1981 Winter Simulation Conference Proceedings
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TWO SIMULATION APPLICATIONS TO OUTPATIENT CLINICS

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ABSTRACT

This paper describes two applications of simulation modeling for outpatient clinics in a major urban medical center. The first application was developed for the Ear, Nose and Throat (ENT) Clinic where patients first see the physician and; when the physician requires a hearing test to be done immediately before a diagnosis can be made and treatment prescribed, then the patients see an audiologist. The simulation model tested various scheduling policies for scheduling patients for ENT physicians to provide a uniform hearing test load to the audiologists. In the other application, a simulation model was developed for a general practice medical clinic. This model provided results on patient waiting times and utilization levels for resources at different staffing levels and configurations of reception areas, nursing areas and combination office/exam rooms. The experience with the two models indicated that simulation modeling can be of great help in testing various strategies and configurations and thus assisting in the development of efficient and cost-effective outpatient clinics

1. INTRODUCTION

Simulation has been used often in industry to assess the effects of various strategies on queueing systems. Applications of simulation in the field of outpatient health care for such queueing systems have been few, the most common being the simulation of emergency room services. The flow of patients through the clinics has been considered more or less deterministic as appointments are made in advance for patients to be seen on a particular day. In practice, the flow of patients through the clinic is probabilistic due to high no-show rates and cancellations, large numbers of walk-in patients, large variations in physician service times, and random arrivals of patients around their appointment times. Moreover, outpatient clinics also generate probabilistic demand on the services of other clinics or support areas. For example, the patients in the general medicine clinic might need blood drawing, x-rays, or an appointment in other clinics. With the pressures to cut health care costs, the attractiveness of studying patient flows, waiting times, and staff utilizations in an outpatient clinic to improve the efficiency and cost effectiveness of clinic operation has been increasing.

In this paper two different simulation models are presented which were used to study operational characteristics of outpatient clinics.

81CH1709-5/81/0000-0657$00.75

The first application was developed for the Ear, Nose and Throat (ENT) Clinic at a major urban medical center. This clinic has physicians who see patients with ear, nose or throat problems, as well as audiologists who perform specialized hearing tests as ordered by the physicians.

In this clinic a patient is scheduled for an appointment with a physician by the receptionist. After examining the patient, the physician may require that a hearing test be performed immediately before the diagnosis is made and the treatment is prescribed. If referred for a hearing test, the patient goes to audiology without an appointment, waits for the next free audiologist, and has the test performed. The patient then returns to the physician, and the visit is completed. During a study of the clinic operations, it was observed that audiologists had periods where there are minimal requests for hearing tests and periods when there are many people waiting for tests, causing long stretches of idle time followed by very busy periods. The objective of the study was to find a scheduling strategy that would smooth out patient demand for the audiologists.

The second application of simulation was developed in studying the consolidation of six general practice clinics in the hospital. These six clinics employ a total of nineteen staff physicians, fifteen secretaries, nine receptionists, and twenty-two nurses and nurse practitioners who see about 1,050 patients in a week.

Due to the current economic situation and because of the constant effort to find ways of cutting the costs of patient care, a project was started to investigate the possibility of consolidating the six clinics and to estimate the savings derived from such a merger. The focus of the project was to determine appropriate staffing levels and space requirements under different possible configurations of the consolidated area. The configurations were analyzed in terms of space costs, patient waiting times, and the need for standardization of functions in the consolidated clinic.

Simulation models were developed in both projects to test the effects of various strategies and physical layouts. While the project objectives were fundamentally different, it was felt that simulation could give important objective criteria (utilization, waiting times) with which to analyze different policies. In both cases, clinics were modeled as network queueing systems and General Purpose Simulation System (GPSS) models of patient flow were developed. This paper describes the important aspects of the two models, data collection, simulation results, and the experience in general with the simulation of outpatient clinics.

