APPLICATION OF SIMULATION MODELING FOR STREAMLINING OPERATIONS IN HOSPITAL EMERGENCY DEPARTMENTS

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ABSTRACT

The Emergency Department (ED) at a regional hospital provides the setting for this paper, that examines the problem of extended waiting times for health services. A field observation was conducted to document the current operation of the ED. A Flexsim computer simulation model of the ED was then developed to analyze the patient flow within the ED. The validity of the model was established by comparison of simulation results with actual data. In the final phase, the model will be utilized to evaluate the impacts of different proposed operating strategies on the waiting times and throughput rates for patients in the ED.

INTRODUCTION

The problem of long waiting times is common for all entities of the health care system. Much attention has been given to the problem of uninsured individuals' use of the Emergency Department (ED) for many routine health concerns that more properly should be addressed in the physician's office setting. In this circumstance, the primary health care provider is forced to offer the best outcomes within limited resources. Optimization of patient flow and bottleneck

elimination in key departments could become a possible solution that decreases operational cost and boosts quality of care.

The authors collected actual data over a one-year period for arrivals, waiting times, service times, and the severity of the patients' conditions. These data were categorized by month, day of the week, and time of day. The data were collected for four different waiting situations within the ED system. The objective was to identify those strategies which led to shorter waits for the patients, and therefore greater throughput rates and higher efficiency for the hospital, but without sacrificing the quality of patient care or significantly increasing costs.

The ED is one of the most highly congested units that faces greater pressure, compared with other components of the health care system. Delays in the Emergency Department may have particularly dramatic outcomes for patients. Several factors that contribute to the higher use of the ED have been identified. Padgett and Brodsky (1992) and Baker et al. (1994) determined that people from low socioeconomic class and racial minorities use the emergency health services as a regular source of primary care. The uninsured and the people on Medicare and Medicaid use the ED as a primary care provider much more often than those covered by private third-party payers (Nadel, 1993).

Under these pressures, it is crucial for hospitals to develop methodology for improving patient flow, providing the best possible care in a timely manner, and ensuring maximum utilization of limited resources. This study employs the Flexsim simulation software to model the operations of the ED in a regional hospital and evaluate strategies that will ease the bottlenecks and reduce waiting times for patients in the ED.

MODELING THE ED USING COMPUTER SIMULATION SOFTWARE

From a queuing theory standpoint, an emergency department can be thought of as a network of queues and different types of servers. A quantitative analysis of the wait time problem in an emergency department is dependent upon the identification of a methodology which recognizes the structure of the problem as that of a queuing system. Two modes of analysis are generally suggested by the structure of this type of problem: queuing models and discrete event simulations.

Over the past thirty years, a significant amount of research has been done in the area of discrete-event simulation modeling in health care. Recent innovations in object-oriented models enable the construction of large integrated systems that become powerful tools for analysis of and innovations in health care systems (Jun, et al, 1999).

In some studies, researchers have generated models that were able to make accurate predictions of measures such as waiting room times and patient care times. One such model was developed by Rossetti et al. (1999) using the Emergency Department at the University of Virginia Medical Center in Charlottesville as a case study. This model was used to test alternative ED attending physician staffing schedules and their impacts on patient flow and resource utilization. Shift

modification was also tested in the McGuire (1997) study (Emergency Services department in a SunHealth Alliance hospital), which allows choosing a solution that reduces average length of stay for patients by up to 50 minutes.

Lloyd G. Connelly and Aaron E. Bair (2006) used the Extend DES modeling package (EDSIM) to develop a model of the ED. This validated model was used to compare two alternatives for optimization of patient flow: the fast-track triage and the acuity ratio triage (ART). Results of this study suggested that the EDSIM model has the potential to predict average patient service times within 10% of actual values. On the other hand, its potential to predict an individual patient path was limited (28% of individual patient treatment times had an absolute error of less than one hour). A preliminary comparison of two triage methods showed that the ART approach reduced imaging bottlenecks and average treatment times for some patient types.

