

**U.S. ARMY-BAYLOR UNIVERSITY
GRADUATE PROGRAM IN
HEALTH CARE ADMINISTRATION**

**Optimizing Resource Utilization in the Keller Army
Community Hospital Emergency Room Through
Simulation**

A Graduate Management Project Submitted to:

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20000107 033

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May 1997

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE May - 1997	3. REPORT TYPE AND DATES COVERED Final Report (07 - 96 to 05 - 97)		
4. TITLE AND SUBTITLE Optomizing Resource Utilization in the Keller Army Community Hospital Emergency Room Through Simulation		5. FUNDING NUMBERS		
6. AUTHOR(S) Captain David M. Farrick, U.S. Army, Medical service				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Medical Department Activity & Keller Army Community Hospital UnitedStates Military Academy West Point, NY 10996-1197		8. PERFORMING ORGANIZATION REPORT NUMBER 26-97		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Medical Department Center and School Bldg 2841 (MCCS-HRA) U.S. Army-Baylor Program in Health Administration 3151 Scott Road Fort Sam Houston, Texas 78234-6135		10. SPONSORING/MONITORING AGENCY REPORT NUMBER		
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited		12b. DISTRIBUTION CODE		
13. ABSTRACT (Maximum 200 words) The purpose of this project was to simulate the significant operational aspects of the Keller Army Community Hospital Emergency Room. Concerns existed among the senior leadership that services in the Emergency Room were not being delivered as efficiently as possible. Freed resources could then be applied toward primary care. The Status Quo model represented a valid model of the KACH ER with simulation patient service times statistically no different than the empirical data ($t=-.38$, $df(13369)$, $p=.70$). The results show that the KACH ER may be appropriately staffed with one nurse on duty without significantly increasing patient services times. While qualitative arguments must still be considered by the hospital executives in their decision to further transform the KACH ER, the quantitative information gathered from this study will provide a solid foundation for future decisions.				
14. SUBJECT TERMS Simulation; emergency room		15. NUMBER OF PAGES		
		16. PRICE CODE		
17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT	

ACKNOWLEDGEMENTS

Many thanks are owed to several people for the completion of this project. To LTC Charles McGibony for allowing me the time to work on this project and for shielding me from the innumerable day-to-day issues of a Military Treatment Facility. MAJ Patrick Delany helped tremendously as the ProModel expert at the United States Military Academy Department of System Engineering. MAJ Mark Perry who first introduced me to operations research analysis in health care administration and who also provided expert guidance and advice throughout the entire project. Last, but certainly not least, special thanks go to my my wife and children for their support and understanding.

Abstract

Purpose of Project: The purpose of this project is to simulate the significant operational aspects of the KACH Emergency Room. Data from the current operations of the Emergency Room will be collected, analyzed and modeled using simulation software.

Background: Prior to the current executive leadership, management embarked on tremendous organizational change (Bachman 1996). Concerns now exist among the leadership that services in the Emergency Room are not being delivered as efficiently as possible. Any resources freed after thorough analysis of the Emergency Room may then be reallocated toward primary care.

Methodology and Discussion: The Status Quo model represents a valid representation of the KACH Emergency Room. Appendix 5 details two primary performance measures: total patient service times and patient arrivals by week. The simulation patient service times were statistically no different than the empirical data ($t = -0.38$, $df(13369)$, $p=.70$). Similarly the model's patient arrivals were also not statistically different than the empirical data ($t = .76$, $df(23)$, $p=.46$). Additionally, total patient visits to the KACH Emergency Room equaled 12562, 11807, 12265, and 11929 for FY 96, FY 95, FY 94, and FY 93, respectively. While no statistical significance was demonstrated using these numbers, they do appear extremely close to the status quo simulation's fifty-weeks of replications, 12356. In fact, the simulation patient arrivals may demonstrate the slightly greater workload bias of the simulation model. Staff observation of the model also provided face validity. The visual flow of patients and staff looked very similar to actual operations in the KACH Emergency Room.

Recommendation: The one recommendation that is most clear based upon the alternative staffing configurations is that the KACH Emergency Room may be appropriately staffed with one nurse on duty. Another recommendation to maximally utilize the resources already present at the KACH Emergency Room during off-peak times, for instance 2300 - 0600, is to schedule routine patients. The benefit is there would be very little additional consumption of KACH resources given the available capacity to handle patients during off-peak hours.

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INTRODUCTION

The Military Health Services System (MHSS) is an extremely costly and complex system. Currently, due to several external forces, the MHSS has undergone scrutiny for its cost-effectiveness and efficiency. In general, simulation can be an extremely valuable tool for evaluating processes (Austin 1995). Specifically, this study will attempt to optimize the resource utilization in the Keller Army Community Hospital (KACH) Emergency Room through the use of simulation.

Conditions Which Prompted the Study

Three principal factors converged on KACH to prompt this study. First, KACH, like most other medical facilities in the Department of Defense (DoD), took a budget reduction in FY 97. This budget reduction caused increased scrutiny among high cost services. One of these services is the Emergency Room. Contract costs alone for personnel staffing on weekends and holidays is estimated to be approximately \$400,000 for FY 97. This is the single largest contract item in the KACH budget.

Secondly, Region 1's transition to TRICARE and alternative financing has forced KACH to address internal primary care access issues. Essentially, addressing this issue consists of developing a KACH internal health maintenance organization (HMO). An absolutely critical piece in developing the internal HMO

is a sound primary care program. This potentially includes any combination of an after-hours clinic, an acute minor illness center, an urgent care center, advice nurse phone lines, and 24-hour, 7 days a week primary care manager availability to name just a few programs. In order to support these initiatives, efficiencies may be found in the high-cost Emergency Room. Resources freed from the Emergency Room may then be re-allocated elsewhere.

The third factor that prompted this study is the DoD small hospital study. The review, conducted by DoD Health Affairs(HA) targeted several military treatment facilities (MTFs) for a reduction in services. These MTFs are from all DoD services: Army, Navy, and Air Force. The Air Force is particularly singled out since approximately twenty of the facilities they operate are on the targeted list. Among the Army facilities targeted by DoD (HA) is KACH. Although this project proposal was not directly caused by the DoD (HA) small hospital study, the potential conversion to a "super clinic" may require a thorough evaluation of emergency services.

Statement of the Problem

Prior to the current executive leadership, management embarked on tremendous organizational change (Bachman 1996). Concerns now exist among the leadership that services in the Emergency Room are not being delivered as efficiently as possible. Any resources freed after thorough analysis of the

Emergency Room may then be reallocated toward primary care. The emphasis will be on increasing availability of primary care rather than high-cost emergency services since KACH and Region 1 will shortly begin implementation of TRICARE. Any reallocation of resources toward primary care will potentially boost primary care availability.

Specifically, the most important concern is that personnel are not being used in the most effective manner. A gap between contracts for physician coverage of the Emergency Room highlighted this problem to the leadership. Military primary care providers began covering the Emergency Room 24 hours a day, 7 days a week. In turn, this led to restricted availability of primary care appointments, during normal operating hours. The assumption was that the use of primary care physicians in the Emergency Room was a waste of resources and should be directed back to the primary care arena.

