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USING SIMULATION TO REDUCE LENGTH OF STAY IN EMERGENCY DEPARTMENTS

Frank McGuire

SunHealth, Inc.
Charlotte, North Carolina

ABSTRACT

A growing number of hospitals are using healthcare-specific simulation technology to help identify process improvements, particularly when there are a number of alternatives under consideration. New software is now available which specifically meets the unique needs of healthcare. This article describes how a team at one Emergency Services department in a SunHealth Alliance hospital used simulation technology to test alternatives and choose a solution to significantly reduce the length of stay for patients in the Emergency department.

1 INTRODUCTION

Hospital emergency departments are having to cope with increasing pressures from competition, reimbursement problems and healthcare reform. The hospital's customers are less willing to accept long waits in any department, but especially so in the Emergency Department. Since a significant percentage of a hospital's total admissions come through the Emergency Department, the need to have satisfied patients is especially important. As pressures increase on the "bottom line," hospitals must accelerate their search for ways to reduce costs and increase customer satisfaction. Simulation software has been highly effective in this pursuit.

2 THE PROJECT

The object of the simulation study is a medium to large sized hospital in the southeast. There are approximately 40,000 annual visits to this emergency department which acts as a Level II trauma center. The average patient wait time was 157 minutes, which was significantly greater than the acceptable average of 120 minutes. Faced with an increasing number of patient complaints about long waiting times, the hospital decided to take action and chose simulation as a tool for evaluation of alternative courses of action.

The emergency department has 18 examination rooms, two of which are designated as trauma rooms, one as a psychiatric room, one as a muscular/skeletal room, one as an Eye, Ear, Nose, and Throat (EENT) room and one as an OB/GYN room. There is also a fast track area (four rooms) for lower acuity patients during the evenings and from 3 p.m. until 11 p.m. on the weekends. A clinic (four rooms) for low acuity pediatric patients is operated from 6 p.m. until 10 p.m. seven days a week.

A team was organized which included the Emergency Services medical director, nursing director, and administrative director, the managers of the lab and radiology departments, an RN from the Emergency Department, and a management engineer. With input from the team, the management engineer was responsible for building the model and assisting in interpreting the results.

The hospital had already been considering several possible ways to reduce patient wait times; however, there were significant differences of opinion over the relative merits of the different courses of action. The conflicting opinions was one of the key reasons the hospital administration decided to use simulation. No other tool allows you to test alternatives and view the results on-screen as effectively as simulation technology.

3 THE SIMULATION SOFTWARE

The simulation software chosen for the project was MedModel™, a healthcare industry-specific simulator package produced by PROMODEL Corporation. MedModel™ has several advantages over traditional manufacturing-based models, including:

- The ability to capture and release resources, such as doctors, nurses and technicians, independent of each other and without specific "labor cycles".
- The use of "pathway networks" to allow resources to walk up and down hallways and through doors without forcing automatic guided vehicles or conveyers to "make" it happen. Resources and entities (patients) are assigned speeds in feet per minute.
- Nurses can go to the waiting room and escort the patient to an examination room. The time required for both the nurse and the patient is collected by the system and the interaction is shown graphically.

4 STEPS IN THE PROJECT

The steps necessary to complete a project using process simulation are as follows:

1. Identify the process to be simulated
2. Define the goals and objectives of the study
3. Formulate and define model
4. Collect data
5. Build the model
6. Verify the model
7. Validate the model
8. Set up alternatives for evaluation
9. Run multiple replications on each alternative and evaluate results
10. Choose best alternative or combination of alternatives for presentation

4.1 Identify the Process

In this case, the process identified was patient flow through Emergency Services. The study would focus on all the steps that occurred from the time the patient entered the emergency department until the patient was released, admitted to a ward, or transferred to another facility.

4.2 Define the Goals and Objectives of the Study

The objective of the study was to reduce the patient's length of stay. Several possible ways to accomplish this were under consideration when the hospital administration decided to use simulation, such as adding another registration clerk or another RN. With simulation, each alternative could be tested on-screen and evaluated for effectiveness.

4.3 Formulate and Define Model

The model should be planned and defined up front, with data collection requirements thought out and scheduled in advance. Unfortunately, this step is often done "on the fly." Failure to take the time to design the model is one of the biggest reasons for projects not being completed on time. While data collection is often tedious and time consuming, it needs to be part of an organized plan. What often happens is that model building is interrupted several times for additional data collection. Each time the modeler must stop and wait for additional data, the project is delayed. If the model is planned up front, the total time lost due to delays will be sharply reduced. Also, having to backtrack and redo parts of the model can be a result of improper planning.

