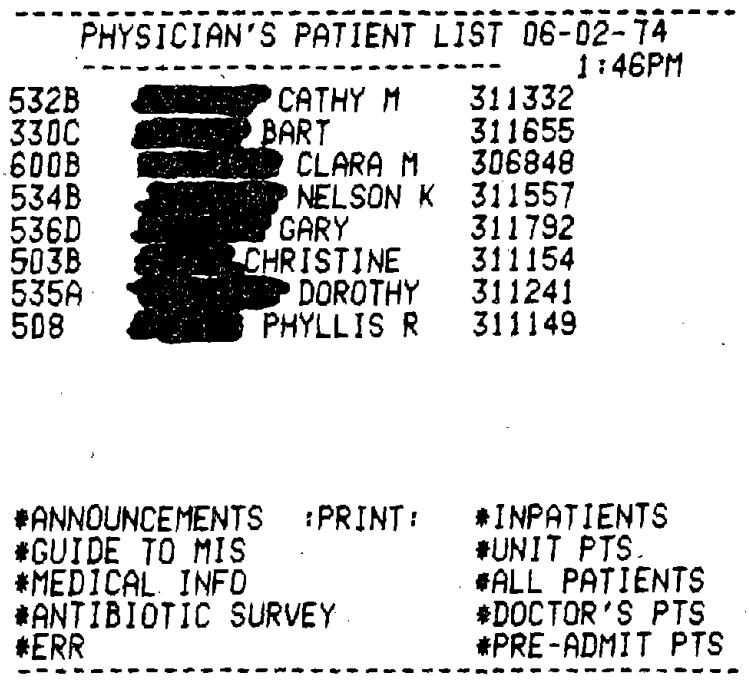


Figure A-4. Example of a Physician's Patient List.

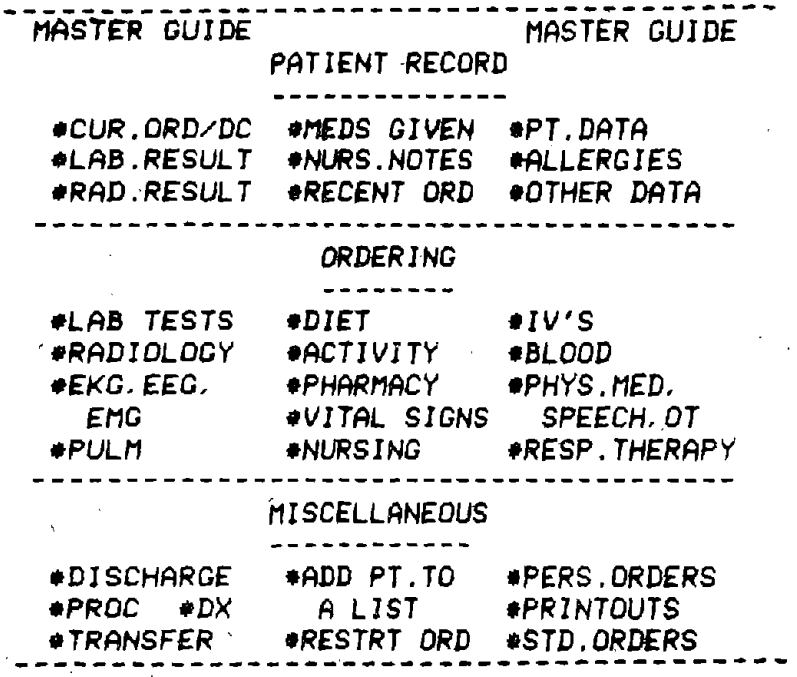


Figure A-5. Physicians' Master Guide.

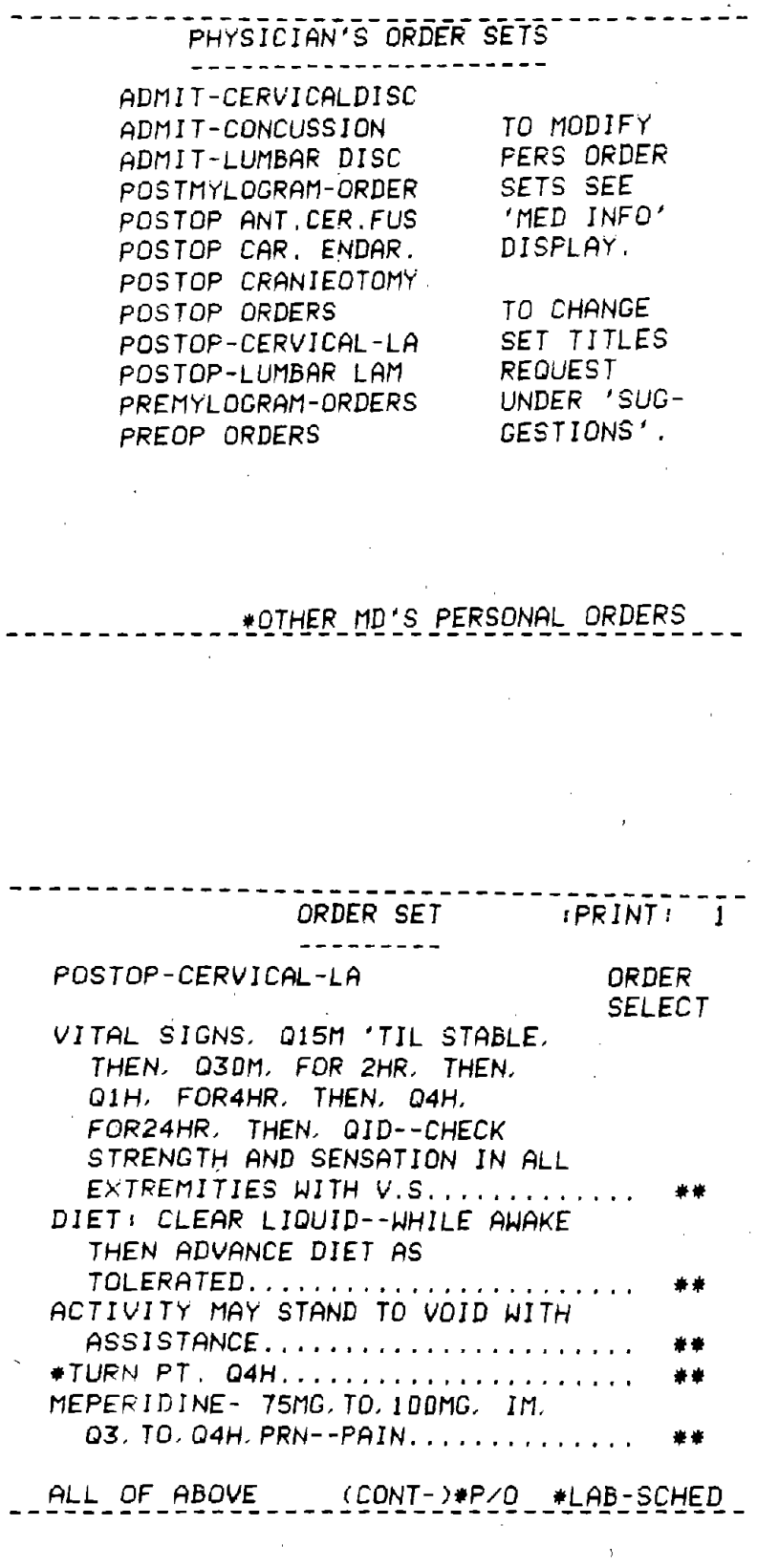


Figure A-6. Example of a Physician's Personal Order Sets: Complete Sets (above) and Orders Within a Set (below).