Literature Review

The service industry is unique from the manufacturing industry in four key aspects:

1. Services are intangible; they are not things.
2. Services are perishable; they cannot be inventoried.
3. Services provide heterogeneous output.
4. Services involve simultaneous production and consumption (Harrel 1995a).

The unique aspects of service industries, such as health care, pose challenges

particularly in the area of staffing, facility layout, process design, and equipment selection. Simulation as a quantitative tool can assist health care administrators in addressing those challenges while maintaining balance between cost, quality, and access.

Simulation is perhaps "one of the most powerful analytical tools available to health services managers in making resource allocation decisions and in determining if and how processes can be improved" (Rakich 1992). Simulation involves the development of a detailed, computer-based model to represent variables of interest. The advent of powerful personal computers has made the use of simulation much more popular and easier to perform. It would be practically impossible to manually compute the vast amount of calculations that personal computers can perform using simulation software.

Two important reasons to use simulation as a tool are its credibility and use of uncertainty (Mahachek 1992). Simulation is credible because of its structured approach to analyzing processes, resources, entities, and networks among other variables. In addition, the combination of these variables and theoretical and / or empirical distributions allow for the chance occurrences that can happen in health care delivery.

A wide range of literature is available regarding the use of simulation in the health care setting. Most analysis centers around three specific areas of

healthcare management: outpatient healthcare setting (Williams 1967; Carlson 1979; Levy 1989; Rising 1973; Keller 1973), manpower analysis (Uyeno 1974; Standbridge 1978; Graff 1990; Gupta 1971), and scheduling (Carter 1992; Barnoon 1968).

An extensive analysis and computer simulation of the most efficient use of providers in a family practice clinic was conducted by Ledlow (Ledlow 1996). Ledlow modeled a family practice clinic to determine the optimal provider staffing and process configuration. Summary results were that an 8 physician model cost approximately \$777,688 and patient total time in system was approximately 41 minutes. A combination model of five physicians and four physician extenders cost slightly more, \$778,381, but the patient's total time in system was reduced to approximately 30 minutes. Interestingly, Ledlow recommends to implement the all-physician model on the grounds of greater physician availability, cost and effort of implementing physician extenders (the family practice clinic was located at a military treatment facility in Germany), and the short time to enroll members in the managed care program.

The topic of emergency services is also of particular importance to healthcare managers. Given the capitated environment, more and more hospitals are analyzing their operations and reengineering the services they provide. Emergency services are one of the first areas to be examined since they are

generally among the highest cost services of a hospital. Numerous models have been developed to address staffing and operational issues of emergency departments (Draeger 1992; Garcia 1995; Graff 1990; Handyside 1967; Klafehn 1987; Kraitsik 1992; Ritondo 1993; Valenzuela 1990).

A common theme in several studies is reducing the time the patient spends in the Emergency Room. McGuire, Kirkland, Draeger, Garcia, and Klafehn all address the time spent in the system by the patient.

Klafehn and Owens investigated resource utilization in a hospital Emergency Room. They developed a model to examine the patient service time when a second orthopedic grouping is present. As they stated almost ten years ago, "the use of simulation provides a valuable tool to investigate the effect of changes before people are hired, before rooms are rearranged, and before capital expenditures are made" (Klafehn, 1987). This statement remains applicable today; however, the focus now is on creating effective systems using the fewest resources possible. In other words, since the current hospital system is not expanding, but rather under severe budget constraints, emphasis is on reducing resources while still providing an acceptable level of service.

Smith-Daniels et al. were perceptive in their suggestions for future research on this topic (Smith-Daniels 1988). They suggested future research on vertical integration, multihospital systems, hospital subcontracting, subcontracting

services, freestanding ambulatory care clinics, HMOs, and diagnosis related groups (DRGs).

Purpose

The purpose of this project is to simulate the significant operational aspects of the KACH Emergency Room. Data from the current operations of the Emergency Room will be collected, analyzed and modeled using ProModel simulation software.

Variables

Initially, the simulation will model operations as they presently exist. Specifically, the pertinent information gathered was the number of emergency medical service (EMS) calls per day, patient acuity, number of arrivals by time of day, the length of time required for EMS runs, task requirements (laboratory or radiology requests), staff shift schedules, and patient service times.

In this study, the following triage categories were used to categorize patient acuity: emergent, urgent, and non-urgent. The operational definitions of these terms were taken directly from the instructions for completion on the back of the Standard Form 558, Emergency Care and Treatment.

Table 1 Triage Category Operational Definitions

Emergent	A condition which requires immediate medical attention and for which delay is harmful to the patient; such a disorder is acute and potentially threatens life or function.
Urgent	A condition which requires medical attention within a few hours or danger can ensue; such a disorder is acute but not necessarily severe.
Non-Urgent	A condition which does not require the immediate resources of an emergency medical services system; such a disorder is minor or non-acute.

The independent variables of interest in this study are the staffing of the Emergency Room. The staffing policy decisions will be adjusted, and the dependent variables, or performance measures, will be analyzed. The specific performance criteria to be analyzed are resource (staff) utilization and patient service times.

Objective

Based upon the problem statement and the executive concerns, the following objectives were identified for this study:

- Gain a better understanding of the current operations of the KACH Emergency Room.
- Identify alternatives to the present operations.
- Model alternatives by adjusting operational aspects of the Emergency Room: hours of operation, staffing levels, and performance of missions.

- Identify the best alternative based upon selected performance criteria.

It is important to note that this project will not attempt to evaluate the qualitative issues or value judgments of eliminating the Emergency Room service at KACH. Elimination of services could be one alternative evaluated, but because of the negative impact upon the KACH beneficiary population, this alternative was not considered feasible. Rather, the intent of this project is to objectively evaluate and quantify, using simulation, the time and cost differentials for alternatives, other than closure, to the KACH Emergency Room status quo.

METHODS AND PROCEDURES

Although each simulation study is unique, most studies require the following basic steps: problem definition, statement of objectives, model formulation and planning, data collection, model development, verification, validation, experimentation, results analysis and presentation, and implementation (Harrell 1995b). Harrell and Tumay suggest a slightly more general approach (Harrell, 1995a). Figure 1 illustrates their procedures for conducting a simulation study.

