1-1-2010

An analysis and simulation of an emergency department with aims towards improving network flow and efficiency of care

Amanda M. DuBois

Jakub Skwarek

ENGINEERING CAPSTONE:

An analysis and simulation of an Emergency Department with aims towards Improving Network Flow and Efficiency of Care

By:
Amanda DuBois
With Assistance from:
Jakub Skwarek
Advised by:
Dr. Gary Chen (ISYE Faculty)
2009-2010

University Honors Program

Capstone Approval Page

Capstone Title (print or type): An Analysis and Simulation of an Emergency Department with aims towards Improving Network Flow and Efficiency of Care

Student Name (print or type): Amanda M. DuBois

Faculty Supervisor (print or type): Dr. Gary Chen

Faculty Approval Signature: [signature]

Department of (print or type): Industrial and Systems Engineering

Date of Approval (print or type): 5/17/16

1. INTRODUCTION

1.1 Purpose

The purpose of this project is to help improve E.R. operations, by minimizing patient wait times and utilizing resources fully and properly. One of the biggest issues in an ER is effectively serving all patients quickly without over burdening the human resources of the system. To do so staff must be utilized correctly, patients prioritized, and processes optimized and balanced within the system. However, many hospitals have very little data on actual times within the system or a true understanding of where delays occur. The project will seek to both determine what processes in the hospital are most detrimental to patient wait times along with giving the hospital recommendations on how to improve wait times and resource utilization. Ultimately the goal is for a system that will allow them to better serve their patients.

1.2 The Problem Description

The hospital is located in a suburb of Chicago. The hospital's ER room is fairly large, and plans to nearly double the capacity are currently in the works. The neighborhood the hospital is in serves an elderly and aging community, and hence, demands for the hospital and in particular, the Emergency Department, are steadily growing.

The hospital at this time often has issues meeting their demand during high volume periods, and also has little data on what internal process times are. They know how long a patient is in the system, but have limited information on the break down within the system for both how long a patient is with each type of worker or takes to receive different treatments.

1.3 Objectives

1. To determine what changes if any could be made to help make the current E.D. more efficient decreasing patient wait times and improving employee utilization

2. To adjust the model to fit the new E.D. and determine what staffing levels and changes could be made to decrease patient wait times and improve resource utilization

3. To run several extreme situations for short durations to analyze system response and how resources must be increased to meet demand while keeping patient time in system low

1.4 Process Description

1.4.1 Overall Process

The ER has three primary sections, the registration triage section, the Fast Track section, and the main E.R. ward. Each of the three sections is described in more detail below.

The hospital utilizes three teams of nurses, doctors, and P.A.'s in their E.D., each of which is assigned certain rooms to oversee. The main E.R. employs the majority of the nurses and both the doctors, with up to 7 nurses on staff at the busiest time of the day and 2 doctors, 4 nurses and 1 doctor are always present within the E.R. From 11 am – 11 pm a separate area for the lowest category patients is available. This are employs only 1 nurse and 1 P.A., physician's assistant although a doctor and an additional nurse are shared with main E.R. Most of the lab and X-Ray work in the ER is done outside the ER although there are mobile X-Ray units that can be brought in by the techs, and simple labs are sometimes performed on site.

The hospitals patients are primarily elderly folks who commonly come in with heart issues, dizzy spells, or falls. The hospital averages around 2,600 patients a month. The hospital rates patients on a scale of A1 to A5 with A1 being the most serious, patients in the A1 category are not stable on entering the hospital, and A4 being the least serious, typical injuries such as a twisted ankle are considered A4. A5 patients are also very low category patients, but are a rarity in the system and often come from within the hospital's other departments.