Waiting time in the ED can be reduced through implementation of quantitative methods, understanding of best practices, and commitment to change. For instance, queuing models of emergency department activity have a broad range of potential applications. One of the most promising areas is the study of ED overcrowding. A critical capability afforded by patient flow simulation is the identification of the factors that are responsible for overcrowding. This allows a more detailed understanding of the relationship between the observed conditions and related outcomes that could lead to informed optimization decisions.

RESEARCH

This study of emergency room patient flow using a medium size hospital as a case-study model has three distinct phases: data collection and critical factor identification, model building, and scenario testing.

During the first phase, a field observation was conducted to study the operation of the ED over a number of different shifts. The purpose of the study was to determine the flow of patients through the ED and to identify the data elements required to complete a quantitative analysis of waiting time issues. The results of this study were used to design a full scale data collection procedure.

The second phase of the study will be devoted to building and validation of a simulation model using the Flexsim simulation software (www.flexsim.com) for modeling, analysis, visualization, and optimization of target processes within the ED. Flexsim simulation software was traditionally used by the manufacturing industry for process modeling and optimization. It uses 3D objects that represent process activities and queuing. This software was chosen because it allows user customization of objects, views and object parameters. It also has an option to simulate “what-if” scenarios with the opportunity to analyze the performance of each scenario by a number of user-defined performance indicators such as utilization, throughput, waiting time, LOS (length of stay), etc. These options permit construction of models with high potential to predict actual processes that could be modified to test different scenearios and optimization

approaches. The accuracy of model output will be tested by comparing predicted and known patient service times.

In third phase of the study, the basic model will be extended to simulate the effects of different operating strategies on patient waiting time in the ED. The purpose of this phase of the project is to determine which of the possible optimization strategies suggested in the first phase could be expected to produce the greatest reduction in patient waiting times.

GENERAL FEATURES OF THE HOSPITAL AND PROCESS MAP FOR THE ED

The subject of our study is 180-bed Hospital in rural Mississippi which provides the following key services: general medical and surgical care, general intensive care, cardiac intensive care, pediatric medical and surgical care, pediatric intensive care, physical rehabilitation, obstetrics, emergency department, and trauma center.

In terms of patient flow, the Hospital could be viewed from several different perspectives. At the highest level of detail, the hospital includes three general subdivisions: Outpatient, Inpatient and Emergency. The fourth area, the outpatient community clinics associated with the hospital, was not studied in this research.

The Emergency Department serves a greater number of patients than the inpatient and outpatient sectors. The majority of emergency patients are walk-ins; however there are a considerable number of patients brought in by ambulance. Approximately 12 % of in-coming emergency patients require hospitalization, around 1.5 % are transferred to the university medical center, and on average 9.5% leave waiting areas and treatment rooms without being seen by physician.

The Emergency Department consists of several major areas: triage room, admitting area, nursing station and treatment rooms. The first patient-personnel interaction occurs in the triage area, where the patient is seen by triage nurse once he or she enters the ED. The nurse assesses patient's vital signs, determines the seriousness of the patient's condition and assigns a corresponding triage category which ranges from 1 (least severe) to 4 (most severe). Patients with category 1 and 2 proceed to the admitting area, whereas patients with category 3 and 4 are walked or transported directly to the treatment room and are registered while in the treatment rooms, or the escorting persons register the patients in the admitting area.

The same principle works for the patients transported by ambulance in a critical condition: they are brought directly to the treatment room, where the severity of their condition is assessed, and the registration procedure occurs later. Before the incoming patients see the triage nurse they may have to wait in the triage waiting area. While awaiting registration, patients stay in the admitting waiting area until admitting representative calls them to the registration desk (Chart 1).