MIS Documents. The medical staff uses a variety of computer-produced printouts in analyzing and documenting the patient's status and care. Twenty-four hour summaries are printed at designated times during the day, nursing data are printed just prior to morning rounds, laboratory data prior to afternoon rounds, and order summaries during the night. In addition, all stat. work is printed immediately after it is entered into the computer. MIS also produces 7-day accumulative reports for test results, medications, and intake/output. These 7-day reports enable the physician to quickly spot trends. After the patient is discharged, the computer produces a complete printout of all laboratory and X-ray reports. A copy of this document is mailed to the physician's office. The physician can obtain an Insurance Form from MIS for use by his office in filing for third-party payments.

Nursing

Nursing personnel use MIS extensively. One or more VMT's is located at each nursing station. These VMT's are used by registered nurses, licensed vocational nurses, aides, and ward clerks. The VMT functions of each user class are determined by hospital policy. The nursing functions upon which the computer system has had an impact include the following:

- Patient care planning
- Medication administration and reporting
- Requisitioning tests and supplies, including medicines
- Reporting of nursing data (charting)
- Verbal and telephone orders

Patient Care Planning. On either a daily basis or an each-shift basis, MIS prints two copies of a Care Plan for each patient. One copy is retained by the head nurse, and the other copy is used by the nurse(s) responsible for patient care. Figure A-7 shows an example of a Patient Care Plan. The Care Plan consolidates all appropriate (i.e., current) medical orders, nursing instructions, and general patient information that has been entered into the computer at various times by various personnel. The format of the Care Plan is optional. The following kinds of information may be included:

- Basic patient data (name, age, sex, attending physician, and so on)
- Diagnoses and surgical procedures
- Vital signs orders
- Diet and fluid balance orders and instructions
- Hygiene/activity/safety orders
- Medication orders
- Other orders (e.g., laboratory tests, X-rays, and electrocardiogram orders)
- Care planning instructions, problems, objectives, and target dates.

```
4WEST-2954          EL CAMINO HOSPITAL
 1/26/74  1:22 PM          PAGE 001          PATIENT CARE PLAN.
[redacted] CARMEN          F 59 226B  SERV: SURG
  301928      ADM: 01/20/74 [redacted] DEAN T. MD          7:00 AM  1/26/74
```

DX:
CHOLELITHIASIS
01-21-74:CHOLECYSTECTOMY WITH CHOLANGIOGRAMS.

PT CARE PLANNING:
1/20 PT WEARS GLASSES
1/20 MED TAKEN:--MAALOX
1/20 ALLERGIC TO: NONE KNOWN
1/20 EXISTING COND:ANXIETY
1/20 --PRIMARY SYMPTOMS HAVE BEEN GAS & HEARTBURN. 65 HAD HYST. & HERNIA REPAIR. LIVES WITH SON& DGHT.IN LAW. IS VERY ANXIOUS & NEEDS LOTS OF REINFORCEMENT & SUPPORT.LLW
1/20 CHOLECYSTECTOMY C/WO CDE SCP

DIET AND FLUID BALANCE:
1/25 DIET: REGULAR LOW FAT. (DTC).

HYGIENE/ACTIVITY/SAFETY:
1/21 POSITIONING: ELEVATE FT OF BED 20DEG. (DTC).
1/22 ACTIVITY. AMBULATE WITH ASSIST. (DTC).
1/25 HYGIENE: SHOWER. (DTC).

PROCEDURES:
1/21 #CATHETERIZE PRN. (DTC).

MEDICATIONS:
1/21 TIGAN-INJ: TRIMETHOBENZAMIDE- 200MG. IM. Q3H. PRN NAUSEA. (DTC).
1/21 MEPERIDINE- 50MG.TO.100MG. IM. Q3H. PRN PAIN. (DTC).
* 1/23 DALMANE CAP-30 MG. 1.PO QHS PRN. (01/23 09PM-..). (DTC).
1/23 DALMANE CAP-30 MG. 1.PO MR X1. (DTC).
1/25 PHENAPHEN&CODEINE-30 MG.CAP. #1 TO #2.PO. Q3H. PRN. (DTC).

OTHER DEPT:
1/21 INCENTIVE SPIROMETER. (DTC).

LAST PAGE

-#-

Figure A-7. Example of a Patient Care Plan.

Medication Administration and Reporting. In the MIS nursing data system there are no Kardex files or medication tickets. Instead, the computer prints an hourly Medications Due List for each nursing station, showing all medications to be given during that hour. The Medications Due Lists can be used in conjunction with a conventional pharmacy dispensing system or with a unit-dose pharmacy system as described below under Pharmacy. After medications are administered, they are reported at the VMT by selecting *given* or *not given* to correspond to each order. When reporting injectible medications, the site is also selected by light pen. When a medication is reported as *not given*, the VMT immediately displays a list of reasons why the medication was not given, from which the nurse selects the proper choice. If a particular medication is not reported, a Reminder Notice is printed by the computer. Medication reporting generates both daily and weekly reports and also triggers computer billing for the precise amount of the medication that was administered. There is no need to adjust the billing for unused medications.

Requisitioning Tests and Supplies, Including Medicines. All medical orders entered into the VMT by physicians are automatically transmitted (as requisitions) to the proper departments; therefore, nursing personnel do not have to transcribe orders onto either requisition forms or charge slips. Both the initial supply and follow-on supplies of medications are sent to the nursing station by the Pharmacy, based upon computer-produced printouts in the Pharmacy. When Central Service supplies are required, the nurse uses the VMT to request the desired items. The computer then prints a requisition in the Central Service Department and inserts the correct charges into the patient's billing file.

Reporting of Nursing Data. The scope of nursing data entered into the computer system may vary from nursing station to nursing station. For instance, while all stations may report medications given, intake/output, and patient care planning instructions, certain stations may also use the VMT to report vital signs, activity, procedures, and general nursing notes. The system lends itself to goal-oriented care planning and reporting using exception reporting principles.

Two modes of entering nursing data by VMT are programmed into MIS. The first---*functional reporting*---permits the nurse to enter routine vital signs or scheduled medications for all patients on the unit instead of calling up each patient's record, one at a time. This reporting procedure is very efficient for recording one particular type of data for a series of patients. The second method---*individual reporting*---involves calling up a particular patient's record and entering one or a series of data items for that patient only. This method is used for nonroutine vital signs, diet and fluid balance, unit tests and examinations, hygiene/activity/safety procedures, unscheduled medications, and miscellaneous information and observations.

The MIS system includes specialized VMT displays for nurse reporting in pediatrics, psychiatry, surgery, maternity, nursery, and other specialties. All nursing data entered into the VMT are printed on periodic Nursing Record and Nursing Notes printouts.

Verbal and Telephone Orders. Nurses use the VMT to enter medical orders which they have received verbally or by telephone. These orders are printed by the computer, showing both the physician's and nurse's names. They are processed like orders entered directly by the physician, except that the doctor must subsequently sign all orders which were entered by a nurse.