Process Map of the Emergency Department Overview

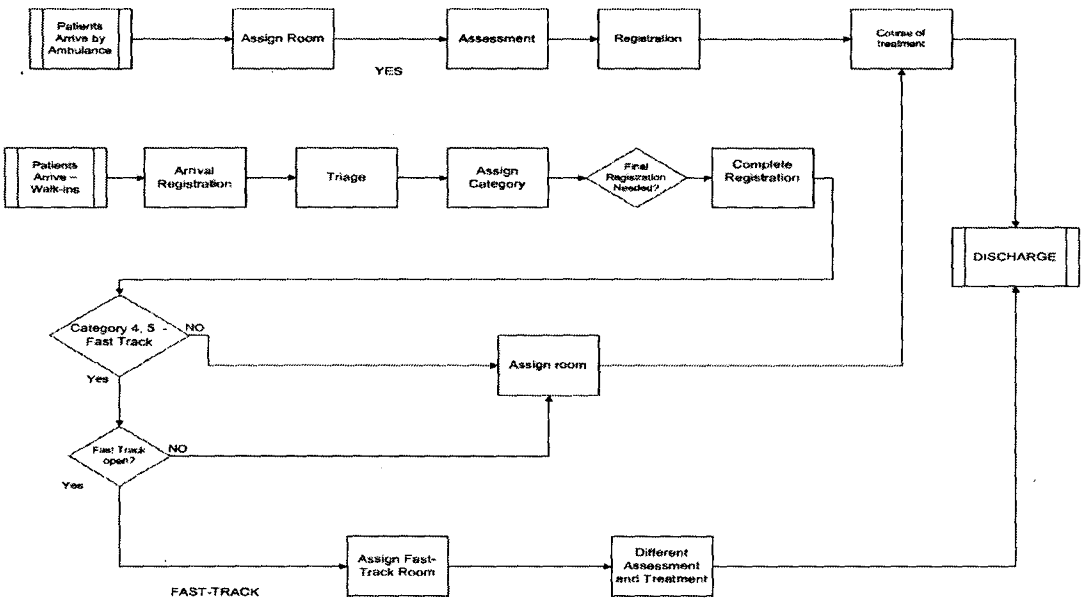

Figure 1.1

The preceding figure shows a general overview of the flow with in the Emergency Department. Patients enter one of two ways either by ambulance or walk-in. Ambulance patients are immediately assigned a room and then receive registration at bedside. Walk-in patients receive registration and then are triaged, assigned a category, then some are required to give additional information to be assigned a room. From there patients are assigned to a room based on their category, and the time of day, whether Fast Track is open or not. After that patients receive their course of treatment and then are discharged.

1.4.2 Registration and Triage

The registration area consists of 2 clerks during the morning and day shift, and 1 clerk during the night shift. It is where general patient information such as residency, name, and insurance information is taken.

Triage is open from 7 am – 11 pm. It is staffed by a single nurse. The triage process consists of determine the severity of the injury or illness and taking general medical information such as blood pressure or temperature. It is that at this station that a patient's category is assigned. During other times triage is often performed in the main E.R. area or a regular nurse is pulled from the E.R to perform the service.

1.4.3 Emergency Room

The emergency room is where category 1, 2, and 3 patients are treated during the times of 11 am – 11 pm, and serves all the patients during other times. There are 13 rooms in the current layout available, 2 of which are always reserved for category 1 patients only. There are five permanent staff member 3 nurses, 1 doctor and 1 technician, and 6 additional part time workers, 2 technicians, 3 nurses, and 1 additional doctor.

Note these are assignments not specific workers multiple workers may cover the shifts or positions in a single day.

