Proceedings of the 1999 Winter Simulation Conference
P. A. Farrington, H. B. Nembhard, D. T. Sturrock, and G. W. Evans, eds.

EMERGENCY DEPARTMENT SIMULATION AND DETERMINATION OF OPTIMAL ATTENDING PHYSICIAN STAFFING SCHEDULES

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ABSTRACT

Efficient allocation and utilization of staff resources is an important issue facing emergency department (ED) administrators. Increased pressure from competition, heath care reform, reimbursement difficulties, and rising heath care costs are primarily responsible for the high level of interest in this, and other ED operating efficiency issues. This paper discusses the use of computer simulation to test alternative ED attending physician-staffing schedules and to analyze the corresponding impacts on patient throughput and resource utilization. The simulation model can also be used to help identify process inefficiencies and to evaluate the effects of staffing, layout, resource, and patient flow changes on system performance without disturbing the actual system. The development of this model was based on the Emergency Department at the University of Virginia Medical Center in Charlottesville, Virginia.

1 INTRODUCTION

The Emergency Department at the University of Virginia Medical Center is a 24-hour emergency care facility with approximately 60,000 patient visits annually (~165 patients per day). There are a total of 34 beds for patient care divided into four distinct care areas. These are the Adult Care Wing (17 beds, 2 trauma beds), Chest Pain Center (5 beds), Pediatric Care Wing (6 beds), and the Minor Emergency Area (4 beds) which is used to treat lower acuity level adult patients from 8 a.m. until 12 a.m. seven days a week. Figure 1 presents the floor plan for the ED at the University of Virginia Medical Center.

A great deal of time, effort, and resources are required to provide high quality care to each of the 60,000 patients seen annually. Providing educational training to students and conducting research only increases the workload at an academic hospital. A number of feasible alternatives exist for addressing the cost reduction and funding issues, such as external grants; however, this project focused on identifying inefficiencies and problem areas within the existing ED system. More specifically, this project challenged the current attending physician staffing schedules and evaluated alternative staffing strategies using a computer simulation model.

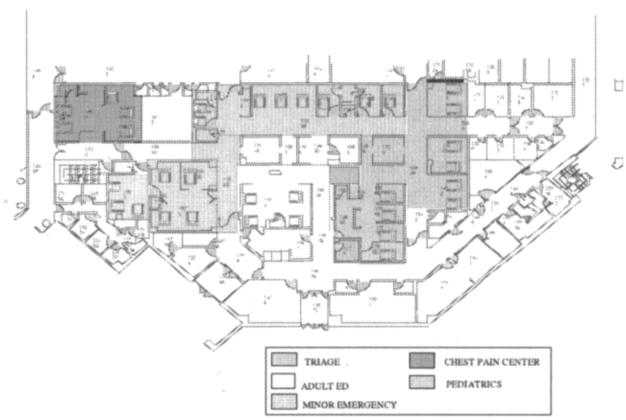

Figure 1: UVA Emergency Department Floor Plan

Staffing and utilization of ED nurse and physician resources is mainly a concern because of expense, but it is also significant because of its impact on patient throughput and overall system performance. While no specific areas within the current staffing process have been identified as problematic, ED management felt that staffing improvements could be identified by considering patient load as a function of hour of the day and day of the week. The motivation for this analysis is to strategically reduce staffing at slower times of the day/week to save on operating expenses and to increase staff resource utilization. In one sense, it is desirable to operate the ED with minimum staff, as long as quality of patient care is maintained, and to eliminate the number of resources sitting idle at any given time. Due to the nature and intensity of the tasks being performed in an ED environment, decreasing operating expenses and increasing staff utilization may result in an increased number of errors due to overworked resources. While it is outside the scope of this project, further study into this problem of quality control for patient care based on the number of errors created by understaffing (i.e. overworked doctors and nurses) is of great significance to the overall performance of the ED system, and is highly recommended. We recommend the use of a quality control analysis before and after the implementation of staffing changes to determine relevant problems and potential solutions.