Laboratories

MIS has an impact on the clinical and pathology laboratories in the following areas:

- Ordering of tests/generation of requisitions and work sheets
- Specimen collection
- Recording and routing of test results
- Billing for laboratory work

Ordering of Tests/Generation of Requisitions and Work Sheets. The MIS VMT displays used by physicians to write orders for laboratory tests contain all of the tests performed in the hospital laboratories, plus any common "send out" tests. When the physician writes an order for a test, the computer analyzes the order in terms of schedule information, fasting requirements, or other necessary preparatory actions for the test, and in terms of the "batch code" for the test. Batch codes are controlled by the laboratory and tell the computer whether or not to batch the specimen for collection, and whether the test will be run on an individual or batched basis. The batch coding capability permits the laboratory to control the flow of work, including both specimen pickup and performance of tests. Nonbatched work flows into the laboratory immediately when it is ordered, and is printed on a single-patient document. Batched work flows in either at specified times, or when requested by the laboratory. Batched documents optionally may be in single-patient or multi-patient format. The format of each requisition and work sheet printed in the laboratory is tailored to the specific test. For example, a CBC (complete blood count) order prints in the laboratory as a work sheet showing the 11 hematology and morphology results to be determined, with spaces for the entry of each result. Stat. tests receive special computer processing. They are clearly marked by the computer, and a light and bell are activated in the laboratory when a stat. requisition prints. Tests ordered for a future date are held in the computer and released to the laboratory on the correct date.

Specimen Collection. Specimen collection documents may be printed on any desired schedule or upon demand. Typically, the laboratory might elect to receive batched blood Specimen Pickup Lists from the computer for the first pickup each morning, and two or three times additionally during the day. The computer prints the Specimen Pickup Lists in bed number sequence, showing patient names, case numbers, tests to be performed, type of specimen (EDTA, clotted, etc.), and volume of blood required. For stat. tests and specimens to be collected at a specific time, the computer prints individual Specimen Pickup Sheets. When making a stat. or other special specimen pickup, the laboratory technologist may request the computer to print all other pickups required for that patient and/or for all patients on the same nursing station.

This capability saves trips to the floor and also eliminates drawing blood from the patient more than once.

Recording and Routing of Test Results. Laboratory test results are entered into MIS by four methods. The most efficient and accurate method is used for each type of test. High volume test results are entered by linking automated laboratory instruments (e.g., SMA 18 and Coulter-S) to the MIS computer. The other methods are by light-pen selections made on special VMT displays, by specialized keyboard entry, and by optical mark reading (OMR) of results cards. When results are entered, they are immediately available for retrieval by any authorized person at any VMT in the hospital. The results also are printed at the nursing station for insertion into the patient's chart under the following controls:

1. Stat. tests print immediately.

2. Routine tests print on daily Cumulative Laboratory Results Summaries (see Figure A-8).

3. The laboratory can signal "RUSH" on any result and thereby cause it to print immediately as though it had been a stat. test.

4. After the patient is discharged, a total Laboratory Results Report is printed in one document for insertion in the patient's medical record.

The computer-produced laboratory results printout shows the normal range for each test, and if this patient's result falls outside of that range, it is highlighted in either red ink or boldface type. If the laboratory fails to enter a particular test result within a specified time, the computer automatically prints a Reminder Notice to the laboratory.

Billing for Laboratory Work. The charge for each laboratory test is stored in the computer system. Every midnight a computer run is made to trigger the correct charge for all tests performed that day.

Pharmacy

MIS is designed to operate in either a "unit-dose" or conventional pharmacy dispensing environment. A hospital installing MIS may wish to simultaneously convert to the unit-dose dispensing method, which has proved to be especially effective and economical when used in conjunction with MIS. MIS also has an impact upon pharmacy operations in other areas including the following:

- Medication orders/routing to the pharmacy
- Preparation of medication labels
- Dispensing of medications
- Review of patient data (medications profile)
- Billing for medications given

1/26/74 8:39 AM PAGE 002

[redacted]ETER J M 77 IC01
302041 ADM: 01/20/74
[redacted] DON C, MD

LAB RESULTS SUMMARY

REPORT PERIOD: 1/20/74 12:00 MN - 8:39 AM 1/26/74

HEMOGRAM

			LO-HI:	PCV VAR-	HGB VAR-	RBC 4.2-6.2	MCV 82-92	MCH 27-31	MCHC 32-40
			UNIT:		GM%	MILLION	CUMICR	MMG	%
SUN	1/25	6AM		35.1 *	11.3 *	3.66 *	96. *	31.1 *	32.2 *
SAT	1/24	9PM		38.1	12.7				
SAT	1/24	4PM		39.9	13.3				
SAT	1/24	6AM		42.3	14.4	4.48	94	32.1	33.9
FRI	1/23	6AM		49.6	16.6	5.21	95.	31.7	33.1
TUE	1/20	3PM		54.1	17.8	5.66	95	31.4	32.7
				54.1					

			LO-HI:	WBC 4.5-10.0	POLY 40-60	STAB 00-00	LYMPH 20-40	MONOS 04-08	EOS 01-03
			UNIT:	THOU	%	%	%	%	%
SUN	1/25	6AM		12.7 *	73 *	18 *	6 *	3 *	1 *
SAT	1/24	6AM		9.8	76	11	9	4	
FRI	1/23	6AM		4.3	68	14	14	4	
TUE	1/20	3PM		8.6	26	55	15	1	

			LO-HI:	META	PLAT	OTHER
			UNIT:	%		
SUN	1/25	6AM		RARE *	42,000 *	(1) *

(1) SLT-MOD ANISOCYTOSIS WITH MACROCYTES; MOD POIKILOCYTOSIS, FEW BIZARRE FORMS; SLT TOXIC GRANULATION; FEW DOHLE BODIES.

CONTINUED

[redacted]ETER J CUMULATIVE LAB SUMMARY.

Figure A-8. Example of Printout of Cumulative Laboratory Results Summaries.

1 26/74 8:39 AM PAGE 004

[redacted] PETER J M 77 ICD1
302041 ADM: 01/20/74
[redacted] DON C. MD

LAB RESULTS SUMMARY

REPORT PERIOD: 1/20/74 12:00 MN - 8:39 AM 1/26/74

ELECTROLYTES

			NA	K	CL	CO2
LO-HI:			135-145	3.5-5.0	095-105	24-32
UNIT:			MEQ/L	MEQ/L	MEQ/L	MEQ/L
SUN	1/25	6AM	131 *	4.3 *	96 *	20 *
SAT	1/24	6AM	131	5.1	94	17
FRI	1/23	6AM	128	5.8	92	17
THU	1/22	6AM	133	5.2	92	22
WED	1/21	6AM	142	5.4	98	20
TUE	1/20	3PM	141	4.7	103	18

BL CHEMISTRY

			FBS	CREAT	BUN	CA	ALB	T.PROT
LO-HI:			70-110	0.7-1.4	10-20	08.5-10.5	3.5-5.0	6-8
UNIT:			MG%	MG%	MG%	MG%	GM%	GM%
SUN	1/25	6AM	135 *	3.5 *	100 *	7.5 *	1.9 *	4.0 *
SAT	1/24	6AM	139	4.0	>100	8.6	2.4	5.0
FRI	1/23	6AM	131	3.7	>100	9.4	3.0	5.9
THU	1/22	6AM	132	3.8	93	10.0	3.4	6.5
WED	1/21	6AM	117	2.9	71	10.7	4.0	7.1
TUE	1/20	3PM	159		50			

			T.BILI	PHOS	MAG-BL	AMYLASE	OSMOL-BL
LO-HI:			0.16-1.00	2.5-4.5	1.8-2.9	35-185	270-286
UNIT:			MG%	MG%	MG%	UNIT	MOS/KG
SUN	1/25	6AM	1.4 *	5.2 *	1.7 *		294 *
SAT	1/24	6AM	1.2	6.7			295
FRI	1/23	6AM	1.6	4.7			
THU	1/22	4PM					325

CONTINUED

[redacted] PETER J CUMULATIVE LAB SUMMARY.