2. SIMULATION OF THE ENT CLINIC

As discussed earlier, the objective of this study was to find out and evaluate various methods for scheduling patients for the ENT physicians such that the load of hearing tests to be done by the audiologists is more uniform. The clinic records were studied to determine the relationship between the type of patient complaint and the need for a hearing test. Based on this information, several scheduling methods were identified. A GPSS model was developed for the patient flow through the clinic, and the alternative scheduling methods were tested on this model. The general patient flow in the clinic is described next. The data collection procedures, simulation model, and the discussion of results follow.

2.1 Patient Flow in the Clinic

The physicians in the ENT clinic see both outpatients and inpatients, many referred from other services for evaluation, diagnosis, and treatment of various medical problems affecting the ear, nose, or throat areas. They also see patients with head or neck cancers on certain days. ENT patients are scheduled by the receptionists for specific individual appointments with a particular physician.

Currently, appointments are made in person and via telephone. When an appointment with a particular physician is requested, the receptionist schedules the earliest convenient available time for that physician. When no physician is explicitly requested, the earliest convenient appointment among all physicians is scheduled. No information on the type of problem (eg. ear or non-ear) is taken when the appointment is made.

Most patients seen in audiology for different types of hearing tests are referred to audiology from ENT physicians on a same-day basis. The results from these hearing tests provide information useful to the physician for diagnosis of the patient's problem. This creates a unique relationship between ENT physicians and audiologists where the physicians have a great deal of impact on the demand for audiology services.

Patients arrive and are cleared through a central receptionist to the appropriate waiting area. When an examination room becomes available, the patient is shown to the room where he waits for the physician. If the ENT physician determines upon examination that a hearing test is needed to make a complete diagnosis, the patient goes to audiology, gets the test, and returns to ENT to wait for his physician with priority over patients who have not seen the physician yet. It should be noted that although the patient is given an appointment with a particular physician, the hearing test is given by any available audiologist.

After seeing the ENT physician a second time, the patient checks out and leaves the clinic.

2.2 Data Collection and Analysis

Data on patient diagnosis, number of clinic visits, number of patients referred to audiology from the ENT clinic, and number of physicians present in the clinic were compiled from clinic records for a two-week period in November, 1980. These data were analyzed to get an idea of what type of patients (i.e. ear, neuro-otological, non-ear diagnosis) came to the clinic, how this patient mix fluctuates over the week and how many patients were referred to audiology. The sample consisted of 480 cases.

The analysis of this data showed that 41% of the patients coming to the clinic have ear problems, 15% have neuro-otological problems, while the remaining 44% have non-ear problems. It also showed that 35% of the patients with ear diagnosis and 32% of the patients with neuro-otological diagnosis were referred to audiology for hearing tests, while 3% of the patients with other diagnosis were sent for hearing tests.

This data indicated the possibility of controlling the hearing test requests generated by ENT physicians by controlling the scheduling of patients with ear or neuro-otological problems. Three scheduling policies were defined:

Policy One: Current system where the appointments are scheduled without consideration of the type of problem.

Policy Two: Alternating ear and neuro-otological appointments with non-ear appointments for each physician while scheduling.

Policy Three: Clustered appointments where a group of ear and neuro-otological appointments are scheduled followed by a group of non-ear appointments. The number of physicians scheduled to see ear and neuro-otological patients at the same time can be varied.

A. Four physicians see ear patients during an hour and non-ear patients during the next hour.
B. Each hour, two physicians see ear patients, while two see non-ear patients. At the end of each hour, they switch.

The data also showed a cancellation and no-show rate of about 25%. This would mean that even if the patients are scheduled using a certain policy, the actual arrival pattern as far as diagnosis are concerned will be somewhat different than the intended pattern.

In order to test the three scheduling models, a GPSS model was developed. For this model the service time distributions for the ENT physicians and the audiologists were needed.

Data were collected on time intervals spent in the clinic for a one-week period. Total time spent in the clinic was broken up into discrete starting and stopping points. The ENT clinic staff used a data collection form to record clock times for various activities. The means and standard deviations for the various time intervals, patient waiting times, and service times as shown in Table One were determined from the data using MIDAS, a statistical package available through the University of Michigan's time-sharing service. Histograms for the various service times and waiting times were also obtained. These statistics clearly show the high variability in all the time values. Standard deviations of most of these time intervals are almost as large as the means. In general the histograms for the service times showed a skewness to the left. Empirical cumulative distribution functions for the service times from the collected data were used in the GPSS model as the service time distributions.