The staffing problem, as it applies to emergency departments, has been analyzed both qualitatively and quantitatively since the 1960's. Van de Leuv (1987) treats several factors, including shift length and staffing plans for Emergency Medicine. Some approaches to solving the problem of scheduling for an emergency department have used linear programming, integer programming, and computer simulation models. While these are only a few of the possible solution strategies, they represent the most effective methods available.

Although not widely used in the field until the last decade, simulation modeling is a useful tool for emergency medicine and hospital administration research. The application of simulation modeling for emergency department staffing is evident in the literature. Draeger (1992) developed simulation models for three Emergency Departments at Bethesda Hospitals Inc. to explore present nurse staffing concerns and to assess alternatives for improvement. Kumar and Kapur (1989) used simulation to analyze nurse-scheduling alternatives for the Emergency Room Services at Georgetown University Hospital. McGuire (1994) discusses the use of simulation to test process improvement alternatives and to select an alternative to reduce the length of stay for ED patients.

This paper first presents an overview of the patient flow process through the ED. We then present a brief description of the simulation model used to analyze the scheduling alternatives. The alternative attending physician staffing schedules are then presented, followed by a discussion of the comparative analysis, and the results obtained. The paper concludes with recommendations and potential areas for further study.

2 PATIENT FLOW PROCESS

A visit to the ED typically involves a complex series of decisions, activities, and interactions with ED and hospital staff. Although it is impossible to classify all ED patient flow processes exactly, a general flow process for the "typical" ED patient can be determined. Since patient flow can vary from patient to patient based on acuity level and diagnosis, the general process description involves the most common decisions, activities, and interactions a patient will experience during treatment. A patient enters the ED by one of three modes: walk-in, ambulance, or helicopter. This section gives a brief overview of each activity in the general patient flow process.

2.1 Walk-In Arrivals

When a walk-in patient arrives at the hospital and enters the ED, a registration clerk registers the patient by creating a file for this specific visit. After completing registration, patients are sent to a waiting room to wait for a triage nurse to become available and to transport them to the triage area. During the triage process, the triage nurse takes the patients blood pressure and temperature, assesses the patient's condition, and assigns the patient an acuity level and treatment unit. At this point, the patient returns to the waiting room to await admission to their designated wing or treatment unit within the ED.

2.2 Ambulance Patient Arrivals

Similar to walk-in patients, ambulance patients can also be classified as trauma or non-trauma. Non-trauma ambulance patients bypass registration and triage and are admitted directly to the ED upon arrival and follow the same flow as non-trauma walk-in patients. Trauma ambulance arrivals are sent to one of two trauma stations within the Adult Wing of the ED and are treated by ED doctors and nurses while awaiting the arrival of a specialized trauma team.

2.3 Helicopter (Pegasus) Patient Arrivals

Helicopter patients are immediately sent to one of the trauma stations within the Adult Wing of the ED upon arrival. These patients are classified as minor trauma or major trauma based on the severity of the patient's condition. This classification represents two very distinct patient flows. For minor emergency cases, the ED doctors and nurses monitor the patient, stabilize him/her if necessary, and order any preliminary tests that might be needed to better assess the patient's condition. The trauma team for these patients may take hours to arrive within the ED to take over treatment of the patient. Once the team is able to determine the problem and decide on a treatment process, they admit the patient to the appropriate branch of the hospital. In contrast, major trauma patients may wait a matter of minutes, if at all, for the trauma team to arrive in the ED and assume care of the patient. Once the trauma team arrives and stabilizes the patient, the team will transport the patient to the operating room for further treatment. While waiting for the trauma team to arrive, an ED attending or resident physician and ED nurses work to stabilize and sustain the patient to prevent death from occurring.