After registration, patients move to the main waiting room, unless a treatment room is immediately available. The treatment area consists of 10 treatment rooms: 4 trauma rooms (T1,

T2, T3 and T4) with equipment for managing cardiac emergency; three specialized treatment rooms: the eye trauma room (M1), orthopedic room (M2), major medical pediatric room (M3), and three general medical rooms (M4, M5, M6). Any of the specialized rooms can be used as a general room in case of high patient volume. Once a treatment room is available, the patient is called in, and he/she waits to be seen by a physician. While some patients need only to be examined by the physician in order for the treatment plan be developed, others require one or more ancillary tests. The most frequently ordered ancillary service is laboratory tests, followed by radiology services.

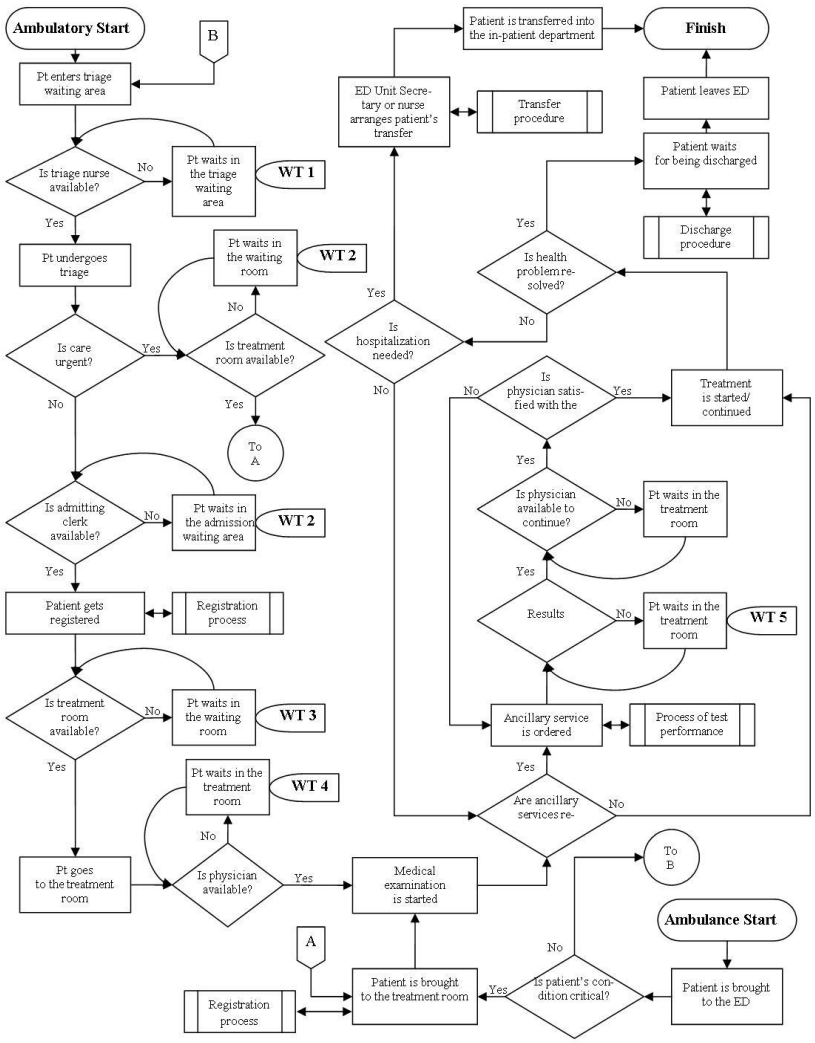

Chart 1. The flowchart for Patient Flow in the ED

The lab provides a wide variety of tests. The flow comprises specimens, mostly blood samples in tubes. The flow starts when an order is faxed to the lab. The order is always labeled "stat", regardless the severity of the patient's condition. The hospital is not equipped with a pneumatic tube delivery system; therefore, specimens are transported to the lab by hospital staff. After the order is printed in the lab, either a lab technician comes to the ED to obtain the specimen and carry it to the lab, or the specimen is collected and hand carried to the lab by an ED nurse. Once the test has been completed and results are verified, the report is automatically faxed to the ED. In the majority of cases, once the specimen is delivered to the lab, it does not take longer than 40-60 minutes before the test is finished and the report is produced.