Figure A-8. Example of Printout of Cumulative Laboratory Results Summaries. (Continued)

1/26/74 8:39 AM PAGE 008

[redacted] PETER J M 77 IC01
302041 ADM: 01/20/74
[redacted] DON C, MD

LAB RESULTS SUMMARY

REPORT PERIOD: 1/20/74 12:00 MN - 8:39 AM 1/26/74

ROUTINE UA

		EPITH
	LO-HI:	
	UNIT:	
WED 1/21 1AM		FEW SQ: FEW RND

SEROLOGY

		VDRL
	LO-HI:	
	UNIT:	
TUE 1/20 3PM		NR

OTHER TESTS

WED 1/21 1AM CULTURE, URINE:
/.
75,000 NON-HEMOLYTIC STREP COL/ML.
12,000 MICROCOCCUS SP' COL/ML 100
COL/ML GRAM NEG. ROD

OTHER TESTS-SPUTUM

THU 1/22 5AM AC FAST STAIN:-
NO ACID-FAST BACILLI SEEN

WED 1/21 1AM CULTURE:-
/E. COLI.
..AMPICILLIN.....S.. .. ..
..CARBENICILLIN.....S.. .. ..
..CEPHALOSPORIN.....S.. .. ..

CONTINUED

Figure A-8. Example of Printout of Cumulative Laboratory Results Summaries. (Continued)

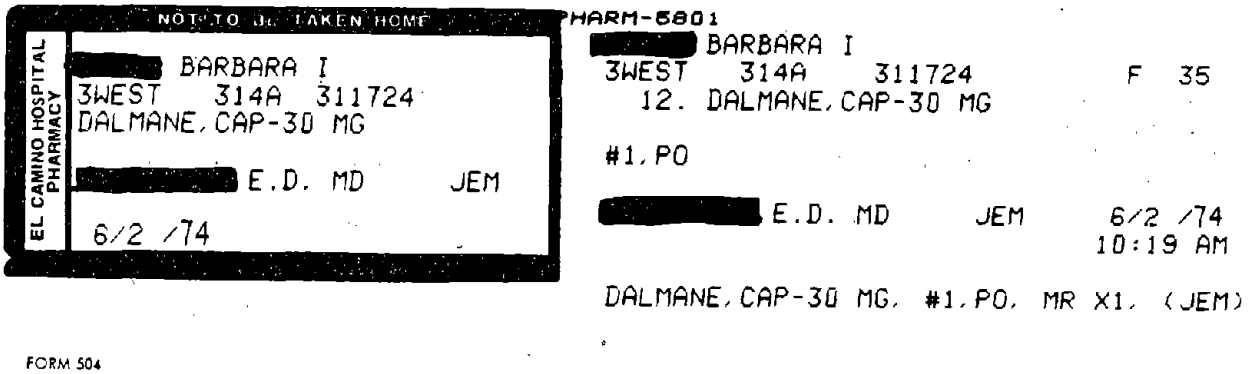


Figure A-9. Medication Prescription Record and Label.

Medication Orders/Routing to the Pharmacy. Physicians use the VMT to write medication orders. The computer analyzes each order to determine if the medication is floor-stocked at the patient's nursing station. If not, the computer generates a prescription record and a medication label, printed on gummed paper, in the pharmacy (see Figure A-9). Stat. orders are specially marked, and a light and bell are activated in the pharmacy. Non-stat. orders are printed immediately in the pharmacy, but do not require special processing. For floor-stocked medications, the pharmacy receives only a prescription record. The MIS system enables the pharmacy to receive all new medication orders promptly and in legible form.

Preparation of Medication Labels. Since the computer produces gummed labels for each new medication order, it is not necessary for pharmacy personnel to type such labels. The label showing the patient's name, bed location, attending physician, and the medication ordered is affixed to the container for the initial supply of the medication. This supply is just enough to last until the next unit-dose servicing of the patient's nursing station. The patient's medication allergies are also printed alongside the medication label to assist the pharmacist in checking for allergy problems.

Dispensing of Medications. When unit dose is used in addition to the initial dispensing of medications, as described above, the pharmacy prepares a medication drawer for each patient, containing a 24-hour supply of medication, packaged in unit-dose form. These medication drawers are prepared with the assistance of a computer-produced "Medications Supply List" (MSL). The MSL shows all medications to be given to each patient during the next 24 hours. The computer prepares MSL's for each nursing station at a different time of day to level the pharmacy workload.

Review of Patient Data. The Chief Pharmacist and other authorized pharmacy personnel use the pharmacy VMT to retrieve patient data, as required. The most frequent use of this capability is to review the patient's medications profile. VMT displays showing all medications that the patient is taking plus his drug allergies are readily obtained.

Billing for Medications Given. The hospital maintains a medication price list in the MIS computer system. As each medication is administered, the nurse's VMT entry causes the appropriate charge to be triggered into the patient's billing account. This system ensures that the patient is billed precisely for the medications actually received. This capability eliminates the need to credit the patient for medications returned from the nursing station to the pharmacy.

Radiology

The Radiology Department, like other hospital departments, uses VMT's and printers to interact with the computer data network. Through these devices, the department has immediate contact with other hospital personnel and direct access to a wide range of information on radiology patients. The installation of MIS significantly changes departmental data processing functions. The affected areas include the following:

- Orders for radiological examinations and their routing to the department
- Preparation and release of radiology reports
- Retrieval of patient data
- Billing for radiological procedures

Orders for Radiological Examinations and Their Routing. Physicians write X-ray orders using VMT displays. These displays contain the standard terminology for all radiological procedures performed at the hospital. The displays are arranged so as to encourage the physician to provide the radiologist with "indications" (the specific reasons why the test is being ordered). New radiology orders are printed in the department as soon as ordered, unless they are to be done on a future date. Stat. orders are specially marked and activate a light and bell in the Radiology Department. In addition to showing the test ordered and indications, radiology requisitions also show the patient's name, age, sex, case number, bed location, attending physician, and diagnosis. The requisition also indicates if a portable X-ray machine is to be used.

Preparation and Release of Radiology Reports. X-ray interpretations are dictated by the radiologists in the usual manner, except that they have the capability to refer to standard, normal sentences or paragraphs which are frequently used. These phrases are permanently stored in the computer. Radiology secretaries type the report for verification by the Radiologist. After the report has been verified, a verification signal is entered into the VMT. This signal causes the report to be released for VMT retrieval throughout the hospital and to simultaneously print at the patient's nursing station (see

Figure A-10). The Radiology Department also has the capability to release reports with a "preliminary" status. A complete summary of all radiology reports (and all laboratory reports) is printed after the patient is discharged. One copy of this summary is mailed to the doctor's office, and one copy is retained in the patient's chart by the Medical Records Department.

Retrieval of Patient Data. If the radiologist requires additional information to that shown on the requisition, he can retrieve patient data using the VMT. VMT retrieval is used for obtaining previous current stay radiology reports, medications that the patient is taking, secondary diagnoses, and other patient data.