2.4 Emergency Department Wings

The Emergency Department at the University of Virginia Medical Center is sectioned into four distinct treatment areas or wings. These are the Adult Care Wing, Pediatric Care Wing, Chest Pain Center (CPC), and Minor Emergency Area (MEA). Patients are assigned to one of these areas based on age, acuity level, and type of illness. A brief discussion of the patient flow through each of these areas is given below.

2.4.1 Adult Care Wing

Patients who are assigned to the Adult Wing of the Emergency Department are assigned to one of the nineteen adult-trauma beds throughout the duration of their stay. Typically, an adult ED nurse initiates the patient care cycle by assessing the patient's condition. After the nurse completes the initial treatment process, an ED doctor (attending, resident, or intern) performs an assessment and continues treatment of the patient. At this point a decision must be made, based on the type of illness and the severity of the patient's condition, as to whether or not the patient requires additional care, is ready to be discharged from the ED, or must be admitted to the hospital. Additional care may include consultation, radiology tests, lab tests, observation, or any combination of these. After each care activity is completed, the patient's condition is reassessed by the ED doctors and/or outside caregivers to again decide the course of action for that patient (i.e. admit, discharge, or additional care). During this cyclical process, a patient may receive multiple visits from ED doctors and nurses. Figure 2 presents the layout of Adult Care Wing.

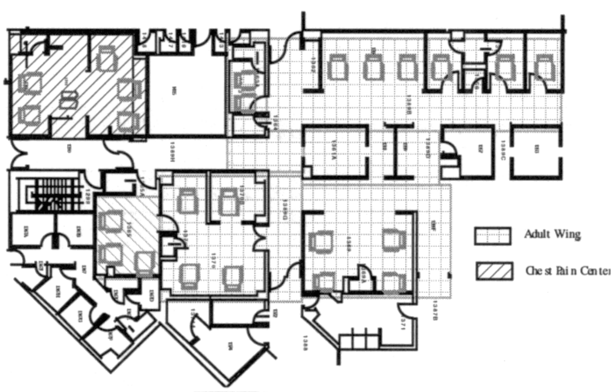

Figure 2: Adult and Chest Pain Care Wings

2.4.2 Chest Pain Center (CPC)

The CPC patient care cycle begins with a visit from a CPC nurse and an ED physician. Following these initial assessments, CPC nurses monitor each patient's heart and vital signs to help determine the cause of the patient's chest pain. In addition, any combination of the additional care options available for treating adult patients may also be used to assess a CPC patient's condition. Throughout the duration of the observational or monitoring period, CPC nurses are also responsible for providing necessary care to the CPC patients. At whatever point during the process, the cause of the patient's chest pain is determined or the patient's status changes the doctor returns to reassess the patient and decide on the best form of treatment. At this point, one of three decisions is made: the patient is discharged, the patient is admitted to the hospital, or the patient remains in the CPC for continued monitoring. One final point worth noting is that the CPC is staffed by the same doctors that are responsible for the Adult Wing of the ED. See Figure 2 for a layout of the Chest Pain Center.

2.4.3 Pediatric Care Wing

The flow through the pediatric care wing is identical to the patient flow through the Adult Wing. The only real difference is that the Pediatric Care Wing, for all but the early morning hours, has a specific group of doctors and nurses who are assigned to care for the pediatric patients. See Figure 3 for a layout of the Pediatric Care Wing.