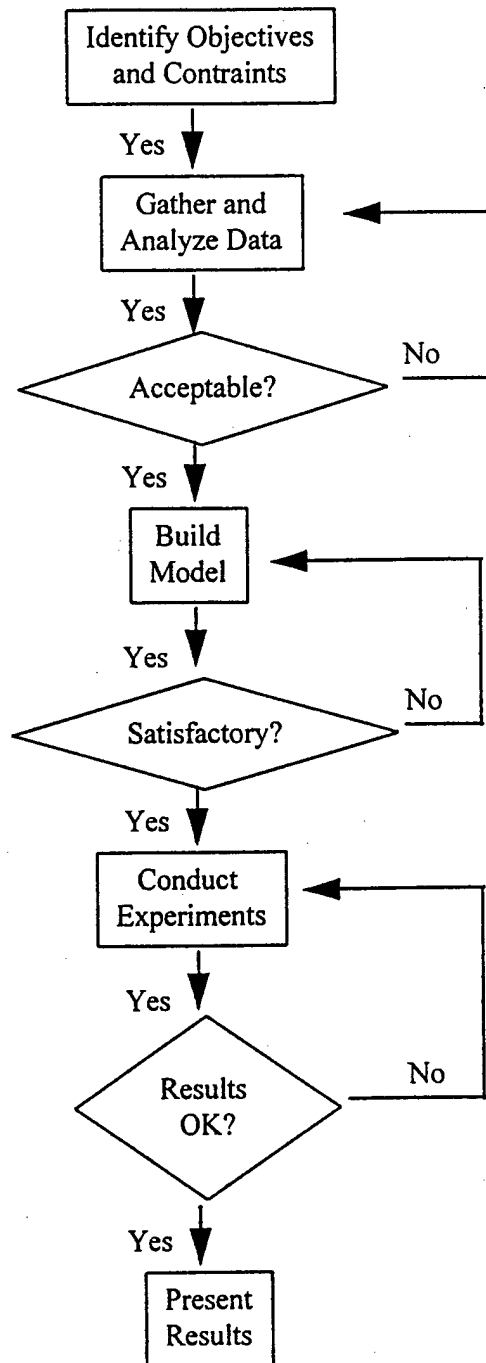


Figure 1 Procedures for Conducting a Simulation Study (Harrell 1995a)

The software used for the development of this model was ProModel 3.0 by ProModel Corporation. The software was readily available via the United States Military Academy (USMA) Systems Engineering Academic Department. Approval was received from the software lab manager to establish an account for this research project. The program was conveniently available from a desktop PC through the KACH network to the USMA network. Other statistical software used was the BestFit program. This software was used to select the most appropriate theoretical distribution based upon the actual data collected. In some instances, the actual empirical distributions were used instead of theoretical distributions.

Problem Identification

The first step, problem identification, is the most crucial of all steps. Even the most detailed and thorough studies will be of little value if it fails to address a current need. Addressing the primary problem is important in order to limit extraneous information and data from the model. While it is important to build a model easily capable of including additional information and variables, it is just as important not to waste time on inclusion of needless elements in a model (Harrell 1995b).

The statement of the objectives derives from the problem statement. One obvious objective for most studies is a time objective. This helps build a sense of

priority for the project and also prevents the project from dragging on indefinitely (Harrel 1995b). In this instance, the study must be completed no later than 27 June 1997.

Model Formulation and Planning

Once the problem has been identified and objectives determined, the modeler could begin to build a conceptual framework for the model (Harrel 1995b). The best way to conceptualize the model is usually through a diagram or process diagram. This helps to both identify the level of detail and to ensure consistent collection of pertinent data.

Data Collection

The next step in a simulation project is to gather data. Data is gathered in one of two ways: assistance is garnered from those individuals working with the system or the information must be gathered by the modeler. If either of these two cases prove impractical, it may be possible to make certain assumptions in the model in the absence of data. Later, these assumptions may be tested with a sensitivity analyses to determine the assumptions' impact on the system (Harrel 1995b).

A very difficult challenge in the data collection process is to collect data on the alternatives that do not yet exist. The data is usually collected via several avenues: similar systems already operational, equipment suppliers and vendors,

and experts in the area of interest. Obviously, one must be careful in using expert opinion as the sole source of data given the inherent bias of the expert(s) involved closely in the project (Harrel 1995b).

Model Development

Once the data is collected, the first iteration of the model is developed. As in any complex software or model development, model development is generally not a linear start-to-finish process. Rather, there is an iterative process of model development and then verification.

Verification of a model may be accomplished in several ways. First, if animation software is used, the animation may be run at a slow speed to visually check to verify if the model is working as the modeler intended. Second, variables and counters may be used to check the status of the system at particular points to verify if they again are what the modeler intended. Finally, having another experienced modeler to review the simulation may verify the simulation (Harrel 1995b).

Validation

Validation of the model occurs after the modeler has expended a great deal of effort and verified the simulation. Often, given that the modeler is attempting to simulate a system that doesn't exist, the validation of the model is a collaborative effort between the modeler and the individuals familiar with the operations. This

may be done in the form of a Turing Test. In the Turing Test, the modeler presents data from both the simulation and the actual system to those most familiar with the system. Failure to discern which set of data is "real" and which set is simulation data is said to validate the simulation model (Harrel 1995b).

Another type of validation is the visual presentation of the computer simulation model to those individuals involved with the operations. Viewing the model in compressed time and watching the flow of patients adds tremendous face validity to the model. Individuals can then comment as to the realism or validity of the model and better understand the model assumptions during the presentation.

Finally, model output may be statistically tested against the actual collected data. Failure to find statistically significant differences between the data sets is evidence that the simulated data is reasonably close to the empirical data.

Experimentation

The next step in the formulation of the model is experimentation. Once the modeler and those involved in the project have an idea about what alternatives to model, the modeler will determine the length of the simulation required to achieve acceptable results. If applicable, the time required for the system to reach steady-state will be determined (Harrel 1995b).

Analysis and presentation of the results is done after experimentation with the

model. In this study a finished report, together with a presentation, will detail results. In many instances, it is important for the modeler to avoid the statistical and technical jargon of the simulation. Use of graphics and animation may be more effective than statistical analysis when presenting results to certain audiences.

Implementation

Finally, if the modeler is successful, the results of the simulation are implemented. The key to successfully implementing a simulation is best summarized by Woolsey's three laws:

1. Manager's would rather live with a problem they can't solve than use a technique they don't trust.
2. Manager's don't want the best solution; they simply want a better one.
3. If the solution technique will cost you more than you will save, don't use it!

(Hesse 1980).

ASSUMPTIONS

Despite significant statistical analysis and the use of theoretical distributions to account for exceptional cases, several assumptions were made for the KACH Emergency Room simulation model. The following assumptions applied to all three scenarios:

1. Upon arrival patients are assigned an acuity level. In reality, patient

conditions may either degenerate or improve. This necessarily causes the patient to be reclassified into a different level of patient acuity.

2. All resources (physicians, nurse, and aides) are available at all times. Break and meal times are not modeled and occur as they would in "real life", when there is system downtime.

3. The main trauma room, labeled Trauma 1, is reserved for either urgent or emergent patients. All non-urgent patients fill the three other rooms on a first-available basis. In the actual KACH Emergency Room, patients are sometimes assigned rooms based upon the type of illness. For instance, patients presenting obstetrical problems are usually brought to Trauma 7. Since this model is not concerned with utilization of rooms, this level of detail was not considered significant to model.

4. Patients awaiting their laboratory results remain in their originally designated treatment room. In reality, when patient load is heavy, non-urgent patients awaiting laboratory results may be brought to the waiting area prior to release, to accomodate patients who have just arrived to the Emergency Room.