Billing for Radiological Procedures. As radiology reports are keyed into the VMT, a procedure number is also entered. The computer uses this number to look up the appropriate charge and to post it to the patient's billing file.

Other Diagnostic and Therapeutic Departments

Using the MIS system, *all* medical orders are entered into the computer. Consequently, all diagnostic and therapeutic departments receive their requisitions in the form of computer printouts. Computer-produced requisitions and work sheets are tailored for each specific department and for each specific test. In general, the requisitions contain the patient's name, case number, age, sex, nursing station, bed location, diagnosis, attending physician, date and time of the order, and the precise wording of the order as written by the physician. Stat. orders are clearly marked for special attention. Orders to be accomplished on a future date are held in the computer and released to the appropriate department on the correct date. Optionally, some departments elect to receive future orders a day early for workload planning purposes. Some ancillary departments enter treatment notes into the computer system by VMT. Other departments elect to handwrite or type their treatment notices into the patient's chart. All departments perform patient billing via the computer. Each department can optionally establish fixed charges for specific procedures, generate individual charges for each activity, or use a combination of the two charging methods. Personnel of the various ancillary departments use the VMT to access patient data (e.g., medications, previous test results, and dietary information) as necessary for their work and as permitted by hospital policy. The computer controls each individual's access, based upon his identification code. All diagnostic and therapeutic departments use the MIS system---EKG, EEG, EMG, Physical Medicine, Pulmonary Medicine, Nuclear Medicine, Respiratory Therapy, and others.

Dietary

Dietary orders and special instructions are entered into the VMT by both physicians and nurses. Three times daily, prior to each meal, the computer prints an up-to-the-minute Diet Orders Listing in the dietary office. There is one page (more if required) for each nursing station. The printout shows each patient's name and bed location, together with all current diet orders and instructions.

5EAST-5513 (R) EL CAMINO HOSPITAL
6/2 /74 2:41 PM PAGE 001

XRAY

RADIOLOGY RESULTS

[redacted] DOROTHY F 59 535A
311241 ADM: 05/24/74
[redacted] JOHN C., MD

[redacted] L. A., MD
[redacted] RALPH J., MD

ORDER: ABDOMEN-3WAY 74.01

XRAY FILE: 00-22-20 RADIOLOGIST: [redacted] C.MD

ABDOMEN: 6-2-74. AIR CONTAINING SLIGHTLY DILATED SMALL BOWEL IS NOTED IN THE MID AND LEFT LOWER ABDOMEN. THERE IS A SCARCITY OF AIR IN THE COLON. THE PSOAS MUSCLE AND RENAL OUTLINES ARE GROSSLY NORMAL. MULTIPLE METALLIC CLIPS ARE NOTED ABOUT THE SUPERIOR ASPECT OF EACH KIDNEY, PROBABLY RELATED TO ADRENALECTOMY?

IMPRESSION: SMALL BOWEL CHANGES SUGGEST THE POSSIBILITY OF SMALL BOWEL OBSTRUCTION, PARTIAL. LOCALIZED INFLAMMATORY CHANGES IN THE RIGHT LOWER QUADRANT ARE ALSO POSSIBLE. HOWEVER, THERE IS NO EVIDENCE OF AIR OR ILEUS WITHIN THE RIGHT COLON.

LS

LAST PAGE

-*-

Figure A-10. Example of a Radiology Report.

Dietitians also can use the computer system to communicate information to physicians and nurses. When a dietitian's note is entered into a VMT, the computer prints the note both at the nursing station for inclusion in the patient's chart and at the Dietary Department for inclusion in their patient file.

The Dietary Department has an option to receive all patient admission, transfer, and/or discharge notices as they occur throughout the hospital, to be used to supplement the Diet Orders Listing in routing food trays to patients.

Medical Records

MIS impacts on Medical Records in two broad areas: the contents of the chart and general aids to medical records operations. The chart has both MIS components and non-MIS components. The MIS components include laboratory and X-ray results, doctors' orders, the nurse notes and reports (including medications sheets), and the admit/discharge record. The major distinguishing characteristics of the MIS portions of the chart are that they are legible and that they have a standard format. Thus, the patient name, hospital number, and physician name all appear in the same place on each document. The computer automatically puts a date and time on each report, so it is easy to keep the documents in proper sequence.

Each order entered by a physician for a patient is assigned an order number. For each patient, these order numbers are in sequence. A quick scan of doctors' orders allows one to determine if all of the orders are in the chart. It also allows easy reference to any telephoned orders which the physician may not have signed while the chart was at the nursing station. (In the hospitals currently using MIS, orders which are entered directly by the physician do not require a handwritten signature.)

Shortly after patient discharge, a complete listing of laboratory, radiology, and other test results is printed at Medical Records. This printout guarantees that all results entered into MIS will be included in the chart---there is no need to check for lost test results. This printout also indicates any orders for which the results are not yet reported (e.g., cultures).

A Patient Abstract form is printed at approximately the same time as the test results listing. This form is used as a source document for medical records abstracting. MIS fills in much of the form: name, case number, diagnoses, and so on, from information extracted from the patient file. Other data are transcribed onto the form by hand to provide the data source for medical records abstracting.

Unless Medical Records elects early or delayed release, the patient's file is removed from computer disk storage two days after the patient is dismissed from the hospital. However, all computer records are saved on magnetic tape.

Central Service

The Central Service Department receives its requisitions from the computer. When nurses or other personnel require central service items, they place their order by VMT, indicating the patient for whom the item is needed.

Central service requisitions print immediately and, in contrast to the pre-MIS system, contain standard nomenclature printed in fully legible form. Billing for central service items is automatically and accurately processed by MIS.

Business Office

Technicon provides a comprehensive Business Office System (BOS) package which is integrated into the total MIS system. It also can function as a stand-alone system. The total integrated system works as follows: Each real-time computer process (admission; transfer; discharge; medical order; laboratory, X-ray, and ancillary report; medication given; central service order; etc.) generates an appropriate charge, based upon charge tables stored in the computer. Adjustments and credits are also fed into the computer (by VMT) as appropriate.

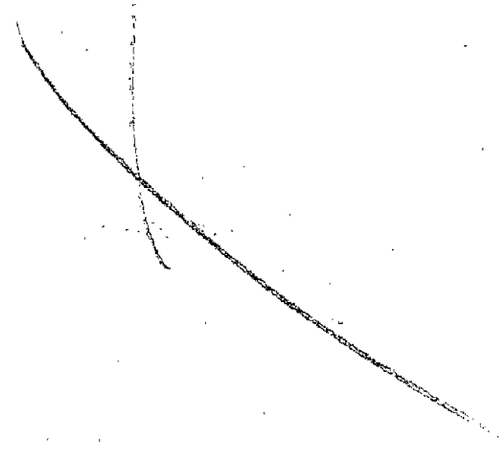
Each night the computer searches all records for all inpatients and outpatients and posts the appropriate charges to each patient's billing file. The computer automatically produces the patient's bill, incorporating insurance prorations.

In addition to preparing patient bills and Accounts Receivable documents, the Business Office System portion of MIS also provides a full range of computer processing and documents for other financial and administration controls. These services include the following:

- Accounts Payable
- General Ledger
- Budgetary Control
- Employee Payroll
- Labor Distribution
- Workload Statistics

Other Departments

Nearly every hospital department is served by MIS, either directly or indirectly. For instance, the Housekeeping Department uses computer-produced Bed Status Reports to determine bed make-up requirements related to the discharging of patients. Similarly, the Mail Room, Flower Room, Information Desk, Chaplain Service, and other departments use computer-produced Patient Locator Lists throughout the hospital. The application of MIS-produced documents and data is almost limitless in scope.