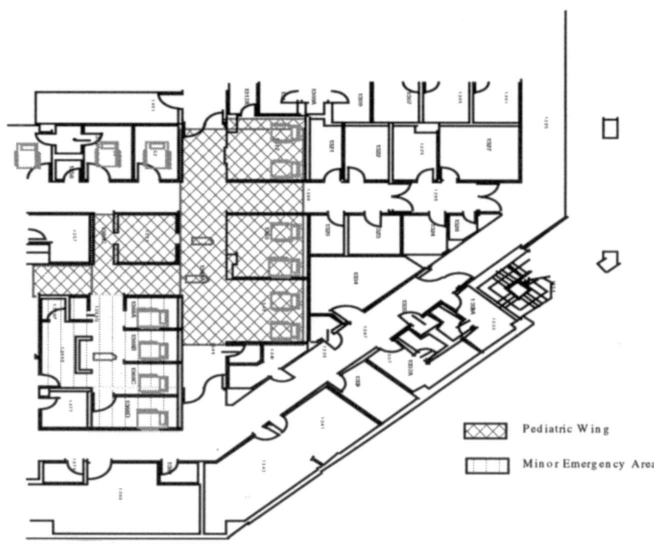

Figure 3: Pediatric Care and Minor Emergency Wings

2.4.4 Minor Emergency Area (MEA)

The MEA is used to treat low acuity level adult patients between the hours of 8 a.m. and 12 a.m. During all other hours, patients who would normally be assigned to the MEA are sent to the Adult Care Wing for treatment. The typical MEA patient flow process is initiated by a visit from a nurse practitioner that is responsible for performing a patient assessment and completing the treatment process. While the majority of MEA patients are discharged at this point, it is possible for a MEA patient to require additional care through lab or radiology tests. At the completion of either of these processes, the patient is given the appropriate care by the nurse practitioner and discharged. See Figure 3 for a layout of the Minor Emergency Area.

2.5 Additional Care

As previously mentioned, a patient's treatment may require some additional care alternatives. Among these were consultation, lab tests, and radiology exams. The consultation process is identical to an ED doctor visit, except the doctor is from some branch of the hospital outside of Emergency Medicine. Radiology exams for a patient may be performed within the ED without the patient leaving their bed. In most cases, however, a radiology exam is ordered, the patient is transported to Radiology, the exam is completed, and the patient returns to the same room and bed to await the interpretation of the results by a doctor. Lab testing is very similar, in that ED nurses or technicians will obtain the sample and send it to the lab for analysis. Lab testing concludes with the patient waiting for the results to be interpreted by a doctor.

2.6 Departing the Emergency Department

Being admitted to the hospital, being discharged from the ED, balking (leaving the ED before treatment), and death are the only four ways a patient may exit the ED. Admitting a patient to a particular area of the hospital requires representative consults from that area to assess the patient's condition within the ED. Only after completing this assessment process can a patient be admitted to the hospital. Should the consult decide that a patient does not need to be admitted to the hospital, that patient is discharged from the ED. Once the decision has been made admit or discharge a patient, an attending physician (adult attending for CPC and Adult Wing and a pediatric attending for the MEA and Pediatric Wing) must sign off and complete documentation of the patient's chart. This is done to show that the attending physician is satisfied with the patient's overall assessment and treatment and to officially release the patient from the ED.

3 MODEL DEVELOPMENT

The main objective of the simulation model was to develop an understanding of system performance relative to various attending physician staffing schedules. This was accomplished by modeling the overall patient flow and ED system processes for realistic operating conditions. Using the patient flow process descriptions and their corresponding activity flow diagrams as a guide, each section of the patient flow process was translated into Arena 3.0 simulation logic. Arena allows the user to model real world and proposed systems using a set of templates of graphical modules, elements, and support blocks for different modeling constructs and capabilities. It is important to note that the simulation model was developed using a number of assumptions to simplify the modeling effort by eliminating any insignificant parameters and/or events. A few of the most significant assumptions used in constructing the model were:

1. All patients remain at the same acuity level throughout their stay in the ED. The acuity level is assigned during Triage or immediately after entering the ED.
2. All trauma patients (minor and major) are equivalent to high acuity level adult wing or CPC patients and do not require separate modeling constructs. Since trauma patients represent a very small percentage of all patients seen in the ED, special handling, treatment times, and external resource requirements can be ignored.
3. At midnight, all MEA patients are removed from the MEA waiting area and redefined as adult wing patients. This assumption is used to handle the closing of the MEA at midnight and the treatment of these patients by adult staff thereafter.