4.4 Data Collection

In our case study, the project started several months before simulation was brought in as a tool for evaluating alternatives. Ideally, simulation is chosen before the project starts and the data collection activities are consolidated. Gathering the data became a problem as a Joint Commission visit and the annual budgeting process fell during the same time span. Data was collected and analyzed for a three month period of time. Data came from the emergency department logs, patient records, Quality Assurance department's records, direct interviews and direct observation. The need to have a central database of information on patient visits became apparent. The type of data needed for the study is the same data that is needed over and over again to track progress and for assessment of current trends.

Patients were segregated into 14 categories, including orthopedic, cardiac, trauma, fast-track patients and patients for the pediatric clinic. Flow charts were made for each of the patient types (categories) with the appropriate treatment times and patterns. The flow charts should be of two types, high level and detailed. The high level would show the flow of the patient through the emergency department without the treatment detail. The detailed flow chart would expand the high level chart to include treatment times and care providers. A sharply abridged example of such a flow chart follows:

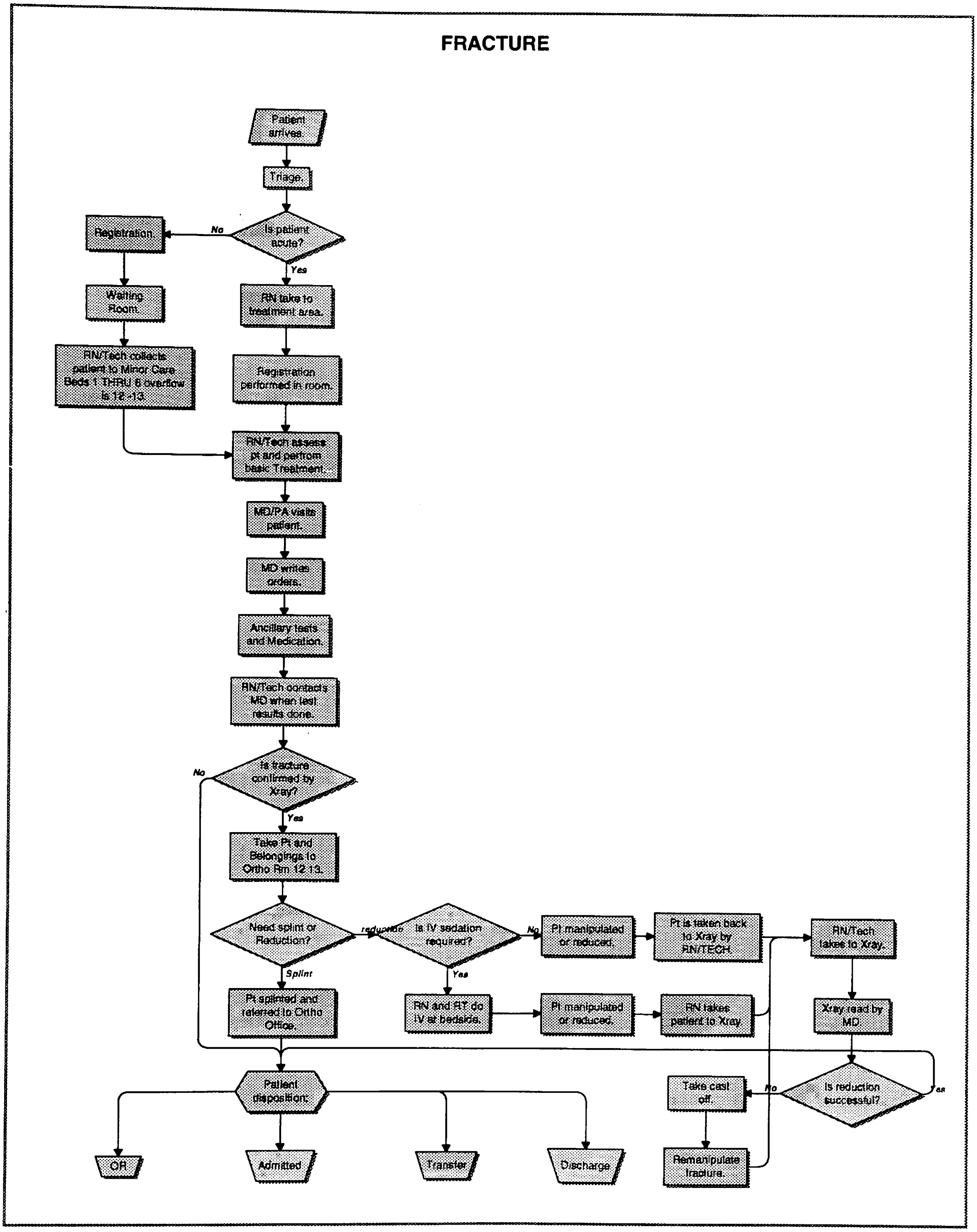

Figure 1: Abridged Flow Chart for Orthopedic Patient

Historical data for patient arrivals was segregated first by the day of week and then by the hour of the day. The number of patients arriving each day was represented by Poisson distributions. The patient arrivals was further broken down into a percentage of patients for each two hour segment of the day. Exponential inter-arrival times were then set for the 12 two hour segments of each day.