TABLE ONE: DESCRIPTIVE STATISTICS FOR PATIENT WAITING TIMES, SERVICE TIMES AND SOME OTHER SELECTED INTERVALS

	Mean (Minutes)	Standard Deviation (Minutes)	Sample Size
Waiting Times			
Wait to enter ENT exam room	21.5	22.0	198
Wait for ENT physician once in exam room	16.2	16.2	186
Wait to see Audiologist after ENT physician refers	14.6	14.5	34
Wait to enter ENT exam room after Audiologist completes test	5.0	7.7	29
Wait for ENT physician to come in for second time	11.3	13.4	28
Service Times			
First ENT physician service time	17.8	12.2	199
Audiologist service time	33.8	25.1	70
Second ENT physician service time	12.7	11.1	47

(Cont.) TABLE ONE: DESCRIPTIVE STATISTICS FOR PATIENT WAITING TIMES, SERVICE TIMES, AND SOME OTHER SELECTED INTERVALS

	Mean (Minutes)	Standard Deviation (Minutes)	Sample Size
Other Intervals			
Arrival Time - Appointment Time	-7.8	19.2	223
Total Time Spent in Clinic			
(a) For patients who saw audiologist	98.9	39.8	78
(b) For patients who did not see audiologist	62.2	30.4	170

2.3 Simulation Model

A queueing model was chosen to describe the chain of events in the ENT clinic. Within this framework pateints arrive at the clinic, wait to see their ENT physician, and are either referred to audiology or leave the clinic. If they are referred to audiology, they wait for a free audiologist, obtain a hearing test, and again see their ENT physician. The queueing model was analyzed in terms of how long patients wait in the system and how well the ENT staff is utilized.

The data collected for the study was used to describe how patients arrive at the clinic, how frequently they are referred to audiology, and how much time they spend with the ENT physicians and audiologists.

Figure 1 shows schematic representation of the simulation model developed for the ENT clinic. Salient features of the model are:

1) Each physician generates his own set of patients who enter the queue to see him.

2) Based on patient mix data, each patient is assigned one of three diagnosis types (ear, neuro-otological, or non-ear).

3) Each patient has a fixed chance of being referred to audiology after seeing the ENT physician once.

4) Patient obtains service from the first audiologist who becomes available.

5) All patients referred to audiology re-enter the queue for their ENT physicians upon completion of the audiologist's service. These patients have priority, and they go to the head of the waiting line.