Within the model, entities are used to represent:

- ED patients
- Phone calls and other indirect care activities
- Logical entities for initializing the model and generating patient arrival rates for walk-in, ambulance, and helicopter arrivals.

3.1 Verification

Verification is the process of ensuring that the simulation model is built correctly and performs as the modeler intended. While there are a number of different strategies that can be used to perform model verification, the following is a partial list of common sense suggestions that was used for the ED simulation study (Banks, Carson, and Nelson 1996, pg. 401):

1. Have someone familiar with the system (other than the developer) check the computer simulation model for problems.
2. Generate an activity flow diagram of the system. This should include logic for all possible activities an entity may encounter while in the system.
3. Examine the reasonableness of the model output for a variety of input parameter values. A wide variety of output statistics should be used for this analysis.
4. If possible, animate the computer model to verify that what is seen in the animation imitates the behavior of the actual system.

3.2 Validation

Validation is the process of ensuring that the model is an accurate representation of the actual system and behaves in the same way. This can be achieved by comparing the output results for a number of performance measures to the corresponding results from the actual system. Discrepancies between the model results and actual results can then be used to improve the model and therefore the accuracy of the results. This process is repeated until the desired level of precision is obtained for the model's output. A widely used three-step approach formulated by Naylor and Finger (1967) has been developed to aid in the validation process. The three steps are as follows:

1. *Face Validation* - Face validation involves asking model users and others who are knowledgeable about the actual system being modeled, whether or not the model and its behavior are reasonable. For the ED simulation study, each section of the model logic was discussed in detail with ED staff before construction of the model began.
2. *Validation of Model Assumptions* - Due to the complex nature of the ED system and its large number of interactions with other areas of the hospital, assumptions were used to simplify the simulation modeling effort. Structural assumptions, those involving the system's operation, were proved after spending greater than 45 hours observing day-to-day activities within the ED. Any data assumptions used in constructing the simulation model or specifying the model's input parameters were validated during the Data Analysis phase of this project using the Input Analyzer tool.
3. *Validating Input-Output Transformations* - Unlike the subjective validation methods used in the previous two steps of the model validation process, the third step, Validating Input-Output Transformations, requires an objective analysis. This is achieved by testing the simulation model's ability to predict the future (or past) behavior of the real world system being modeled. Ensuring that the simulation model's output measures mirror the corresponding output measures from the actual system does this. With regard to the ED simulation study, nearly all of the simulation input parameters were developed from historical data, either from the detailed work sampling methods or a computerized patient tracking system. The measures of performance used to validate the simulation model are given in Table 1. The simulation was run for 10 replications, each of 5 weeks in duration.

All of the performance measures pass at the alpha = 0.01 level except for CPC ED time. In comparing to the historical, one must also be aware that the historical values are also estimates. In fact, we believe that the problem with the CPC ED time is related to the fact that only a small number of CPC patients were observed during the data collection process described in the next section. The performance measure that we placed the most weight on in terms of accepting the validity of the model was the Adult ED time because good historical data was collected and because it represents total system performance. With a minimum acceptable difference of 3 minutes the Type II error associated with the alpha 0.01 level test for the Adult ED time is 0.06 which we feel is quite acceptable.

Table 1: Validation Results

	Hist. Mean	**Sim. Avg. (Std. Dev.)**	**p value**
Admit Wait Time	56.26	56.5 (2.23)	0.74
Adult ED Time	193	191 (5.8)	0.30
Consult Time	88.36	86.9 (2.31)	0.08
CPC ED Time	186	220 (5.79)	0.00
MEA ED Time	191	197 (7.9)	0.04
Patient Care Time	159	158 (2.21)	0.19
Pediatric ED Time	195	203 (8.3)	0.01
Registration Time	3.13	3.13 (0.023)	1.00
Total ED Time	193	197 (3.64)	0.01
Triage Time	3.92	3.96 (0.05)	0.03
Wait Room Time	27	28.8 (2.17)	0.03

4 DATA COLLECTION AND ANALYSIS

A simulation model's value as a tool for system research and analysis depends on the representative nature of the input data and the statistical accuracy of the model. While the majority of information was already being collected and stored by the ED's computerized patient tracking system, the radiology department's computer database, and the various lab computerized databases, these systems were only partially used to obtain input data for this study. Due to the complexity of the ED system and the large number of stochastic elements involved in the patient flow process, the data collection effort was separated into four different phases.