Ancillary department response times and result turn times were analyzed and fitted to a distribution using

Unifit2™ software by Averill Law and Associates (the results were checked with the statistical software package Statgraphics™). The response times were most often represented by Weibul distributions. The time necessary to process the lab samples and make the results available to the physicians resembled a Weibul distribution but was best represented by a "Log-logistic" distribution which is a special distribution provided by Unifit2™.

It is often prohibitive to try to collect a reliable number of data points when many patient types and many caregivers are involved, especially when the data being collected is treatment times. Some of the patient types occur infrequently and without warning. The time necessary to collect such data could be many months. Doctors are often not willing to keep logs and nurses have problems keeping logs of his/her times when the emergency department is busy. When this is the case, estimations of the distribution must be made. Estimated distributions were designated for the different treatment times, most often using a "Beta" distribution. The Beta distribution is an approximation using the least probable time, the maximum probable time, the most likely time and the average time. The result is far more accurate than assuming the distribution is normal or using a triangular distribution. Treatment times or service times, such as initial doctor assessment, are rarely represented by a normal distribution. Log-normal or Weibul shaped distributions are far more likely. The necessary information for the estimated distribution is usually obtained by direct interviews with several caregivers that perform the task being studied. Treatment times (task times) have certain characteristics that cause the distribution of these times to "look" like a Weibul distribution. The first characteristic is that there is a minimum amount of time the necessary treatment will take. This time is usually not far from the time the treatment will most likely take. This is because most practitioners are competent at what they do, so unless unexpected delays occur, the elapsed time will probably be much closer to the minimum time than it will be to the maximum time. The average time will usually be larger than the most likely time because of occasional long delays that can occur, inflating the overall average time. This results in a distribution that looks similar to the following:

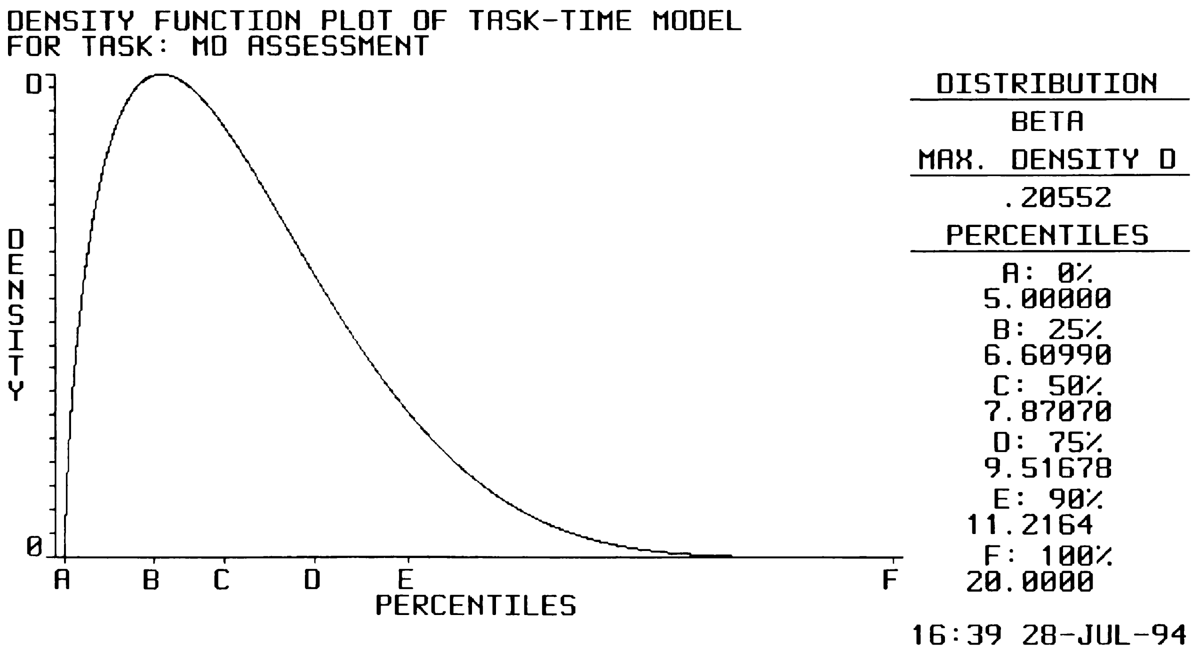

Figure 2: Typical Distribution for Treatment Times

The above diagram is of a "Beta" distribution created using Unifit2™.