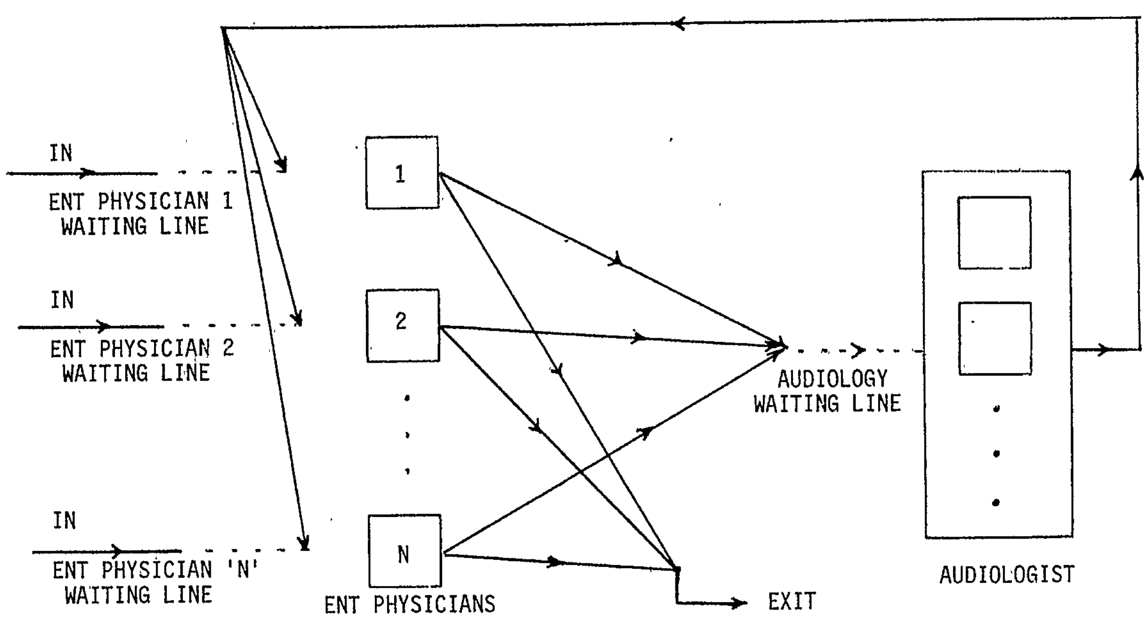

Figure 1: Schematic of the Simulation Model

Development of Inter-Arrival Time Distribution for Patients - The number of patients coming to the clinic on any day is dependent upon the number of ENT physicians scheduled to work on that day. The number of physicians working in the clinic varied from four to six. The model used here simulated the day when only four physicians are working. According to the current appointment procedures, appointments are made for each physician at fifteen minute intervals. For the four hour duration of the clinic (8:00 a.m. to 12:00 noon and 1:00 p.m. to 5:00 p.m.), the appointments are made only for the first three hours.

The data collected earlier determined the frequency distribution of the time interval representing arrival time minus the appointment time. This time interval was found to be normally distributed with a mean of minus 7.8 minutes and standard deviation of 19.2. The inter-arrival time distribution was developed by generating appointment times fifteen minutes apart, generating normal deviates to simulate arrival "offset" (random variation) around the appointment time, and finally applying a Bernoulli switch with p = .75 to determine whether or not the patient actually shows up at the clinic. The cumulative distribution of the inter-arrival time was then determined. When compared to the smaller sample of inter-arrival times collected from the data, we found our generated distribution almost identical with the sample distribution.

Simulation Model Parameters - The values of the different parameters used in the simulation model runs for comparing the various scheduling policies are shown in Table Two.

TABLE TWO: VALUES OF MODEL PARAMETERS

Number of ENT Physicians		4
Number of Audiologists		1
No Show/Cancellation Rate		25%
Patient Mix by Diagnosis Type	Ear	52.1%
	Neuro-Otological	2.8%
	Non-Ear	45.1%
Percentage Seeing Audiologist by Diagnosis Type	Ear	32.9%
	Neuro-Otological	34.9%
	Non-Ear	0%
ENT Physician and Audiologist Service Times	From Empirical Data	

2.4 Results

Table Three presents simulation results for each of the three scheduling alternatives and for the current system. Policy Three-B, with clusters of ear patients scheduled for two doctors and clusters of non-ear patients scheduled for the other two doctors gave the smallest mean and smallest standard deviation for audiologists waiting time. This scheduling policy gave an average 45% decrease in expected waiting time and 26% decrease in standard deviation of waiting time compared to the current system. As the focus in this project was on smoothing demand on audiology, Policy Three-B was chosen for implementation. Table Three also shows the percentage change in the average waiting time and the standard deviation of the waiting time for various policies as compared to Policy One.

TABLE THREE: COMPARISON OF AUDIOLOGY PARAMETERS FOR SCHEDULING POLICIES

	Policy One	Policy Two	Policy Three-A	Policy Three-B
Number of Patients	6.2	6.0	6.0	6.0
Average Waiting Time (Minutes)	17.54	10.78 (-38.5%)	26.64 (+51.9%)	9.70 (-44.7%)
Standard Deviation of Waiting Time	18.38	14.23 (-22.6%)	23.74 (+29.2%)	13.65 (-25.7%)
Average Utilization	.566	.505	.669	.562

Average audiologist utilization is dependent upon the hearing tests generated by the ENT physician and in general should not be affected greatly by the different scheduling procedures. It does give an indication of the possibility of assigning additional work load to the audiologist.