5. Administrative time spent preparing reports (other than medical documentation), ordering supplies, performing collateral administrative duties, and filing paperwork are not included in the model. This data was not readily available and is not included as a part of this study.

6. No patients leave the system without being seen. In reality, some patients balk; however, in the sample data collected they amounted to three cases out of 1029 or 0.29% and were not considered significant to the outcome of this study.
7. Emergency Medical Service (EMS) requests are generated to simulate the non-availability of the enlisted personnel. When an EMS request arrives at the Emergency Room according to the arrivals schedule, enlisted personnel are called away from the Emergency Room for a period of time and then return. There was no attempt to gather patient arrivals via ambulance since it did not provide meaningful data for the purpose of this study.
8. All emergent and urgent patients required both radiographs and laboratory tests. Non-urgent patients were assigned the requirements of radiographs and laboratory tests based upon a fixed percentage. This assumption is needed due to the lack of modeling specific types of services provided patients; e.g. orthopedic, surgical, psychiatric, etc.
9. All treatment rooms but the main trauma room, used primarily for urgent and emergent cases, have downtimes based upon the entry and departure of one patient. This approximates reality since the main trauma room would still be used for an emergent arrival even if it had not been thoroughly cleaned and re-stocked.
10. Military physicians are called to the Emergency Room for all urgent and emergent patient arrivals. This approximates the actual Emergency Room

operations for several reasons: only military physicians have admitting privileges, only military physicians have the capability and authority to arrange transportation to other medical facilities, and the clinical limitations of the contract physician assistants.

RESULTS

Model Specifics

Since the full version of ProModel 3.0 was used, there were no programming constraints for entity attributes and system variables. The only limiting factor was the amount of memory in the computer. The main elements of the status quo simulation model are summarized in Table 2.

Table 2 Significant Elements of the Status Quo Computer Simulation Model

Significant Model Elements	Comment
Time Unit	Minute; measured to 1/100th of a second
Warm-Up Period	24 hours
Entities	Patients Lab Samples EMS Runs
Resources	Clerk (1) Military Physician (1) Nurse (7) Enlisted Personnel, LPN (11) Contract Provider (1) X-ray Technician (1)
Entity Attributes	Patient Acuity Patient ID Patient Room EMS Service Times Patient Service Times
Variables	Bed Occupied System Time EMS Total Time
External Files	Shift Schedules Patient Arrivals Patient Service Times EMS Runs

Both expert opinion and observation was used to construct the following Emergency Room patient flow diagram. In general, this patient flow scheme was used to develop the operational programming of the simulation model.

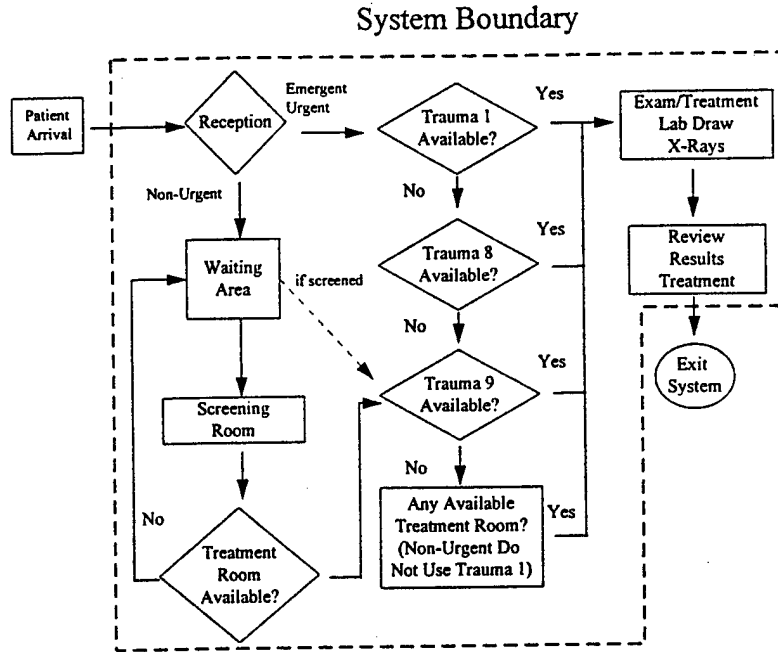


Figure 2 Emergency Room Patient Flow and System Boundary

The above diagram also illustrates the boundaries of this simulation. The Emergency Room is modeled as a self-enclosed entity. Patients enter the system (in reality they enter by several methods), are processed and then exit the system. When patients exit the system, there is no differentiation as to how they exit. Typically patients exit the system in one of three manners: released to home, referred to an outpatient clinic for follow-up, or admitted to the hospital.

Operational Programming of the Status Quo Model

The heart of any computer simulation model is the actual operational logic. Appendix 1 details a small sample of the actual logic used in the status quo

model. The status quo simulation model's programming logic consists of approximately 665 lines of code.

Collected Data

Collection of the data for the basis of the model was derived from several sources within KACH. As one might expect in a complex model, there was no single source from which to obtain the data. Where possible, data was cross-referenced from other sources for verification. There were three primary sources of data: computer databases, paper records, and expert opinion. Each source of data along with analysis, if applicable, will be presented.

Surprisingly little data was collected from computer databases. In fact, the only data collected from a computer database was the number of lab tests conducted on Emergency Room patients. The data was collected from the Composite Health Care System (CHCS) and used to verify the approximate percent of patients requiring laboratory tests.

The largest source of data for this project was the paper record. The Standard Form (SF) 558, Emergency Care and Treatment, was used to gather the majority of information. Among the information collected from this form was patient arrival times, time first screened, patient departure times, and patient acuity. Patient arrivals by time of day were remarkably similar to Draeger's hourly patient arrival pattern (Draeger, 1992). In this model, the empirical distribution

was used instead of a theoretical distribution given the similarity with Dreager's findings and because arrivals had occurred at all hours.