A chart review is another method of collecting the data necessary for the simulation model. Many times the only records that contain patient type, patient acuity, ancillary tests and disposition information are the actual patient charts. A representative sample of these charts from the correct period of time can be used to provide differentiation data for the patient population.

Patient logs kept in the department represent another source of valuable data. A condensed extraction of data from such a log follows:

Summary of ED Log—Cast Patients

Arrival Time	Arr	ESA Prv	Disp	Depart	LOS	DOW
9:32am	ems	esa	admit	2:15 pm	283	MON
6:13am	ems	esa	T&R	8:30 am	137	SAT
3:26pm	ems	esa	T&R	5:00 pm	94	MON
3:48pm	ems	esa	T&R	5:30 pm	102	TUE
9:20pm	ems	esa	T&R	10:20 pm	60	WED
11:37p	ems	prv	admit	12:12 pm	755	WED
11:39p	pov	prv	admit	12:16 pm	757	FRI
10:40a	pov	both	T&R	2:45 pm	245	SAT
7:56pm	pov	both	T&R	9:55 pm	119	SAT
9:18pm	pov	both	T&R	11:20 pm	122	TUE

Figure 3: Sample ED Log

4.5 Building the Model

After completion of the data collection process, we were ready to build the model. Architectural drawings were used to draw the background to scale using MedModel's graphics package. Then the treatment locations and pathway networks were added, along with the rest of the elements needed to complete the model. These elements included 17 resources, 4 entities, 29 shifts, 6 results files, 20 variables, 20 attributes, 1 array, 8 subroutines, 12 macros, 8 function tables, 2 distribution tables, 11 arrival cycle tables, and patient processing and routing logic.

One of the problems unique to healthcare simulation projects has to do with patients leaving the treatment room for tests at another location and later returning to the treatment room. Keeping other patients from being sent to the temporarily vacated room can be a problem. "Dummy" locations with "dummy" entities can be used to prevent the room being captured by waiting patients. This method (work-around) is unfortunately tedious and time consuming. "Ghost" entities were used to occupy the room until the patient returned. The room is not considered vacant and therefore utilization figures are accurate.

4.6 Verification

Verifying the model is a process of comparing the actual patient flow process with the on-screen patient flow. The various documents (such as flow charts, arrival rates, and treatment patterns) should be combined with records of the various team meetings to form an "assumptions document". This is a record of the understandings that led to construction of the model. It is necessary to verify that the information included in the documents and therefore in the model reflect the system as it exists. The team should meet and go over these documents carefully to find any errors or misinterpretations.

The verification process should include watching the patient flow through the system to see if the patient went to the proper places and was treated by the appropriate personnel in the proper order. Traces of the logic and routing as it occurs should be printed and compared to the flow charts. This process will (of course) be done in detail by the modeler prior to the verification meeting. There are two reasons why this step is so important. First is that the team members that are part of the system being studied need to believe in the system model. The second reason is that any errors not found here can make the model impossible to validate. For example, there were several changes made to the flow charts during our verification meeting. The team members from the lab were unhappy with the data related to the time necessary to receive completed lab results. After analysis it was discovered that errors were made while manipulating the raw data.

4.7 Validation

This next step involves testing the model to ensure that the actual system length of stay times are mirrored by the simulation model. Our case model proved difficult to validate. While some patient types validated with relative ease, any patient type with significant admission rates would not validate, and in general the length of stay times were significantly too high. Going back to the drawing board was appropriate and additional data had to be collected for any patients that were to be admitted. Correcting the distribution used for the time necessary to wait for an available room helped correct the problem and the model validated.

Validation is an area that is often the source of confusion. This model was run for two weeks and three days with a three day warm up period for a total of ten replications. How many replications to run and how long should each replication be are only two of the questions that have to be answered. How close does the simulation model's values have to be to the actual system's values before the modeler can be confident that validation has occurred? I try to make sure that the actual system's values fall within the confidence intervals of the simulation model for the same values. If the actual system value is close to the middle of the confidence interval, I am comfortable with the validation, especially with the 99% CI.