The most commonly performed diagnostic procedures in the radiology department include X-ray tests, CT-scans, and ultrasonograms. The location of the Radiology Department (RD) is favorable for patient flow, because the department is situated in the immediate proximity of the ED, so it takes a few minutes to walk or transport the patient to the RD. Upon test completion, the patient is transported back to the treatment room where he/she stays until the report is faxed to the ED.

After report has been printed in the ED, it may take several minutes before the physician receives the report and makes his/her second visit to the patient. If physician is satisfied with the results, the patient is advised on the treatment plan and the discharge procedure is initiated. If the results do not provide the necessary information, other ancillary tests may be required. The decision about patient transfer into the inpatient ward can be made by the physician at any stage of the care process.

EVALUATION OF PATIENT FLOW IN THE ED

To evaluate monthly patient flow through the ED, the internal report for fiscal year of October 2006 – September 2007 was analyzed. According to the report, the number of patients per month varied from 1186 (June 2007) to 1492 (December 2006) with an average of 1360. During this year, the ED provided services to 16,316 patients.

For the purpose of further patient flow assessment in the department, historical data for the period of January '07 - September '07 (273 consecutive days) were analyzed. The information was obtained from various sources: ED Registers, Patient registration logs, ED and RD internal reports, hospital computerized database, discussions with focus groups, patient surveys, and staff interviews.

The patient volume in the ED ranged between 27 and 63 per day with the mean of 43.8 and σ = 6.45. On an average day, the period between 12 am and 7 am was not associated with any significant activity in the department – the patient load would remain equal to about 1 patient per hour or even less than that. The inflow would increase starting from 9-10 am and peak up to 3 patients per hour at 11am - 12 pm. During next 12 hours, patient inflow would stay relatively constant – around 2-2.5 patients per hour.

When studying patient flow in the ED, it is important to determine the ratio of severely ill patients to the moderately ill. The proportion of different triage categories (classes) best reflects the relations between different patient groups. The patient is assigned a triage category when he/she arrives in the ED. The category depends upon the severity of patient's condition and is a number between 1 and 4, where 1 indicates the least severe condition and 4 the most severe. The speed with which the patient is moved through the system is determined by various factors, among which the triage category is one of the most critical. The most severe cases are taken care of first, then the service is provided to the patients with less severe conditions, and so forth.

For example, after triage, patients with triage category 3 and 4 are moved directly to the treatment room, where they are seen by a physician almost immediately. Category 1 and 2 patients first walk to the admitting area and then wait for an available treatment room. Once in the treatment room, they must wait for the physician to come. To reveal the ratio of patients with different triage categories, the data of a 4-month period (January '07 – April '07) were collected and analyzed. The study revealed that a great majority of patients were assigned category 2, which indicates a mild health problem.

Perhaps one of the most crucial parts of this project was waiting time analysis. The authors identified 5 major stages at which patients had to wait on their way through the system. Waiting was always associated with some sort of transitional state, when one event had already taken place and the patient was waiting for the subsequent event to occur. The stages are summarized in the Table 1.

Stage number	Stage name (location)	Preceding event/ location	Subsequent event/ location	Abbreviation	Number of cases studied
1	Triage waiting area	Arrival	Triage	WT 1	187
2	Admitting waiting area	Triage	Registration	WT 2	121
3	ED main waiting room	Registration	Treatment room	WT 3	93
4	Treatment room	Awaiting being brought to treatment room	Being seen by physician	WT 4	81
5	Treatment room	Physician's visit	Lab report to arrive to the ED*	WT 5	91

*- The time of radiology tests completion was not available; therefore, the time of waiting for radiology test report was not counted in WT5. However, the results of personnel survey indicate that waiting time for radiology report is about 40 minutes which is roughly equal to the wait for lab report.