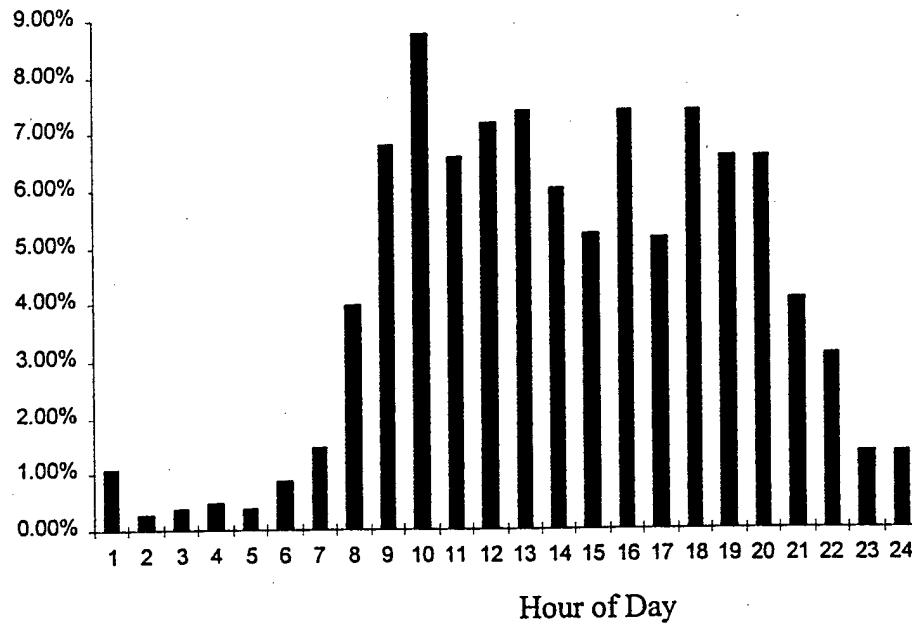


Figure 3 KACH Emergency Room Patient Arrivals by Hour of Day

As previously mentioned, data concerning the triage category of patients arriving in the Emergency Room was collected and produced the following distribution of patients listed in Table 3. The formal analysis was further validated by several practitioners who stated that the urgent and emergent cases compromised about fifteen percent of the workload.

Table 3 Total Emergency Room Patient Arrivals by Triage Category

Acuity	Patient Arrivals	Percent
Emergent	8	0.80
Urgent	139	13.50
Non-Urgent	882	85.70
Total	1029	100.00

In addition to the SF 558, the Personnel Time Schedules for the nursing and enlisted staff were used. The schedules used in the status quo model were for the week of 2 February 1997. These schedules were then converted into shifts in the ProModel program.

The physician schedules were similarly modeled. The contract providers were the easiest to model since their hours were set. In the status quo model, the contract provider worked weekends and during the day from 1000 – 2200. Military physicians worked from 2200 – 1000.

The number of patient arrivals was collected from the daily Emergency Room report. A one-way ANOVA analysis was performed on the nine weeks worth of data. There were no statistically significant differences found between patient arrivals for any day of the week. Data and results in standard form are detailed in Appendix 2. The actual daily patient arrivals in the status quo model were assumed to be normally distributed with an average of thirty-six and a standard deviation of seven patients.

Data for the EMS requests was collected over a twelve week period. Since the simulation model was programmed to run for a one week period, EMS requests were calculated for a week period also. The average number of runs per week equaled five with a standard deviation of three. The EMS interarrival data for each week was converted into minutes by the following formula, (# days x 1440 minutes) + (# hours x 60 minutes). For instance, if there was an ambulance request on Thursday at 1200 hours, the formula would be (4 x 1440) + (12 x 60) = 6480 minutes. The interarrival data for all EMS requests by week were calculated in this manner and then input into BestFit to identify the most appropriate theoretical distribution. Appendix 2 details both the EMS request interarrival times and the selected theoretical distribution.

The processes for x-rays and laboratory tests were modeled based upon data gathered from the patient record. That is, twenty-five percent of all non-urgent patients required a radiograph and / or a laboratory test. The requirement for both procedures in the status quo model were evaluated independent of each other. As mentioned in the assumptions, the level of detail required to correlate non-urgent patients with radiographs and laboratory test was not deemed necessary detail for this computer simulation.

The distance required to travel in the Emergency Room was not modeled in the simulation. Instead, the length of time required to travel to all locations in the

Emergency Room was measured. Measurements were taken using a standard stopwatch and in all instances measurements were rounded-up and then two additional seconds were added. The additional time was added due to potentially slower-moving ambulatory patients and those patients who also require wheelchairs. All times were recorded in seconds due to the small physical area of the Emergency Room. The longest time to travel was approximately one minute to drop-off laboratory samples. All data was then input into the path network for use in the model.

Patient service times were gathered from a combination of observational data, staff interview, and a staff survey. Observational data and staff interview were used for those processes that usually took less than five minutes. For example, check-in, screening, and check-out were all under five minutes and were estimated based on interviews and observation.

Patient treatment times were based upon a staff survey (Appendix 3). Patients were categorized based upon triage category. The length of time required to perform each task was estimated by staff physicians, nurses, and enlisted personnel. Operational definitions of each term was provided on the survey form for clarification. Responses were gathered and an average time for each process was calculated. The information was then programmed into the model. The staff survey was used as the basis of patient service times; in several instances,

however, times were adjusted by the modeler in order to obtain computer output which was not significantly different than the empirical data.

Alternative Model #1

Three alternatives to the status quo model were developed. The first alternative model was developed considering only one staffing change. Instead of utilizing the actual nursing staffing schedule, the Alternative Model #1 used the equivalent of one nurse as "on-shift" at any given time. Programming this change into the status quo model was straightforward. The seven nursing resources were changed to one, and that one nurse resource worked all hours of the week.

Analysis of the results must include the model's limitation of no shift change coordination with other personnel and the instances when a shift worker will stay past normal shift hours to continue rendering services started during normal shift hours.

Alternative Model #2

The second alternative changed the KACH Emergency Room to an Acute Care Clinic (ACC). KACH beneficiaries would be "strongly encouraged" to come to the ACC between the hours of 0700 and 2200. The rationale behind limiting the hours of operation was that based upon the collected data only seventy-six patients, or an average of three patients per day with a standard deviation of two, arrive between the hours of 2200 - 0700. Of those seventy-six

patients, fourteen were classified as urgent or emergent.

The ACC operations were based upon the most current information available since the ACC concept of operation had not been finalized in a written plan or standard operating procedures. The following significant operational changes were made to the status quo model.

Based upon the after hours workload, different arrival cycles were developed for Alternative Model #2. In this instance, two patient arrival cycles were defined based upon the collected data. The actual patient arrival cycles for the status quo model and the Alternative Model #2 are outlined in Appendix 4.

The number of patient arrivals for each arrival cycle also changed. Based upon the information that fourteen emergent and urgent patients arrived during the after-hours time, 2200 - 0700, a triangular frequency distribution was used. The triangular distribution reflected a minimum of zero, a median of one-half, and a maximum of two patients, per day. All patients in this arrival cycle were classified as urgent patients. The normal hours, 0700 - 2000, reflected an average of thirty-three patients, with a standard deviation of seven patients per day using the same acuity distribution as in Table 3.

In addition to the change in the arrival patterns, staffing schedules were adjusted to reflect the following policy changes. The military physician currently on duty in the Emergency Room from 2200 - 1000 would strictly be on-call. The

contract provider would man all hours from 0700 - 2200. Military providers would be called-in for all urgent and emergent patients.

Nursing schedules also reflected the change. There would no longer be a requirement for a nurse during the hours of 2200 - 0700. Incoming telephone calls would be handled by the Intensive Care Unit (ICU) or Medical - Surgical Unit (MSU) nurse. If the patient calling during the late hours with an inquiry did require medical assistance prior to the 0700 opening of the clinic, the provider on-call would be notified and the in-house nursing staff would meet the patient in the former KACH Emergency Room. Additionally, since the KACH EMS mission was continuing, two enlisted personnel would already be stationed at the former Emergency Room area to receive incoming patients during the non-operating hours of the ACC.