APPENDIX B

DETAILED RESULTS OF THE REGRESSION ANALYSES

Two of the three models used to estimate the labor impact of MIS at El Camino Hospital (ECH) relied heavily on regression analysis methods for extrapolations and comparisons. One of these models was the Internal Labor Measurements Model. For this model a trend was determined for pre-MIS conditions where manual methods were employed. These trend lines were extended to extrapolate to post-MIS conditions to estimate labor requirements under the assumption of continued manual methods. A second regression line was determined for post-MIS conditions and compared with the extrapolated trend line. A single regression model was fit to both the pre-MIS and post-MIS data, of the form

$$H = a + bS + cT_1 + dT_2$$

where S = a dummy variable which equaled "0" for a pre-MIS data point and "1" for a post-MIS data point,

T_1 = biweekly pay period number for a pre-MIS data point and "0" for a post-MIS data point ($1 \leq T_1 \leq 105$), and

T_2 = biweekly pay period number for a post-MIS data point and "0" for a pre-MIS data point ($119 \leq T_2 \leq 170$).

For pre-MIS conditions, $S = 0$ and $T_2 = 0$, and the model reduces to

$$H = a + cT_1.$$

For post-MIS conditions, $S = 1$ and $T_1 = 0$, and the model becomes

$$H = (a + b) + dT_2.$$

Thus, the model accommodates different intercepts and slopes for each time period and yields the results presented in Section 5. Further statistics for the regressions are presented in Table B-1. All of the regressions had R^2 values which were statistically significant at the .05 level of probability. The Student *t*-values are presented to indicate the relative significance of the coefficients in the model.

The Internal Labor Measurements Model also required regressions on patient days and admissions in order to convert labor savings to dollar savings. The results for these regressions are presented in Table B-2. This table also contains regression results for labor and delivery, an area which was handled differently than the other nursing areas. The criterion variable for this area was chosen to be "labor hours per delivery." However, labor hours data were recorded biweekly, and deliveries were recorded monthly. Hence, separate regressions were determined for each variable, after which the end points of the base-line period were determined from the regressions. The ratios of these end points yielded two points for nursing hours per delivery. The line for these two points was determined and was used as the trend line for nursing labor hours per delivery. This line was extrapolated to the end of the experimental period and compared with the ratio of labor hours per delivery from the two post-MIS regression curves.

The second model using regression analysis methods was the Inter-Hospital Labor Trend Comparison Model. The regression results used in this model are summarized in Tables B-3 through B-7. The regressions using 12 months of data involved 13 points for ECH since biweekly data were available, while the other hospitals had 12 monthly data points. The 18-month regression likewise used 20 data points for ECH and 18 data points for the other hospitals. Because of suspected seasonal variations, the 12-month regressions often had significant R^2 whereas the 18-month regressions were less likely to be significant. The results tend to emphasize the need for a more complex model to adjust for seasonal and other effects.

TABLE B-1

RESULTS FOR REGRESSIONS USED IN THE INTERNAL LABOR MEASUREMENTS MODEL

Criterion Variable	Regression Model	R^2, Percent Explained Variation	Standard Error of Estimate	Student's t-values				N
				Constant	S	T_1	T_2	
MSO Nursing Hours per Patient Day	$\hat{H} = 5.6359 + 1.3123S + .0063T_1 - .0085T_2$	13.2%	0.5410	52.97	1.79	3.62	-1.70	157
Maternity Nursing Hours per Patient Day	$\hat{H} = 5.7048 + 0.5186S + .0049T_1 - .0030T_2$	6.1%	0.6039	48.06	0.63	2.54	-0.55	157
Pediatrics Nursing Hours per Patient Day	$\hat{H} = 7.6169 - 1.4164S - .0021T_1 + .0048T_2$	14.2%	0.7426	52.17	-1.41	-0.86	0.70	157
Psychiatry Nursing Hours per Patient Day	$\hat{H} = 4.8530 - .0726S + .0160T_1 + .0095T_2$	25.2%	0.8000	30.85	-0.07	6.21	1.29	157
Nursery Nursing Hours per Patient Day	$\hat{H} = 4.4868 + 1.1450S + .0062T_1 - .0065T_2$	9.9%	0.5346	42.69	1.58	3.61	-1.32	157
Selected Ancillary Nursing Hours per Admission	$\hat{H} = 9.7845 + .4773S + .0128T_1 + .0048T_2$	15.6%	0.9339	53.12	0.38	4.25	0.57	156

TABLE B-2

FURTHER RESULTS FOR REGRESSIONS USED IN THE INTERNAL LABOR MEASUREMENTS MODEL

Criterion Variable	Regression Model	R^2, Percent Explained Variation	Standard Error of Estimate	Student's *t*-values Constant	Student's *t*-values Slope	N
MSO Patient Days	$D = 4447.0724 - 9.8581T_2$	37.0%	197.16	88.66	-4.34	52
Maternity Patient Days	$D = 289.0663 + 0.1466T_2$	0.3%	40.07	56.30	0.40	52
Pediatric Patient Days	$D = 488.2362 - 1.4665T_2$	26.0%	37.86	45.72	-3.64	52
Psychiatric Patient Days	$D = 510.9868 - 0.7907T_2$	8.5%	39.71	69.59	-2.08	52
Nursery Patient Days	$D = 208.3398 + 0.8446T_2$	5.8%	52.03	44.88	1.72	52
Selected Ancillary Admissions	$A = 807.3372 + 0.9966T_2$	12.4%	40.60	159.75	2.51	52
Labor and Delivery:						
Biweekly Nursing Hours	$H_1 = 1347.7853 - 2.1194T_1$	27.8%	103.42	------	-----	105
Monthly Deliveries	$B_1 = 258.4367 - 0.8248M_1$	34.4%	15.79	------	-----	48
Nursing Hours per Delivery*	$NH = 5.2151 - 0.0007D$	-----	------	------	-----	2
Biweekly Nursing Hours	$H_2 = 873.1411 + 0.3686T_2$	1.4%	47.54	140.92	0.84	52
Monthly Deliveries	$B_2 = 195.1383 + 1.4956M_2$	13.8%	25.89	------	-----	24

* Determined from end points of base-line period ratios of nursing hours to deliveries.