Table 1. Stages of patient flow at which waiting time was measured.

All cases studied were related to patients of triage category 2, because the proportion of category 1 patients was relatively insignificant (Figure 6) and the category 3 and 4 patients did not have extended waits at any stage. The results of the waiting time study are provided in Figure 1.

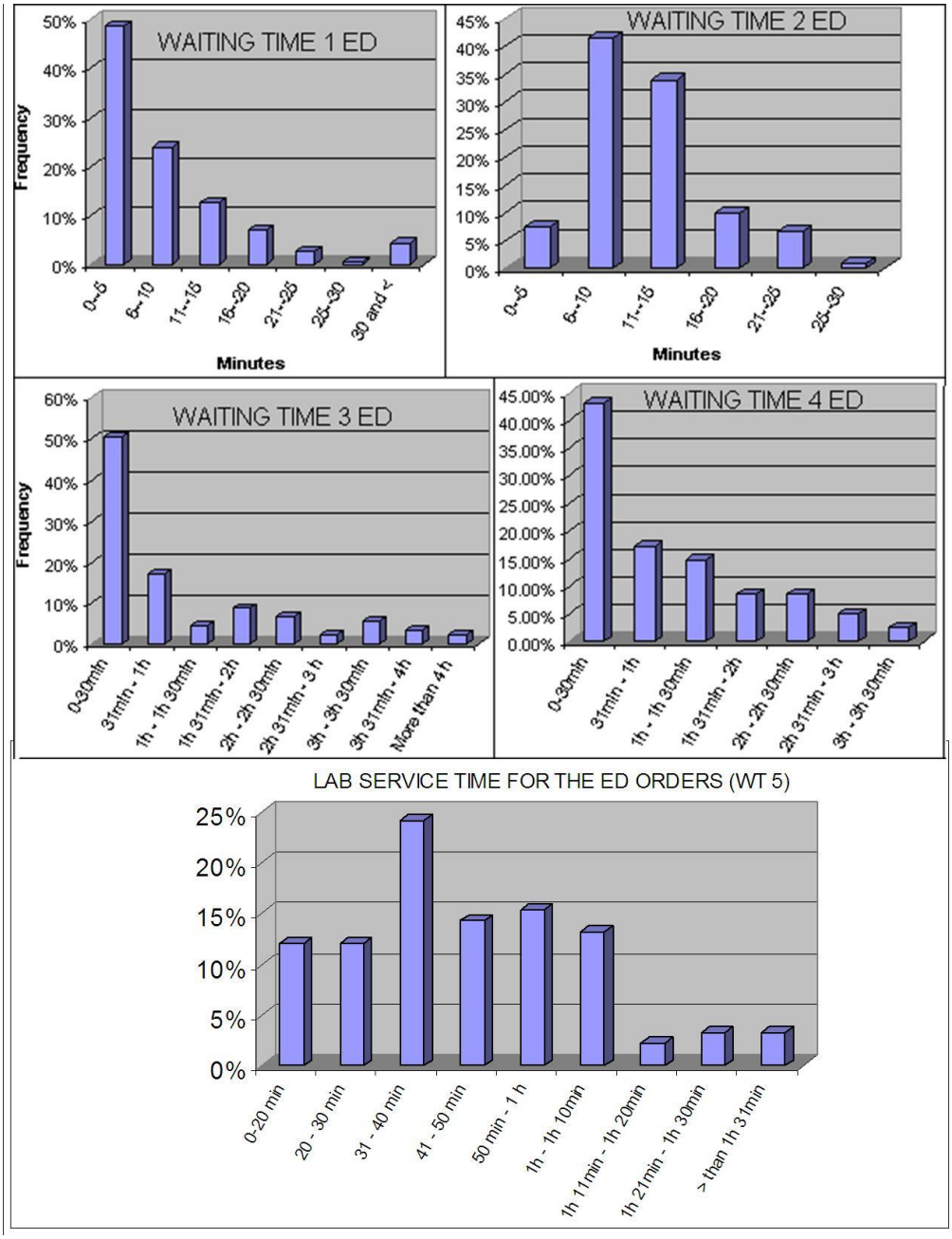

Figure 1. Waiting Time at different stages of Patient Flow in the Emergency Department.