In designing the study of ENT scheduling, one major factor was that the solutions being developed should be such that they could be easily implemented. The selected scheduling policy can be easily implemented by requiring that the receptionists ask the patient about the symptoms and then decide whether the appointment being made is for an ear or non-ear problem. Only minimal errors are expected to result from this determination.

3. SIMULATION OF A GENERAL PRACTICE MEDICAL CLINIC

A major urban medical center was considering the consolidation of six separate general practice clinics. The simulation model is a GPSS model which was developed to assist in investigating the effect of various changes in staffing and area configurations on the patient waiting times and staff utilization. The specific objectives of the consolidation project were to:

1) Investigate the use of combination office/examination rooms.

2) Determine the appropriate number of office/examination rooms for the projected patient load.

3) Determine the optional staffing levels for receptionists, nurses, and other clinic personnel.

4) Keep the patient waiting time and the total time spent in the clinic at an acceptable level.

5) Study the use of centralized blood drawing and specimen collection areas and determine the optimal staffing for them, while keeping the patient waiting time at an acceptable level.

6) Study the use of a secretarial pool for the clinic.

From the patients' viewpoint, two major indicators of the quality of service at a clinic are waiting time and the total time spent in the clinic. A GPSS model was developed for the proposed clinic in order to plan for minimum staffing levels, while still maintaining these waiting times at acceptable levels.

3.1 Patient Flow in the Clinic

When a patient calls the clinic for an appointment, a one-hour appointment for a physical examination or a twenty-minute appointment for a regular clinic visit with a physician is given. On the day of the appointment, the patient arrives at the clinic and checks in with the receptionist. The receptionist fills in a yellow card and sends the patient to the nursing station. The patient checks in at the nursing station, leaves the yellow card, and takes a seat in the waiting area. A nurse calls the patient's name, takes height, weight, and temperature measurements, and enters them into the record. The patient waits until an examination room becomes available. The nurse takes the patient to the examination room when it is available. The patient waits there until the physician arrives to perform the examination. After the examination, the patient goes to the nursing station and obtains instructions about medications, etc., from the nurse. If some laboratory work or x-rays are required, the patient is given instructions by the nurses about where to go. The patient checks out with the receptionist, pays the bill, and makes a return appointment, if needed.

3.2 Data Collection and Analysis

The patients coming to the clinic could be classified into two categories: (1) Patients coming for physical examinations and (2) patients coming for clinic visits for reasons other than physical examinations. In the existing clinics, the patients are scheduled for on hour for the physical, but only twenty minutes for the other clinic visits. Fifteen percent (15%) of all the visits to the clinic are for physical examinations. One decision variable in this study was to determine the best way to spread the scheduled physical examinations over the day. The data kept in the clinic regarding cancellations, no show and added patients showed the following rates as presented in Table Four.

TABLE FOUR: DATA ON PATIENT VISITS

	Physical Exams	Clinic Visits
Cancellation Rate	5%	13.9%
No-Show Rate	22.9%	18.7%
Added Rate	27.0%	28.9%

In order to determine the various service time distributions, data was collected in one of the currently operating clinics. The data were collected for two typical weeks to get a sample of sufficient size. From this data the descriptive statistics were obtained for the various time intervals representing either waiting times or service times at different stages of the patient flow.

The inter-arrival time distribution was determined by starting with the appointment schedule and then determining the actual arrival by using the probability distribution of the time interval "check-in time minus appointment time". The inter-arrival time distribution was then obtained from this sequence of arrivals using a simple computer program. Service time distributions used in the GPSS model came directly from the data collected in the clinics.

The means and standard deviations were determined for the various service times using MIDAS, a statistical package available on the Michigan Terminal System. Table Five shows the descriptive statistics for these time intervals.

TABLE FIVE: DESCRIPTIVE STATISTICS ON SERVICE TIMES

	Mean (Minutes)	Standard Deviation (Minutes)	Sample Size
Receptionist Service Time at Check-In	0.8	1.3	322
Nursing Service Time for Height and Weight	3.4	2.8	289
Time Spent in Examination Room	35.9	21.0	303
Physician Service Time	22.4	15.3	310
Receptionist Service Time at Check-Out	3.3	3.6	321

3.3 Simulation Model

A GPSS model was developed to simulate the flow of patients through the clinic. The important features of this model are the following:

1) The servers in the model are the receptionists, nurses, physicians, and the examination rooms.