TABLE B-3

RESULTS FOR REGRESSIONS USED IN THE INTER-HOSPITAL LABOR TREND COMPARISON MODEL OF MEDICAL-SURGICAL NURSING HOURS PER PATIENT DAY

Regression Data Period	Hospital	Experimental (Post-MIS)			Base Line (Pre-MIS)		
		Regression Model		R^2, Percent Explained Variation	Regression Model		R^2, Percent Explained Variation
		Intercept	Slope		Intercept	Slope	
18-Month Period	1	6.04	-0.0009	0.0%	6.54	-0.0100	1.0%
	2	4.69	0.0565	32.6%	6.43	0.0065	1.1%
	3	10.00	-0.0363	7.8%	9.57	-0.0609	17.5%
	4	6.34	0.0225	4.6%	7.72	0.0143	2.7%
	5	5.70	0.0051	0.5%	6.23	-0.0114	3.0%
	6	6.57	0.0477	12.4%	7.20	0.0291	15.8%
	ECH	7.57	-0.0194	10.0%	6.23	0.0662	43.9%
	AVERAGE*	6.67	0.0121	3.1%	7.11	-0.0015	0.0%
First 12-Month Period	1	6.23	-0.0082	0.6%	6.89	-0.0752	19.7%
	2	7.40	-0.0365	15.3%	6.72	-0.0463	21.8%
	3	10.65	-0.0588	8.7%	10.47	-0.2282	69.7%
	4	8.75	-0.0597	20.2%	7.99	-0.0420	12.5%
	5	7.79	-0.0667	39.2%	6.50	-0.0642	32.6%
	6	9.54	-0.0542	9.5%	7.56	-0.0385	16.8%
	ECH	9.22	-0.0712	49.1%	6.28	0.0516	17.6%
	AVERAGE*	8.39	-0.0474	24.3%	7.56	-0.0720	36.6%
Last 12-Month Period	1	5.03	0.0262	4.9%	5.52	0.0608	24.9%
	2	1.50	0.1420	80.9%	5.84	0.0496	32.5%
	3	8.37	0.0067	0.2%	8.35	0.0294	2.3%
	4	3.39	0.1001	35.4%	6.84	0.0792	34.2%
	5	2.95	0.0784	46.0%	5.31	0.0538	34.9%
	6	2.09	0.1680	68.3%	6.57	0.0754	47.6%
	ECH	5.04	0.0420	26.4%	5.56	0.1085	46.3%
	AVERAGE*	4.32	0.0748	50.7%	6.29	0.0648	32.2%

* Regression on average of six other hospitals' data.

TABLE B-4

RESULTS FOR REGRESSIONS USED IN THE INTER-HOSPITAL LABOR TREND COMPARISON MODEL OF MEDICAL-SURGICAL NURSING HOURS PER ADMISSION

Regression Data Period	Hospital	Experimental (Post-MIS)			Base Line (Pre-MIS)		
		Regression Model		R^2, Percent Explained Variation	Regression Model		R^2, Percent Explained Variation
		Intercept	Slope		Intercept	Slope	
18-Month Period	1	35.32	0.3179	39.5%	50.71	-0.2128	6.9%
	2	44.92	0.0882	4.3%	54.15	-0.2017	21.6%
	3	49.73	0.1898	2.6%	59.94	-0.5132	31.7%
	4	26.80	0.2520	11.1%	40.10	-0.0735	2.2%
	5	41.91	-0.0452	0.7%	48.39	-0.2366	11.4%
	6	50.39	0.0302	0.2%	46.47	0.1698	10.7%
	ECH	42.11	-0.1563	22.2%	36.64	0.2390	28.3%
	AVERAGE*	40.54	0.1719	13.3%	49.49	-0.1476	9.9%
First 12-Month Period	1	42.14	0.0807	3.6%	54.10	-0.8202	35.0%
	2	59.41	-0.4087	50.9%	54.58	-0.2712	16.8%
	3	73.65	-0.6152	23.7%	60.27	-0.4922	15.1%
	4	40.42	-0.2099	3.9%	41.88	-0.4499	39.5%
	5	56.52	-0.5432	48.9%	50.60	-0.6467	27.7%
	6	62.43	-0.3816	10.5%	48.67	-0.2356	11.4%
	ECH	53.65	-0.5192	81.5%	36.52	0.2180	23.1%
	AVERAGE*	55.76	-0.3463	37.4%	51.23	-0.4680	32.0%
Last 12-Month Period	1	29.46	0.4737	32.4%	42.41	0.3737	11.4%
	2	29.10	0.5100	58.2%	55.33	-0.2893	19.4%
	3	29.59	0.7216	12.0%	61.44	-0.6300	21.9%
	4	12.26	0.6429	53.3%	34.68	0.3245	17.6%
	5	23.95	0.4322	30.4%	42.73	0.1553	4.5%
	6	30.69	0.5566	35.2%	44.07	0.3474	14.3%
	ECH	31.82	0.0934	4.1%	35.64	0.2988	16.2%
	AVERAGE*	24.29	0.6042	66.0%	46.11	0.0873	1.7%

* Regression on average of six other hospitals' data.

TABLE B-5

RESULTS FOR REGRESSIONS USED IN THE INTER-HOSPITAL LABOR TREND COMPARISON MODEL OF SELECTED ANCILLARY SERVICES HOURS PER ADMISSION

Regression Data Period	Hospital	Experimental (Post-MIS)			Base Line (Pre-MIS)		
		Regression Model		R^2, Percent Explained Variation	Regression Model		R^2, Percent Explained Variation
		Intercept	Slope		Intercept	Slope	
18-Month Period	1	13.46	0.0711	9.2%	16.26	-0.0487	10.3%
	2	15.07	0.0633	8.7%	16.53	-0.0781	24.5%
	3	6.41	0.1925	34.5%	11.63	-0.0292	6.2%
	4	4.22	0.1535	57.4%	7.42	0.0829	52.9%
	5	15.01	-0.0119	0.2%	13.85	0.0762	13.9%
	6	14.23	-0.0498	8.1%	12.15	0.0127	1.3%
	ECH	11.16	0.0072	0.8%	10.61	0.0296	13.3%
	AVERAGE*	10.72	0.0927	21.6%	12.49	0.0114	2.7%
First 12-Month Period	1	19.81	-0.1482	22.5%	16.69	-0.1285	23.0%
	2	20.38	-0.1209	23.4%	17.03	-0.1713	40.7%
	3	13.80	-0.0586	6.4%	11.52	-0.0082	0.3%
	4	6.79	0.0669	10.9%	7.36	0.0905	35.2%
	5	23.53	-0.3043	70.2%	14.40	-0.0366	2.1%
	6	18.30	-0.1898	40.8%	12.36	-0.0244	2.0%
	ECH	13.86	-0.0782	46.8%	10.94	-0.0265	13.2%
	AVERAGE*	17.10	-0.1258	39.8%	13.31	-0.0537	20.2%
Last 12-Month Period	1	5.07	0.2946	63.2%	15.18	0.0306	2.3%
	2	9.54	0.2105	32.0%	16.34	-0.0629	7.6%
	3	- 0.76	0.3831	47.2%	12.03	-0.0589	13.0%
	4	1.68	0.2219	74.3%	7.81	0.0558	21.0%
	5	5.35	0.2452	36.5%	12.65	0.1600	24.0%
	6	8.02	0.1156	33.4%	12.31	0.0000	0.0%
	ECH	8.90	0.0621	17.9%	9.57	0.0970	41.7%
	AVERAGE*	3.36	0.2885	74.9%	12.68	0.0267	5.7%

* Regression on average of six other hospitals' data.