Finally, the length of stay (LOS) was documented as a time difference between arrival and discharge time, and varied significantly, depending on whether or not ancillary services had been ordered. Patients whose condition did not require ancillary services stayed in the ED for 2 hours and 10 minutes on average, whereas those who needed laboratory or radiology tests spent 3 h. 31 min. and 2 h. 58 min., respectively, in the ED. Among 236 cases of triage category 1 and 2 selected randomly, the rate of ancillary services utilization was distributed as follows: Laboratory - 29%, Radiology - 24%, Cardio (mostly ECG) - 6%, Respiratory - 6%, none - 38%.

RECOMMENDED IMPROVEMENTS

First phase of the study resulted in numerous recommendations that will be tested by Flexsim simulation model in third phase of the study. All scenarios are summarized according to the service stages.

1. Recommendations related to the triage procedure.

A Fast Track system should be designed to serve patients with minor problems in a speedier manner. Most of patients in the ED department are considered non-urgent, and cycling of 40-50% of total patient volume through this type of speedy system would have a dramatic impact on total waiting time and length of stay for all patient groups (Hall, 2007). This process will be simulated by a Flexsim model using different scenarios, depending on patient volume; thus, the effectiveness of this change will be predicted.

2. Recommendations related to the registration procedure.

Introduction of a computerized tracking system that will allow collection of a valid database is suggested. A variety of alternatives are available, such as a barcode system that is compatible with the current hospital information system. Real-time data collection, in combination with a customized modeling system, would allow managers to allocate resources to the right place, at the right time, in the right amounts. The ability to access data regarding a system is the foundation for the development of a valid simulation model.

3. Recommendations for treatment room utilization and staff scheduling.

a. Optimization of scheduling requires a complex approach, and should be based on forecasting of the most likely impact of any future changes. Computer simulation will support better decisions.
b. Establishment of protocols for top diagnoses that would provide a total set of agreed-upon steps to be taken. Introduction of a protocol-based system will help to reduce delay in the ED.

4. Recommendations for ancillary services utilization.

High patient load in the Radiology department during busy hours may contribute to excessive wait time and LOS. Introduction of a separate imaging unit should help to increase the speed of patient flow through the system. Introduction of a separate ancillary facility as well as staff hiring and training will require additional resources. The computer simulation model will be used

for assessment of the effectiveness of this innovation, expenditures planning and resource allocation.

5. Recommendations for hospitalization and discharge procedures.

a. A Bed Management System will improve communication between nurse stations and the ED and significantly reduce time of the in-patient admissions process. The Bed Management System facilitates the information exchange, thus making the information about bed availability easily and quickly accessible. Introduction of this system will eliminate unnecessary steps in the nurse unit-to-unit communication and significantly reduce the length of the bed assignment process. Simulation of this process will give better understanding of possible impacts of this innovation, not only on the ED but on the admitting department and wards as well.

b. Establishment of a discharge waiting unit (Discharge Lounge) within the ED will increase treatment room turnover rate and decrease critical waiting for treatment room time. Creation of this new entity would require room rearrangement and additional staff training, and may have an uncertain impact on patient flow. Therefore, it should first be simulated by the basic system model.

The final phase of the project will be to employ the model to gain acceptance by the hospital administration, as well as the health professionals who provide the care for the patients in the ED, that the proposed changes represent cost-effective improvements in the quality of the health care delivery system**.**

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