Two significant programming changes were made to reflect the above policy changes. First, prior to the nurse and contract provider going off-shift, there was a system check to determine if all patients had left the system. Second, both the nurse, in this instance the nurse would be the ICU nurse, and the military provider would be called-in if an urgent or emergent patient arrived after hours.

Alternative Model #3

The Alternative Model #3 incorporated the changes in Alternative Model #2 and the effects of the following two operational policies: the implementation of

evening primary care clinics and the use of contracted physician assistant coverage 24 hours per day, 7 days per week.

Due to the anticipated implementation of the clinics, the number of arrivals occurring per 24 hour period was reduced to a normally distributed population of thirty-three patients with a standard deviation of seven. The assumption was, on average, the evening clinics would reduce each days patient population in the ACC by three patients.

Staffing of the second alternative was changed to reflect the use of physician's assistants. Physician assistants were assumed to be capable of independently handling all routine patients. However, KACH's military physicians would be on-call during the entire time and would be called-in for all emergent and urgent patients.

As in the previous models, one nurse was continuously assigned to work the ACC along with the contract provider. In this manner the overall utilization of the nursing staff could be compared with the status quo model. The enlisted and clerical staff was the same as the status quo model since their mission did not change; EMS was still a requirement along with their roles as medical assistants to the nursing and provider staff.

DISCUSSION

Simulation Model Results

The Status Quo model represents a valid representation of the KACH Emergency Room. Appendix 5 details two primary performance measures: total patient service times and patient arrivals by week. The simulation patient service times were statistically no different than the empirical data ($t = -0.38$, $df(13369)$, $p=.70$). Similarly the model's patient arrivals were also not statistically different than the empirical data ($t = .76$, $df(23)$, $p=.46$).

Additionally, total patient visits to the KACH Emergency Room equaled 12562, 11807, 12265, and 11929 for FY 96, FY 95, FY 94, and FY 93, respectively. While no statistical significance was demonstrated using these numbers, they do appear extremely close to the status quo simulation's fifty-weeks of replications, 12356. In fact, the simulation patient arrivals may demonstrate the slightly greater workload bias of the simulation model.

Staff observation of the model also provided face validity. The visual flow of patients and staff looked very similar to actual operations in the KACH Emergency Room.

Comparison of Alternative Models

The patient arrivals were collected for a period of fifty replications which

equals almost one year worth of data. Specifically, the patient arrivals were written to an external file and analyzed using a spreadsheet program. The status quo model, Alternative Model #1, Alternative Model #2, and Alternative Model #3 each had 12356, 12245, 11573, and 11257 patient arrivals, respectively.

A pair-wise t-test of means was then performed on patient service times and resource utilization. Of significance is the methodology by which the ProModel program calculates utilization percentages. Percentages are calculated based upon the resource scheduled "on-duty" time. Therefore, the military provider's utilization figures for Alternative Models #2 and #3 approach the 100% level, since the provider has no scheduled "on-duty" shifts, they're strictly on-call. The small amount of travel time to the patient accounts for the approximate 1% of non-utilization. Table 4 summarizes the results.

Table 4 Status Quo ProModel Comparison to Alternative Models

	Status Quo Alternative #1 Alternative #2 Alternative #3	Status Quo and Alternative #1 t, df p =	Status Quo and Alternative #2 t, df p =	Status Quo and Alternative #3 t, df p =
Patient Service Times (average, s.d. minutes)	85, 112 82, 112 74, 65 65, 53	t = 2.12 df = 24599 p = .03	t = 9.64 df = 23927 p < .00	t = 17.68 df = 7866 p < .00
Military Provider Utilization (%)	53 52 99 99	t = .40 df = 49 p < .68	t = -31.46 df = 49 p < .00	t = -31.42 df = 49 p < .00
Nurse Utilization (%)	32 28 39 22	t = 2.85 df = 49 p < .00	t = -5.11 df = 49 p < .00	t = 8.12 df = 49 p < .00
Contract Provider Utilization (%)	46 45 50 32	t = .622 df = 49 p = .53	t = -3.45 df = 49 p < .00	t = 12.20 df = 49 p < .00
Enlisted Staff Utilization (%)	23 24 22 21	t = -1.40 df = 49 p = .17	t = 1.32 df = 49 p = .19	t = 2.34 df = 49 p = .03

The Alternative Model #1, where the only variable adjusted was the nurse staffing, showed statistically significant differences among the alternative models for patient service time and nurse utilization, but no statistically significant differences for contract provider, enlisted personnel, and military provider utilization. Most interesting was the decreased percent utilization of the nursing

staff in the Alternative Model #1. In fact, in the Alternative Model #1, nurses were working less and patients were being serviced in less time.

This may be attributed to several reasons. First, the random number of arrivals and the fact that there were one hundred and eleven fewer patient arrivals from the status quo model to the Alternative Model #1. Second, there is no downtime for nursing staff. That is, patients get serviced quicker due to the lack of shift changes since there is no travel time to the duty location or periods when staff is in transition. Finally, because of the lengthy simulation period, almost one year's worth of patient service times, the degrees of freedom for the t-statistic is infinity for all practical purposes. Therefore, to display statistical significance requires a smaller t-value than with a much smaller sample size.

Enlisted utilization remains fairly constant throughout the scenarios except statistical significance is displayed in the Alternative Model #3. Similar to the nurse utilization decrease discussed above, the reason for statistical significance is due to the decreased number of patient arrivals since there was no mission or policy changes for the enlisted personnel in any of the models. There were 1099 fewer patient arrivals in the Alternative Model #3 than the status quo model.

Interestingly, all simulation models produced an average patient service time less than ninety minutes. The 90% confidence intervals for total patient time in the system are listed in Figure 4 below. Based upon this analysis, management

can presently state they have a great amount of confidence, 90% confidence specifically, that the status quo simulation contains the mean of all patient service times.

