RURAL MEDICAL CARE CLINIC SIMULATION MODEL

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ABSTRACT

An experimental medical care delivery system was established to provide medical services for a doctorless rural community by linking a remote rural clinic staffed with midlevel medical personnel to supervisory physicians at an urban location. This paper presents a GPSS computer simulation model designed to evaluate alternative configurations of the experimental medical care delivery system. First, the operational components of the delivery system are briefly described. Next, a description of the computer simulation model is presented. Finally, the results of four experiments conducted with the simulation model to evaluate variations in operational configurations are summarized.

I. DESCRIPTION OF MEDICAL CARE DELIVERY SYSTEM

A partitioning of the delivery system into two operational components linked by a communication component provides a functional perspective of system behavior. The elements of the rural operations component include the clinic facility, the diagnostic and treatment equipment, and the midlevel medical personnel staff. The staff consists of a specially trained family nurse practitioner (FNP), a laboratory aide (LA), and a receptionist. The FNP interviews patients recording their medical histories, performs physical and X-ray examinations, consults with supervisory physicians, and administers therapeutic procedures. The LA performs selected laboratory tests, admits patients to examination rooms, measures and records patients' vital signs, and administers telephone-linked electrocardiographic examinations. The second operational component is comprised of two physicians, an internist and a pediatrician, who provide medical consultation for patients being processed at the rural facility. A telephone linkage between the two operational components is the third delivery system component. After an initial examination of a patient, the FNP initiates a telephone call which pages the appropriate supervisory physician via a portable electronic sensor. The physician responds by directly placing a telephone call to the clinic. As a result of reviewing the patient's condition during the telephone consultation, additional diagnostic tests or a specific treatment may be prescribed.

This project was performed pursuant to Contract No. HSM 110-69-241 with the Health Services and Mental Health Administration, Department of Health, Education, and Welfare.

II. COMPUTER SIMULATION MODEL

A stochastic computer simulation model was developed to evaluate alternative operational configurations of the experimental medical care delivery system. The model has been designed as both an aid for analyzing potential changes in the existing experimental system and for planning the installation of new delivery systems in other rural communities. It is programmed in General Purpose Simulation System (GPSS) language for an IBM 360/67 computer. The event-step simulation program uses less than 128K bytes of core and requires approximately 0.15 seconds to process an average patient.

The computer simulation imitates the interaction between the patient and the basic elements of the rural component during system operation. The model consists of a patient visit generator and three processor modules: patient, family nurse practitioner (FNP), and laboratory aide (LA). The visit generator creates the patients, assigns their visit characteristics, and schedules their arrival. The rate and type of demand for patient processing activities are determined through the initial assignments of visit and patient attributes by the patient visit generator. The patient processor module contains the logic which prescribes the sequence of activities involved in providing patient care. The duration of processing activities is basically controlled by the decision logic contained within the clinic personnel modules. The FNP logic module provides for the activities performed to determine and relate the patient's condition to the supervisory physician. The source of ancillary activities required to facilitate patient care is the LA logic module.

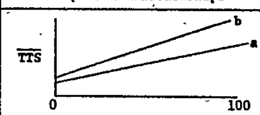
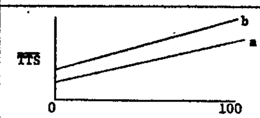
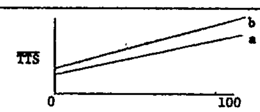
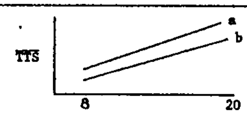
Time study data collected on the experimental medical care delivery system provide the probability distributions for the patient and visit attributes, the sequence and duration of processing activities, and the set of activity priorities and decision logic used in the personnel logic modules.

Measures of patient processing form the basis for evaluating system performance. Standard queueing statistics and elapsed time measurements are collected during the simulation and presented at the completion of the simulated time interval. From the patient's perspective, relevant process criteria include total time in system, time to first service, and time spent in direct contact with clinic personnel. Other criteria included a monitoring of FNP and LA utilization. The influence of controllable administrative and medical policies on operational efficiencies may be assessed from these process criteria. In addition, noncontrollable input variables such as number and type of patient visitations per day affect measures of patient process. It is appropriate to consider the influence of noncontrollable demand factors in forecasting the performance of this delivery system in other rural communities.