4.1 Phase 1: Patient Visit Time Study

Phase 1 of the data collection process was geared towards gathering detailed information about each stage (i.e. Registration, Triage, Discharge, etc.) of a patient's visit to the ED. This was accomplished using self-reported work sampling techniques to gather information on all ED patients during the week of February 22 through February 28, 1999. A total of 1,175 patient visit data sheets were completed over this period.

4.2 Phase 2: Service Distribution Time Study

The second phase of the data collection process compiled information on the amount of time that ED doctors, nurses, and nurse practitioners spent on patient care activities. This was accomplished using a time study restricted to ED patient visits in specific areas during the week of February 22 through February 28, 1999 between the hours of 12 p.m. and 8 p.m. The sample data set consisted of 115 complete patient visits and 30 partially completed visits. For the purposes of this study, the partially completed data sets were omitted.

4.3 Phase 3: Patient Arrival Processes

Phase 3 of the data collection process was used to determine appropriate arrival rates for each of the three patient arrival processes (walk-in, ambulance, and helicopter) present in the model. This information was extracted from a computerized patient tracking system database, using a customized query to sort the information into the necessary arrival types by hour and day of the week. A total of 17 weeks (November 2, 1998 - February 28, 1999) were analyzed to determine each average arrival rate by hour and day. Figure 4 illustrates the total average number of arrivals by hour. The peaks in the data represent the hours of operation between 9 a.m. and 10 p.m. This data was modeled as a non-stationary arrival process for generating patient entities.

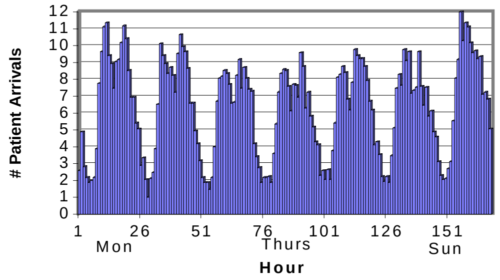

Figure 4: Patient Arrival Rates by Hour and Day

4.4 Phase 4: Transport and Routing Times

The fourth and final phase of the data collection effort obtained estimates on transport and routing times for patients and caregivers between various arrival stations and ED areas and between different areas within the ED. To collect the appropriate travel time data, the distances between various points were approximated (in feet); then divided by a random walking velocity distribution (in feet per minute). This approach provides random transport/ routing times into or within the ED (based on means of arrival and wing assignment) for use within the model.

For each set of data obtained, either an appropriate random distribution was estimated using Arena's Input Analyzer or the necessary probabilities were computed.

5 ALTERNATIVES

According to the current staffing schedule, there is at least one attending physician on-duty to cover the entire ED twenty-four hours a day, seven days a week. In addition, a pediatric attending physician is on-duty to cover the Pediatric Wing and Minor Emergency Area for twelve hours a day (11 a.m. - 11 p.m.), seven days a week.