2) To obtain service from the physician, the examination room must also be available at the same time.

3) For certain patients, the nurse, physician, and examination room must be available for the examination to take place.

4) For all the servers, only those tasks in which the server comes in direct contact with the patient were included in the model. Other tasks which were done while there is no direct patient contact were excluded provided that the server was able to provide service immediately to a patient upon his arrival. For example, if the receptionist is supposed to handle telephone calls for making appointments, this task was added to the model to provide reliable patient waiting times for the receptionist, since the receptionist will not be serving the patient until after the telephone call. Tasks such as preparing medical records and appointment slips were not included in the model.

5) Various configurations of offices, examination rooms, and combination office/examination rooms were modeled. This configurations are:
   a) Two combination office/examination rooms assigned to each staff physician.
   b) One private office and one examination room assigned to each staff physician.
   c) One assigned combination office/examination room for each staff physician and an unassigned pool of five examination rooms for each group of five physicians.
   d) One assigned combination office/examination room for each staff physician and an unassigned pool of four examination rooms for each group of five physicians.
   e) One assigned combination office/examination room for each staff physician and an unassigned pool of three examination rooms for each group of five physicians.

6) In order to test the various office and examination room configurations, the patients were generated for each physician based upon a pre-set schedule. The same set of patients with exactly the same pre-assigned service times were sent through the models with different configurations.

7) Number of physicians needed in the consolidated clinic were calculated from the projections of clinic visits for next year. Inter-arrival time distributions for the patients were generated from the appointment schedules of these physicians. Simulation runs were made with different staffing levels for receptionists and nurses to determine the staffing levels which would give satisfactory patient waiting times. These staffing levels were modified by taking into account the time needed to do other functions which were not included in the simulation model.

The schematic of the simulation model is shown below in Figure 2.