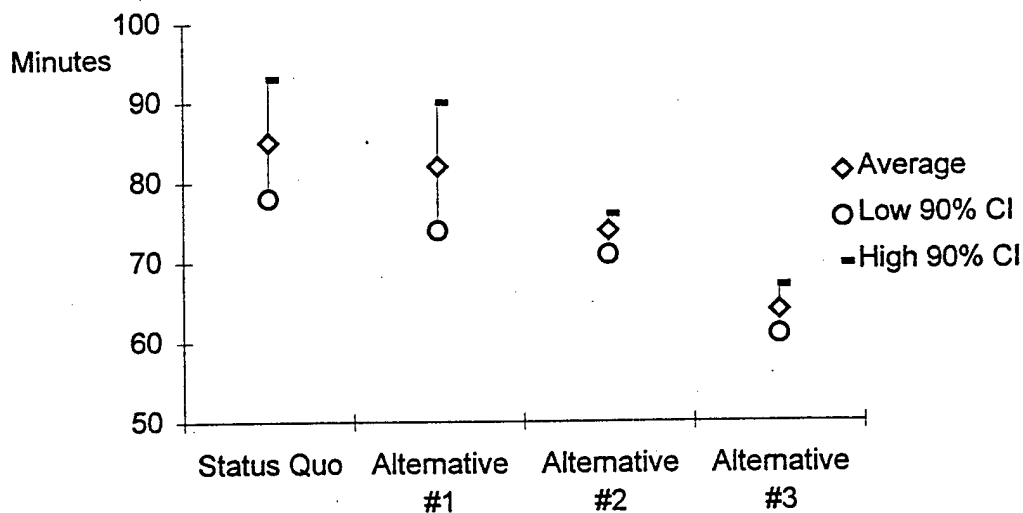


Figure 4 Patient Time in System Confidence Intervals (minutes)

CONCLUSION AND RECOMMENDATIONS

The one recommendation that is most clear based upon the alternative staffing configurations is that the KACH Emergency Room may be appropriately staffed with one nurse on duty. Peripheral observations identified during the course of this study are located at Appendix 6.

Undoubtedly, during periods of heavy patient load, patient service times will increase with one nurse on duty; however, management can confidently state that

the Emergency Room patients are being serviced, on average, within an appropriate time.

Another recommendation to maximally utilize the resources already present at the KACH Emergency Room during off-peak times, for instance 2300 - 0600, is to schedule routine patients. This would afford another opportunity to schedule appointments for patients. For those individuals working shift work, it may be seen as better customer-service. The benefit is there would be very little additional consumption of KACH resources given the available capacity to handle patients after-hours. In other words, there are significant potential benefits with very little marginal costs. Block scheduling of patients every hour during the evening hours of 2300 - 0600 would be one methodology to accomplish routine scheduling of patients.

In conclusion, the use of computer simulation to model KACH's Emergency Room has provided valuable insight into both existing and planned patient flow, KACH staffing, and patient service times. While qualitative arguments must still be considered by the hospital executives in their decision to transform the KACH Emergency Room, the quantitative information gathered from this study will provide a solid foundation for any future decisions.

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Appendix 1: Sample Simulation Logic for the Status Quo Model

Entity	Location	Operation	Blk Output	Destination	Rule	Move Logic
<i>Patient</i>	<i>Arrivals</i>	IF Pt_Room=10 THEN ROUTE 2 ELSE ROUTE 1				
			1 Patient	Reception_Queue	FIRST 1	MOVE ON ER_Net
			2 Patient	EXIT	FIRST 1	Sys_Time = CLOCK(MIN)-Input_Time WRITELINE(ptsvctim, sys_time, 3, 2) MOVE FOR 0
<i>Patient</i>	<i>Reception_Queue</i>	IF Pt_Room=5 AND Patient_Acuity <3 THEN BEGIN WAIT UNTIL Bed_Occupied8 < 1 OR Bed_Occupied9 < 2 OR Bed_Occupied1 < 2 Route 2 END ELSE BEGIN FREE ALL ROUTE 1 END				
			1 Patient	Reception	FIRST 1	MOVE ON ER_Net
			2 Patient	Trauma_1	FIRST 1	INC Bed_Occupied1 Pt_Room = 1 GET Enlisted_Personnel, 180 OR Nurse, 180 Rad_Requests=1 Lab_Requests=1 MOVE WITH Enlisted_Personnel OR Nurse
			Patient	Trauma_8	ALT	INC Bed_Occupied8 Pt_Room = 8 GET Enlisted_Personnel, 180 OR Nurse, 180 Rad_Requests=1 Lab_Requests=1 MOVE WITH Enlisted_Personnel OR Nurse

Appendix 2: Data and Analysis from KACH Emergency Room

Table 5 Count of Patient Arrivals to Emergency Room

	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Total
1 Sep - 7 Sep	18	30	34	44	36	36	37	235
8 Sep - 14 Sep	33	31	37	37	49	36	37	260
15 Sep - 21 Sep	30	41	31	36	54	28	48	268
22 Sep - 28 Sep	35	24	22	37	30	27	40	215
29 Sep - 5 Oct	33	23	46	32	39	36	33	242
6 Oct - 12 Oct	31	46	41	33	36	38	33	258
13 Oct - 19 Oct	28	43	44	47	39	32	33	266
20 Oct - 26 Oct	18	41	47	41	36	36	31	250
27 Oct - 2 Nov	30	52	41	39	34	48	36	280

Table 6 Patient Arrivals ANOVA

Source	SS	df	MS	F	p
Between Days	713	6	13	0	>.05
Within Groups	662350	56	110392		
Total	663063	62			

Table 7 EMS Request Interarrival Times by Week (minutes)

30	125	318	1033	1575	2582	4843
35	127	367	1122	1609	3021	4978
44	139	376	1186	1673	3290	5952
45	140	420	1220	1899	3382	6001
55	154	500	1266	1981	3512	
65	190	577	1300	2070	3621	
70	193	727	1320	2126	3699	
88	214	880	1468	2341	3900	
97	261	913	1506	2510	3939	
102	310	988	1532	2579	4304	

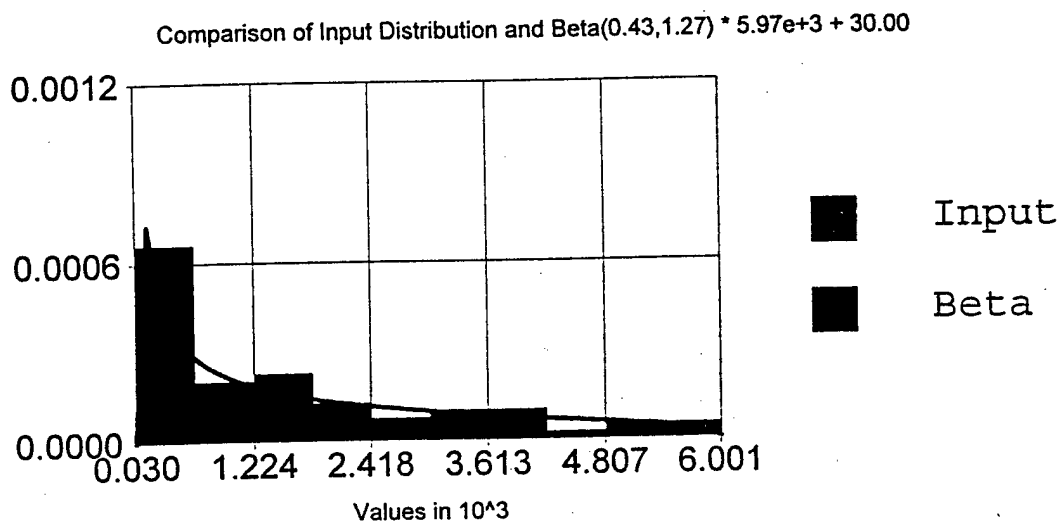


Figure 5 Theoretical Distribution of EMS Interarrival Times

Appendix 3: Informal Data Collection Sheet

Circle 1: Physician/PA
Nurse
LPN/Enlisted

	<i>Screening /</i>	<i>Pt Exam /</i>	<i>Treatment</i>	<i>Lab Draw</i>	<i>Pt Edu.</i>	<i>Administrative</i>
Emergent						
Urgent						
Non-						

NOTE: All times in minutes!
Exclude the patient's time spent at x-ray

Operational Definitions:

Screening / Triage = Time spent gathering vital signs, interviewing patient for complaint and history, and documenting this information
Pt Exam / Assessment = Time spent after the screening / triage period interviewing and examining patient, ordering tests and procedures, and documenting information.
Treatment = Time spent with the patient performing procedures such as CPR, bandage wraps, and IVs minus time spent drawing ordered labs.
Lab Draw = Time spent drawing ordered labs.
Education = Time spent educating the patient and/or family after the treatment period and after tests have been interpreted.
Administration = Time spent completing documentation, coordinating with staff, coordinating transfers, etc.