Four different approaches were used to generate alternatives for attending staffing schedules. The first approach was to ask ED management personnel whether or not they had any strategies for staffing changes. This method was used to take advantage of the ED manager's knowledge and experience with the ED system to provide insight into problems or inefficiencies that may not have been apparent to an outside observer. The resulting design is a unique combination of shift and coverage area changes. The second approach used to generate scheduling alternatives was to maintain the 8-hour double coverage shift of the current schedule, but to vary when that shift was scheduled. Variations on the current 1 PM to 9 PM double coverage shift were based on patient arrival rates for the Emergency Department (Figure 4). This resulted in a total of seven designs including the current case. The third approach used to generate scheduling alternatives follows the same analysis and logic as the previous approach. While the second approach focused on changing the existing double coverage shift of the current schedule, the third approach deals with adding a second double coverage shift to the current schedule. The fourth and final approach made use of the variations in the arrival rates by weekday. For each possible eight-hour shift from 12:00 AM to 11:59:59 PM, the average patient arrival rates were calculated for each day of the week. From this information, the eight-hour shift with the maximum arrival rate was selected for each day as the double coverage assignment.

6 COMPARATIVE ANALYSIS

The eighteen different alternatives for ED attending schedules present a challenge with regards to simulation testing and comparative analysis. For the purposes of this study, a two-stage Bonferroni Approach was used to conduct the comparative analysis of the scheduling alternatives.

The Two-Stage Bonferroni Approach uses an initial sample size (run length and number of replications) to estimate the appropriate number of observations required to meet the desired level of precision. While this approach can be used to achieve different results, the main goal of this simulation analysis is to select the best scheduling alternative (i.e. minimize the total average patient time within the ED). The Two-Stage Bonferroni Approach finds the best design “with high probability whenever the difference between i^* [the best system] and the others is at least some practically significant amount.” (Banks et al. 1996, pg. 498) The seven-step methodology as discussed by Banks et al. was used to complete the Two-Stage Bonferroni analysis for this project.

As a general rule, this type of analysis does not perform as well when comparing more than ten designs at one time. Given that eighteen designs were included in this study, the Two-Stage Bonferroni Procedure was used three separate times. First, to determine the best of the seven designs from method 2. The second analysis was applied to the nine designs in method 3 to select the best. Finally, the analysis was carried out on the four remaining designs to determine the overall winner. It is important to note that this methodology assumes the two designs selected from the initial Bonferroni analyses on methods 2 and 3 are truly the best designs for comparison with methods 1 and 4.

The three analyses were all completed using a significant difference (precision), ε, value of 5 minutes, a probability of correct selection, $1 - \alpha$, of 0.95 to ensure a 95% chance of selecting the true optimal design, and 10 initial replications. A run length and warm-up period of 50,400 and 10,080 minutes were used for each replication to allow the system to reach steady-state operating conditions before collecting the appropriate statistics. Again, the measure of performance used to compare alternatives was the total time spent in the ED.

Since all three Bonferroni analyses were completed in exactly the same manner, the details of the first two will not be covered in this paper. The Bonferroni comparisons for the alternatives developed from method 2 indicate that the 11 a.m. to 7 p.m. double coverage shift (alternative 3) was the best. The Bonferroni comparisons for the alternatives developed from method 3 indicate that the second double coverage shift from 10 a.m. to 6 p.m. (alternative 2) was the best. A summary of the four final designs tested for this project is shown in Table 2 below.

Table 2: Attending Physician Staffing Alternatives

Method : Alternative	*Attending 1 (Coverage)*	*Attending 2 (Coverage)*	*Attending 3 (Coverage)*	*# Attending Hours/Day*
1 : 1	24 Hours (Adult / CPC)	10AM – 5PM (Adult / MEA)	3PM – 9PM (Peds)	45
2 : 3	24 Hours (Adult / CPC)	11AM – 7PM (Adult / CPC)	11AM – 11PM (Peds / MEA)	44
3 : 2	24 Hours (Adult / CPC)	10AM – 6PM (Adult / CPC)	11AM – 11PM (Peds / MEA)	52
4 : 1	24 Hours (Adult / CPC)	Various (Adult / CPC)	11AM – 11PM (Peds / MEA)	44

To gain an understanding of the comparison and selection procedure, the method and results from the final selection analysis (4 designs) is discussed below. Table 3 displays the results of the first stage sample mean calculations and the corresponding standard deviations on these values.