III. EXPERIMENTAL RESULTS

The purpose of the simulation model is to evaluate alternative values of input parameters, changes in operational policies, and modifications in the system configuration. After the delivery system has been operationalized, management considered two major modifications in the operation in order to increase effectivity. One was to permit the physicians to telephone the clinic approximately every hour. The second change was to limit the system operational configuration which would result in an estimated cost savings of $2000 per month. These changes were considered under variable percentages of eligible patients requiring telephone consultations and numbers of daily patient visits. Average patient total time in the system was considered representative of the patient processing performance criteria for the managerial evaluation of the proposed changes. Table 1 gives a comparative summary of the results from the four computer-simulated experiments. The results demonstrate the importance of the relationship between the processing criterion of total system time per patient and the communication component. It appears that system processing times are significantly influenced by the delay resulting from required communication between the urban and rural system components. The simulated decrease in system capacity and operating costs resulting from the limited system configuration yielded an expected increase in time required for patient processing. Additional support regarding the relevance of the communication linkage was ascertained in the final experiment where, under similar rates of daily patient visits, the configuration requiring less telephone consultation produced a more desirable performance in patient processing. Thus, modifications in medical policy and increases in operational efficiencies which streamline the communication process should yield reductions in patient processing times.

TABLE 1
A Descriptive Summary of the Results from Four Computer Simulation Experiments

Description of Experiment	Simulated Conditions	Descriptive Results from Computer Simulation*	
		Graphical Relationships	Linear Regression Equations
1. Contrast FNP and MD as Initiators of Telephone Consultations under Normal System Configuration	Average number of patient visits per day = 9.5. Percent of patients requiring telephone consultation was varied from 0-100% under Normal Configuration Two policies considered: a. FNP Initiates Telephone Consultation b. Supervisory MD Initiates Telephone Conversation	 Percent of Patients Requiring Telephone Consultation	a. $\overline{TTS}$ = 63.3 + .25x with F = 124 b. $\overline{TTS}$ = 64.2 + .45x with F = 183
2. Evaluate Normal and Limited System Operational Configuration with FNP Initiating Telephone Consultations	Total patient visits are held constant to yield average daily rates of 9.5 (Normal) and 14.6 (Limited). Percent of patients requiring telephone consultation varied from 0-100%. Two policies considered: a. Normal (Present) Operational Configuration b. Limited Operational Configuration	 Percent of Patients Requiring Telephone Consultation	a. $\overline{TTS}$ = 63.3 + .25x with F = 124 b. $\overline{TTS}$ = 82.8 + .50x with F = 183
3. Contrast FNP and MD as Initiators of Telephone Consultations under Limited System Configuration	Average number of daily patient visits = 14.6. Percent of patients requiring telephone consultation was varied from 0-100%. Two policies are compared: a. FNP Initiates Telephone Consultation b. Supervisory MD Initiates Telephone Consultation	 Percent of Patients Requiring Telephone Consultation	a. $\overline{TTS}$ = 82.8 + .50x with F = 183 b. $\overline{TTS}$ = 85.6 + .67x with F = 308
4. Evaluate Normal and Limited System Operational Configuration with FNP Initiating Telephone Consultations	Proportions of patients requiring telephone consultation are held constant at 89% and 30% for Normal and Limited Configurations, respectively. Average daily visit rate varied from 8-20 patients per day. Two policies are considered: a. Normal (Present) Operational Configuration b. Limited Operational Configuration	 Average Daily Visit Rate	a. $\overline{TTS}$ = 14.3 + 6.8x with F = 194 b. $\overline{TTS}$ = 16.4 + 5.9x with F = 44

*The performance criteria for each experiment was average total time in system ($\overline{TTS}$) per simulated patient.
Run length for each experiment was 25 simulated days.