TABLE B-6

RESULTS FOR REGRESSIONS USED IN THE INTER-HOSPITAL LABOR TREND COMPARISON MODEL OF TOTAL HOSPITAL HOURS PER ADMISSION

Regression Data Period	Hospital	Experimental (Post-MIS)			Base Line (Pre-MIS)		
		Regression Model		R^2, Percent Explained Variation	Regression Model		R^2, Percent Explained Variation
		Intercept	Slope		Intercept	Slope	
18-Month Period	1	122.30	0.5570	11.4%	144.26	-0.3476	4.2%
	2	126.46	0.3648	7.7%	147.43	-0.4274	16.8%
	3	117.33	0.5224	4.4%	130.82	0.0963	0.6%
	4	46.90	1.0108	47.1%	76.11	0.1785	5.8%
	5	118.26	0.0003	0.0%	121.50	0.2413	2.4%
	6	114.49	0.1120	0.7%	114.96	0.0764	0.7%
	ECH	88.20	-0.0076	0.0%	82.98	0.3410	30.2%
	AVERAGE*	102.60	0.5968	19.8%	117.87	0.0483	0.3%
First 12-Month Period	1	166.51	-0.9675	21.3%	150.09	-1.4583	25.2%
	2	166.74	-1.0254	40.9%	149.46	-0.7989	20.7%
	3	172.29	-1.3350	20.1%	133.22	-0.3510	3.0%
	4	70.34	0.2210	2.2%	77.62	-0.1491	1.7%
	5	160.52	-1.4512	48.1%	125.64	-0.5852	5.9%
	6	132.48	-0.5061	5.3%	117.47	-0.4143	7.9%
	ECH	115.03	-0.8531	62.9%	84.46	0.0929	2.8%
	AVERAGE*	144.81	-0.8440	33.2%	125.24	-0.6389	18.8%
Last 12-Month Period	1	62.21	2.1551	58.1%	130.81	0.6163	5.5%
	2	83.20	1.5200	48.8%	148.61	-0.5091	11.3%
	3	59.10	2.0556	23.6%	130.34	0.1084	0.3%
	4	20.70	1.7151	74.9%	70.80	0.5752	26.1%
	5	67.93	1.3391	31.9%	109.75	1.0547	24.2%
	6	82.85	0.9649	28.2%	111.96	0.2799	3.2%
	ECH	66.65	0.5156	17.7%	76.81	0.7398	44.1%
	AVERAGE*	52.11	1.9399	78.1%	115.36	0.4762	12.1%

* Regression on average of six other hospitals' data.

TABLE B-7

RESULTS FOR REGRESSIONS USED IN THE INTER-HOSPITAL LABOR TREND COMPARISON MODEL

Criterion	Hospital	Time Period	Experimental (Post-MIS) Regression Model Intercept	Experimental (Post-MIS) Regression Model Slope	Experimental (Post-MIS) R^2, Percent Explained Variation	Base Line (Pre-MIS) Regression Model Intercept	Base Line (Pre-MIS) Regression Model Slope	Base Line (Pre-MIS) R^2, Percent Explained Variation
Admissions/Month (Med.-Surg.)	ECH	First 12 Months	770.76	20.8693	77.0%	1,270.05	6.9937	26.1%
		Last 12 Months	1,803.91	- 7.8120	13.1%	1,405.61	- 3.7147	24.9%
		18 Months	1,279.95	4.8400	11.5%	1,292.88	3.3939	19.1%
	Others	First 12 Months	607.69	10.8606	47.5%	908.49	5.0797	18.6%
		Last 12 Months	1,276.55	- 9.1349	46.3%	1,030.79	- 8.0968	36.6%
		18 Months	909.48	0.5991	00.3%	945.12	- 1.9754	6.0%
Patient Days/Month (Med.-Surg.)	ECH	First 12 Months	5,170.51	78.1731	43.9%	7,389.89	26.2677	5.1%
		Last 12 Months	10,643.08	-68.9423	45.0%	8,823.63	-85.3500	64.8%
		18 Months	7,207.44	13.9978	4.1%	7,598.77	- 7.1673	1.0%
	Others	First 12 Months	4,120.13	65.7010	37.5%	6,242.95	32.1759	14.6%
		Last 12 Months	8,215.46	-54.7778	34.3%	7,436.20	-95.2300	58.3%
		18 Months	5,649.21	12.9970	3.6%	6,572.63	-32.8500	19.8%
Average Length of Stay (Med.-Surg.)	ECH	First 12 Months	6.00	- 0.0207	10.2%	5.81	- 0.0103	3.0%
		Last 12 Months	6.06	- 0.0190	6.5%	6.31	- 0.0483	46.7%
		18 Months	5.58	- 0.0076	3.3%	5.87	- 0.0199	23.1%
	Others	First 12 Months	6.76	- 0.0060	1.2%	6.92	- 0.0020	0.2%
		Last 12 Months	6.10	0.0150	3.1%	7.35	- 0.0470	43.3%
		18 Months	6.19	0.0127	6.8%	7.02	- 0.0222	27.0%
Occupancy Percent (Med.-Surg.)	ECH	First 12 Months	66.31	0.0604	0.7%	64.84	0.1099	1.3%
		Last 12 Months	86.16	- 0.4560	26.9%	76.92	- 0.8791	67.3%
		18 Months	71.42	- 0.0992	3.7%	66.85	- 0.2331	14.6%
	Others	First 12 Months	54.07	0.7286	39.6%	77.20	- 0.2573	10.7%
		Last 12 Months	103.17	- 0.7166	42.9%	80.77	- 0.5925	49.7%
		18 Months	72.59	0.0929	1.5%	77.94	- 0.3939	38.5%
Nursing Hours/Patient Day (Med.-Surg.)	ECH	First 12 Months	9.22	- 0.0712	49.1%	6.28	0.0516	17.6%
		Last 12 Months	5.04	0.0420	26.4%	5.56	0.1085	46.3%
		18 Months	7.57	- 0.0194	10.0%	6.23	0.0662	43.9%
	Others	First 12 Months	8.39	- 0.0474	24.3%	7.56	- 0.0720	36.6%
		Last 12 Months	4.32	0.0748	50.7%	6.29	0.0648	32.2%
		18 Months	6.67	0.0121	3.1%	7.11	- 0.0015	0.0%
Nursing Hours/Admission (Med.-Surg.)	ECH	First 12 Months	53.65	- 0.5192	81.5%	36.52	0.2180	23.1%
		Last 12 Months	31.82	0.0934	4.1%	35.64	0.2988	16.2%
		18 Months	42.11	- 0.1563	22.2%	36.64	0.2390	28.3%
	Others	First 12 Months	55.76	- 0.3463	37.4%	51.23	- 0.4680	32.0%
		Last 12 Months	24.29	0.6042	66.0%	46.11	0.0873	1.7%
		18 Months	40.54	0.1719	13.3%	49.49	- 0.1476	9.9%
Ancillary Hours/ Admission Total	ECH	First 12 Months	13.86	- 0.0782	46.8%	10.94	- 0.0265	13.2%
		Last 12 Months	8.90	0.0621	17.9%	9.57	0.0970	41.7%
		18 Months	11.16	0.0072	0.8%	10.61	0.0296	13.3%
	Others	First 12 Months	17.10	- 0.1258	39.8%	13.31	- 0.0537	20.2%
		Last 12 Months	3.36	0.2885	74.9%	12.68	0.0267	5.7%
		18 Months	10.72	0.0927	21.6%	12.49	0.0114	2.7%
Hospital Hours Total/ Admission Total	ECH	First 12 Months	115.03	- 0.8531	62.9%	84.46	0.0929	2.8%
		Last 12 Months	66.65	0.5156	17.7%	76.81	0.7398	44.1%
		18 Months	88.20	- 0.0076	0.0%	82.98	0.3410	30.2%
	Others	First 12 Months	144.81	- 0.8440	33.2%	125.24	- 0.6389	18.8%
		Last 12 Months	52.11	1.9399	78.1%	115.36	0.4762	12.1%
		18 Months	102.60	0.5968	19.8%	117.87	0.0483	0.4%