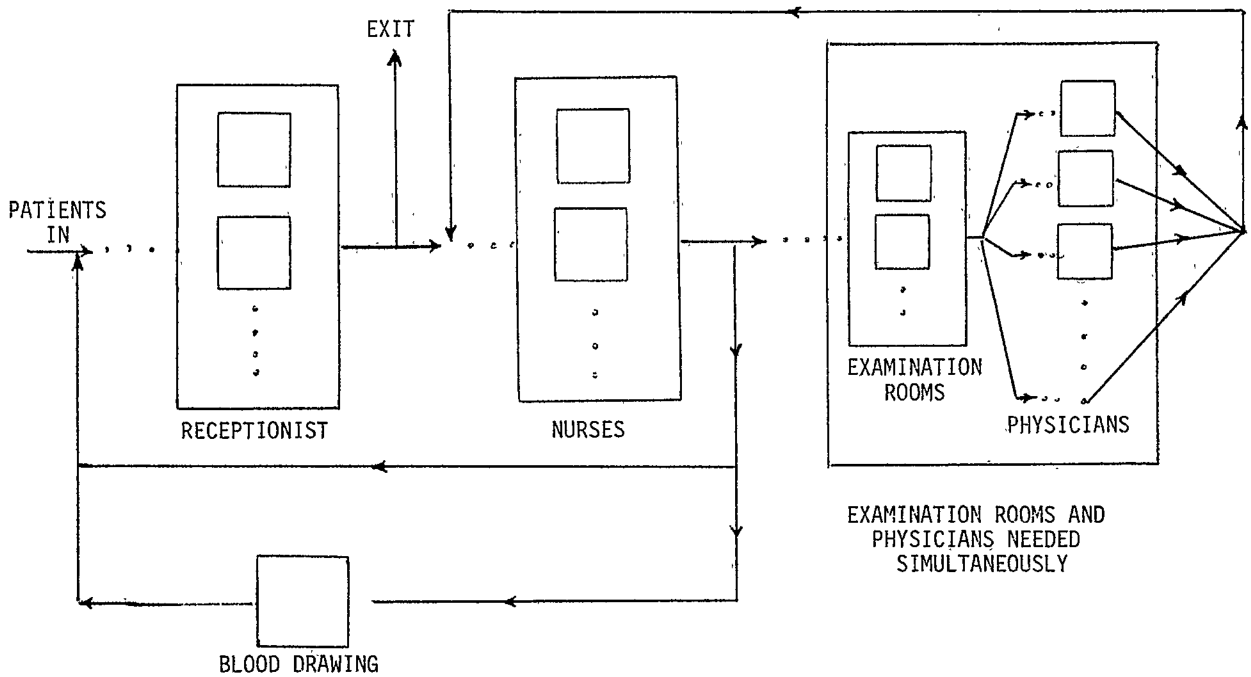

Figure 2: Schematic of the Simulation Model

3.4 Results

The simulation model was used to determine the appropriate staffing levels for the receptionists and the nurses to keep the patient waiting times at acceptable levels. The model also helped in evaluating the various possible configurations for office and examination room assignments to the physicians. Table 6 shows selected data based on the simulation runs for the various configuration described in the previous subsection. This data shows that the configuration of one assigned combination office/examination room per physician and an unassigned pool of three office/examination rooms per five physicians gives the highest examination room utilization while keeping the patient waiting time for an examination room and the overall patient time in the clinic at a satisfactory level.

TABLE SIX: SELECTED DATA FROM SIMULATION RUNS

	Two Assigned Office/Examination Rooms per Physician	One Office - One Examination Room per Physician	One Assigned Office/Examination Room, Unassigned Pool of Five Office/Examination Rooms per Five Physicians	One Assigned Office/Examination Room, Unassigned Pool of Four Office/Examination Rooms per Five Physicians	One Assigned Office/Examination Room, Unassigned Pool of Three Office/Examination Rooms per Five Physicians
Patient Wait for an Exam Room	11.17 (20.1)	13.97 (28.91)	2.24 (10.76)	4.41 (14.69)	7.19 (17.98)
Overall Patient Time in Clinic	57.41	61.64	48.4	51.1	53.3
Exam Room Utilization	.543	.732	.643	.675	.710

4. GENERAL COMMENTS ABOUT THE USE OF SIMULATION IN OUTPATIENT HEALTH CARE MODELING

There have been several applicaitons in the areas of emergency room and operating/receiving room usage analysis (Segal and Strande, 1979; Kwak, Kuzdrall and Schmitz, 1976; Ladany and Turban, 1978; Savas, 1979; Schmitz and Kwak, 1972). Still other applications have dealt with patient flow problems, patient transport, messenger service, etc. (Abrami, 1977; Klima and Tanenbaum, 1974; Kenny and Murray, 1971; Blewett et al., 1972) But the application of sumulation modeling to the operation of a outpatient health care clinic habe been few (Carlson, Hershey and Kropp, 1979).

In this paper, two applications of simulation to improve the efficiency of outpatient clinics were described. Some observations made during these studies are:

1) Simulation applications require good data for service times and other parameters in the model. For collecting good data in the clinics, the cooperation from receptionists, nurses and physicians is necessary. It is important that the purpose of collecting data, the objectives of the project are explained clearly to staff to eliminate any misunderstandings.

2) It is also important that the people involved in the project understand the capabilities and limitations of simulation modeling.

3) Simulation model is still a model which should contain all the important features of the real clinic but cannot include each and every minor detail.

4) Care should be taken when several policies and/or models are being compared. The patients should be generated first with pre-assigned values for service times etc., such that all models are being tested with respect to the same patient group.

5. CONCLUSION

The application of simulation to the opertions of outpatient health care clinics add another dimension to the other methods available for decision making. The first application discussed here showed how simulation could be used to test different patient scheduling policies at the ENT Clinic and the second one showed how the staffing levels, office/examination room configurations could be evaluated to have reasonable patient waiting times in an efficiently working clinic. Simulation models can significantly assist in improving the operations of outpatient clinics.

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