5 ALTERNATIVES AND RESULTS

Five alternatives were tested for effectiveness with the simulation model. Adjustments were made with each alternative, and a combination of the most effective changes was suggested to the hospital's executive management. Listed below are the alternatives and the results of each in reducing patient length of stay.

1. One of the predetermined alternatives was the addition of a registration clerk during the peak hours of the day, which we defined as the 3 p.m. to 11 p.m. shift. The reason stated for this alternative is that the registration clerks were constantly being interrupted by the patient's family with questions and by patients waiting for treatment. Quite often the clerk would have to go find the charge nurse to obtain permission for the family member to visit the patient, or for a status report. However, there was no significant improvement in the patient's length of stay by adding a registration clerk. By using the simulation model to remove the delays and interruptions to the clerk did yield an improvement of about 12 minutes per patient. But some method of answering family member's questions and answering phone calls would have to be developed. Several possibilities were discussed, such as the addition of a patient care coordinator (who would have several duties in addition to greeting patients and answering questions).
2. A second alternative chosen early was to extend the hours of operation of the fast-track and pediatric clinic hours of operation. The hours were extended on the weekend to 11 a.m. - 11 p.m. for both areas, and for the pediatric clinic during the week. The original fast-track hours were 5 p.m. - 10:30 p.m. during the week and 3 p.m. - 11 p.m. on the weekends. The pediatric clinic's hours were 6 p.m. - 10 p.m. seven days per week. This alternative reduced the length of stay for all patients by 16 minutes.
3. A third alternative chosen prior to the model construction was to see what the impact on patient's length of stay would be if the ancillary departments could meet comparative (compared to similar departments in similar hospitals) times for turnaround times (time from the order until the results are ready). The lab turn times were about 85 minutes, and the simulation results showed that about 6 minutes would be saved for the average patient for each 10 minutes reduction in lab turn times. The impact of reducing the turn time to 45 minutes would be a savings of 24 minutes for the average patient (obviously the impact on each patient needing a lab test is the same as the reduction in turn time) .
4. The patients in the emergency department wait in the treatment rooms for the results of ancillary tests and for a hospital bed to become available if the patient is being admitted. If a holding area is available for the admitted patients (with suction, oxygen, and monitors available) the treatment rooms could be used by waiting patients. This should reduce length of stay. The simulation showed that an average of 22 minutes per patient could be saved by using 4 rooms divided by a curtain to accommodate a total of 8 patients.
5. The fast-track patient's length of stay was 123 minutes. This is only marginally less than the 157 minutes for similar patients that stayed in the main emergency department. The accepted standard for fast-track patients is less than 60 minutes. Analysis of criteria used to send patients to the fast-track area and analysis of triage procedures led to the addition of alternatives related to patient selection for the fast-track area. The average length of stay for pediatric patients in the pediatric clinic was 60 minutes. In both cases the patient was intended to be in need of minor care. However, the pediatric clinic had more detailed and more restrictive criteria for a patient's assignment to the area than the fast-track area. Another difference is that the fast-track area used residents for patient treatment and the pediatric clinic did not. Using emergency department physicians instead of residents reduced the length of stay by 14 minutes in the fast-track area. An alternative was added that uses similar criteria for both areas and emergency department physicians instead of residents in the fast-track area. Since the team had already decided to extend the hours of both the fast-track and the pediatric clinic, the

above changes were included and the alternative tested. The average length of stay for all patients in the Emergency Services area was reduced by 50 minutes to 107 minutes. This is well below the acceptable average of 120 minutes.

6 CONCLUSION

The final recommendations included Alternative 1 (the patient care coordinator), Alternative 4 (the holding room for admitted patients), and Alternative 5 (fast track improvements). Alternative 5 was itself a combination of alternatives. Several alternatives were tested and rejected. The addition of a MD on the second shift yielded only slight improvement (8 minutes). The addition of a RN did not have any significant impact on the patient's length of stay. Reassignment of an RN on the second shift negatively impacted the average patient's length of stay but only marginally (4 minutes).

Successful simulation studies are dependent on the cooperation of each department that is affected by the study and that affects the objective of the study. Also, careful planning is necessary to reduce delays and make the data collection as smooth as possible.

7 AUTHOR BIOGRAPHY

Frank McGuire is a manager with SunHealth's Process Design Services unit, which he joined in February, 1991. He currently manages SunHealth's process simulation consulting services and provides simulation training, consultation, and project management to alliance hospitals. He is an Industrial Engineer with extensive experience in emergency departments. His previous assignment with SunHealth was Manager of Software Development. He is a member of **IIE** and **HIMSS**.