Example:

Circle 1: Physician/PA
Nurse
LPN/Enlisted

	<i>Screening /</i>	<i>Pt Exam /</i>	<i>Treatment</i>	<i>Lab Draw</i>	<i>Pt Edu.</i>	<i>Administrative</i>
Emergent	1 min	10 ± 5 min	30 ± 10	n/a	10 ± 5	15 ± 5
Urgent	etc	etc	etc	etc	etc	etc
Non-	etc	etc	etc	etc	etc	etc

Appendix 4: Percent Patient Arrivals

Hour	Status Quo	Alt # 2 (0700 - 2200)	Alt # 2 (2200 - 0700)
1	1.1	0	12
2	.3	0	3
3	.2	0	2
4	.7	0	7
5	.3	0	3
6	1	0	11
7	1.2	1	0
8	3.9	4	0
9	6.2	7	0
10	9.0	10	0
11	6.7	7	0
12	7.4	8	0
13	7.4	8	0
14	6.1	7	0
15	5.2	6	0
16	7.2	8	0
17	5.3	6	0
18	7.5	8	0
19	6.6	7	0
20	6.7	7	0
21	4.2	6	0
22	3.1	0	33
23	1.5	0	16
24	1.2	0	13
Total	100	100	100

Appendix 5: Status Quo Model Statistical Validation

Table 8 Patient Service Times Descriptive Statistics

	Empirical Data	Status Quo Model Data
Descriptive Statistics		
Mean	83.6	85.0
Standard Error	2.5	1.0
Median	59	51
Mode	35	---
Standard Deviation	78.6	111.8
Sample Variance	6182	12498
Kurtosis	11.7	32
Skewness	2.93	4.88
Range	620	1565
Minimum	11	14
Maximum	631	1579
Sum	84894	1050305
Count	1015	12356
Confidence Level(95.000%)	4.84	1.97

Table 9 Patient Service Times t-Test

	Empirical Data	Status Quo Model
Mean	83.64	85.00
Variance	6182.11	12498.62
Observations	1015.00	12356.00
Pooled Variance	12019.53	
Hypothesized Mean Difference	0.00	
df	13369.00	
t Stat	-0.38	
P(T<=t) one-tail	0.35	
t Critical one-tail	1.64	
P(T<=t) two-tail	0.70	
t Critical two-tail	1.96	

Table 10 Patient Arrivals by Week Descriptive Statistics

	Empirical Data	Status Quo Model Data
Descriptive Statistics		
Mean	252.3	247.1
Standard Error	6.6	4.1
Median	258	246
Mode	N/A	N/A
Standard Deviation	19.7	16.4
Sample Variance	386.8	268.7
Kurtosis	.39	.22
Skewness	-.70	.37
Range	65	64
Minimum	215	218
Maximum	280	282
Sum	2274	3954
Count	9	16
Confidence Level(95.000%)	12.8	8.03

Table 11 Patient Arrivals by Week t-Test

	Empirical Data	Status Quo Model Data
Mean	252.67	247.13
Variance	386.75	268.65
Observations	9.00	16.00
Pooled Variance	309.73	
Hypothesized Mean Difference	0.00	
df	23.00	
t Stat	0.76	
P(T<=t) one-tail	0.23	
t Critical one-tail	1.71	
P(T<=t) two-tail	0.46	
t Critical two-tail	2.07	

Appendix 6: Peripheral Observations

Throughout the project, the following peripheral observations were noted to improve KACH Emergency Room operations.

The CHCS printer for laboratory results should be relocated to an area where staff is routinely located. While results are available by the CHCS terminals, staff are usually notified by the printed results. Locating the printer where staff routinely congregate, vicinity of the reception desk, would alert the staff as to patient results immediately.

Equipment in patient rooms that signal when a patient is finished with a process would increase the efficiency of operations. That is, a patient call system could be implemented that, for instance, alerts the enlisted personnel that a provider is finished with a patient. The enlisted and nursing staff would then be alerted that the patient room needs to be cleaned. The system may not be used full-time given the patient volume but would, of course, be of use during extremely heavy patient load times.

Recent discussions have centered around transitioning to an Acute Care Clinic with the ICU nurse receiving calls from patients in need of emergency medical services. In turn, the nurse would call the MOD who would meet the patient at the former KACH Emergency Room. A key point being that the MOD would be on-call and not physically located at the KACH Emergency Room. A

quick risk-analysis of this procedural outline indicates a system with potentially several adverse encounters. Specifically, if there are only three independent events that must occur (patient calls ICU, nurse contacts MOD, MOD arrives at Emergency Room) for the previous scenario to occur and the probability of each scenario happening successfully is 999 of 1000 or .999%, then probability theory indicates that approximately 3 times out of 1000 something will go wrong and the MOD will not meet the patient at the Emergency Room. This translates into approximately 3 adverse incidents every 333 days, given an average of 3 patient visits after the MOD has left from 2200 - 0700.

Finally, the decision to expend additional resources on an after-hours primary care clinic will undoubtedly cause less utilization of the KACH Emergency Room personnel. The implicit assumption with management's decision to allocate additional resources towards night clinics is that primary care should not be provided by the KACH Emergency Room. The validity of this assumption may be tested by changing KACH Emergency Room practices. Instead of focusing strictly on emergency medicine, the staff should reevaluate its processes and provide coordinated primary care services without compromising its role as the community emergency medicine center. It is apparent that the community perceives the KACH Emergency Room as both an accessible, walk-in primary care clinic, since greater than 85% of patient arrivals are non-urgent, and as an

Emergency Room with 15% urgent and emergent patients. Elimination of the 85% non-urgent patients may not justify the continued existence of the KACH Emergency Room mission.

It is realized that using the Emergency Room staff and resources to provide primary care may not be feasible given the recent mandates to the Military Health Services System (MHSS). However, it is this author's opinion that it is a more efficient utilization of resources and in the community's, KACH's, and the patient's best interest, to not allocate additional resources towards an after hours clinic, but to provide more coordinated primary care services concurrently in the KACH Emergency Room.