Table 3: Initial and Final – Sample Mean and Standard Deviation Values from Bonferroni Analysis

	Initial Replications (10)		**Final Replications (21)**	
Method : Alternative	*Sample Mean*	*Standard Deviation*	*Sample Mean*	*Standard Deviation*
1 : 4	184.92	3.67	185.17	4.37
2 : 3	189.13	4.92	193.21	4.64
3 : 2	180.85	3.30	179.44	3.34
4 : 1	193.77	6.42	194.53	6.10
Current	193.23	5.41	193.95	4.69

The paired sample variances (not shown here) used with the Bonferroni procedure were calculated using the sample means (from the initial replications) and the original parameter values for probability and precision. These sample variance values were then used to compute the second stage sample size of 21 replications. The data from the additional 11 replications was generated using the simulation model with the same run length and warm-up period as before. The sample means and standard deviations for these additional runs are also shown in Table 3. In this case, the best design is that for which the sample mean time in ED system is a minimum, thus leading to the selection of the design from method 3, alternative 2. Now, in order to determine whether or not this design performs significantly better than the other three, it is necessary to form the confidence intervals on, $\theta_i - \min_{j \neq i} \theta_j$, where θ_i is the mean time in the ED for alternative i. Thus, if system i is the best, then $\theta_i - \min_{j \neq i} \theta_j$ is equal to the difference in performance between the best and the second best. If system i is not the best, then $\theta_i - \min_{j \neq i} \theta_j$ is equal to the difference between system i and the best. The form of these confidence intervals is given in Banks et al. (1996). The confidence intervals for the final staffing comparisons are shown in Table 4.

Table 4: Bonferroni Analysis - Confidence Intervals

Method : Alternative	2 : 1	1 : 1	4 : 1
Lower Bound	0.00	0.00	0.00
Upper Bound	18.77	10.73	20.09

Since all of these confidence intervals are bounded by zero on the lower end, the attending physician staffing schedule from method 3, alternative 2 is statistically shown to perform significantly better than the other three designs with 95% confidence. For ED administration, this means that the proposed scheduling changes from method 3, alternative 2, are expected to decrease the current total patient ED system time by an average of 14.5 minutes per patient, or approximately 40 hours per day. Given that this alternative maintains the current shift schedules and coverage areas, the one additional attending physician on-duty between 10 a.m. and 6 p.m. everyday, is not expected to have any potential problems or barriers associated with implementation.

Table 5: % Utilization of Attending Physicians and % Long Patient Visits (> 270 Minutes)

	% Long Visit Patients		% Attending Utilization	
Method	*Mean*	*Standard Deviation*	*Mean*	*Standard Deviation*
1 : 4	18.00	1.063	58.34	0.699
2 : 3	21.77	5.561	64.67	0.605
3 : 2	17.68	1.027	52.46	0.924
4 : 1	21.16	1.475	64.70	2.409
Current	*20.90*	*1.285*	*65.01*	*0.869*

Table 5 displays the average attending resource utilization and the percentage of patients whose total ED visit time exceeds 270 minutes. These performance measures are provided to show that the best alternative (method 3) decreases both utilization and percentage of long visits. As defined in the model, attending utilization does not account for any research or teaching responsibilities required for the attending physicians. Since these activities are assumed to occur during "idle" times, it is necessary to discuss the impact of the decrease in utilization with ED administration before making any changes to the actual system. If the decrease in utilization is required to meet academic demands, then the proposed changes should be implemented. If not, ED administration must determine whether or not the costs of decreased utilization outweigh the benefits of shorter average visit times and reduced number of long visits.

7 FUTURE WORK

Attending physician staffing is only one of many components that affect the performance of an ED system. In order to gain a better understanding and to identify areas for improvement, it will be necessary to continue this study through the evaluation of nurse, resident/intern, and staff scheduling changes, as well as alternative layout and patient flow designs.

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