Process Map of Main Emergency Room

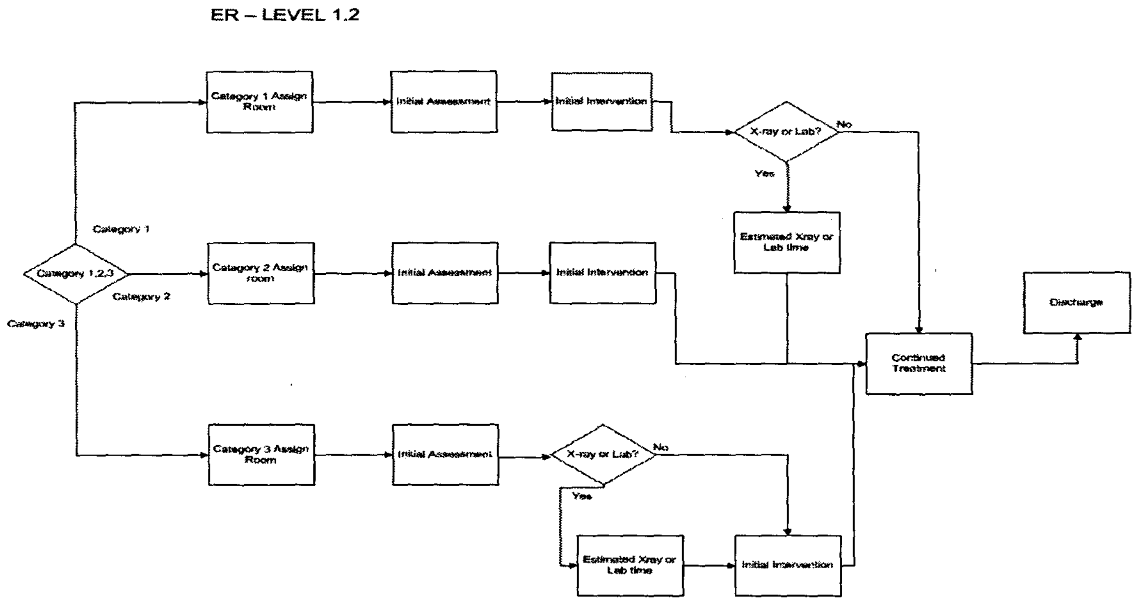

Figure 1.2

Patients who enter the E.R. are treated based on their category. The general process consists of assessment of the patient's condition, necessary testing (x-rays and labs) and treatment consisting of an initial intervention and then additional concluding treatments. Depending on the severity of the patient's injuries the order of processes may be different, but those 4 processes are experienced by all the patients. Category 4 patients who enter the system follow the same layout as the category 3 patients. After the treatment is finished all patients are discharged.

1.4.4 Fast Track

The fast track is an area of the E.D. reserved for treating only the lowest category patients. It is available only from 11 am – 11 pm, and utilizes only 2 full time staff members, a P.A. and a Nurse. It is meant to quickly treat and move patients with common, non-sever injuries, such as broken bones or cuts requiring simple stitches through the system.

Process Map Fast Track

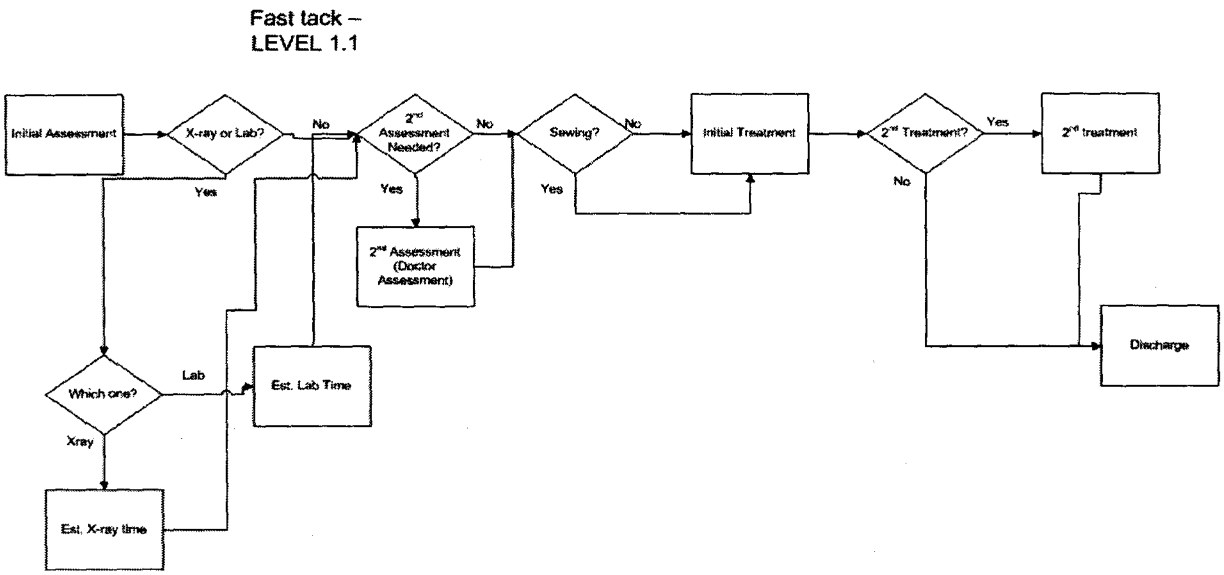

Figure 1.3

The patient which enters the fast track is immediately assessed to determine the course of treatment. Following this they are sent to x-ray or lab if needed, and sometimes a doctor is called in to perform a second assessment if the staff is unsure on the patient's injury or illness. After the patient receives their course of treatment, which may require the services of a professional staff member, P.A. or doctor, or be performable by a nurse, this is reflected in the sewing decision. After receiving their treatment the patient is discharged and exits the system.

1.5 Background on Emergency Department Simulation

Simulation technology offers a great way to improve patient times within Emergency Departments. It offers the ability to look at the ER system and with a "'few key strokes add staff" or change resource allocation to see how the changes affect patient times. (1)

Central Baptist hospital used simulation to good effect to determine 3 common factors looked at in simulation projects.

> "1. Indentifying patient flow barriers within the department
> 2. Reducing overall patient turnaround time
> 3. Reducing patient wait times before entering a room" (1)

These factors are generally what most simulation designs focus on. A study in Mayaguez, Puerto Rico, utilized these tools in a desire to make better use of very limited resources available at the hospital. By identifying where barriers occurred and trying to determine causes they were able to make several recommendations in changing placement and job assignments to fix issues in the system by improving employee utilization and assignments. This led to better service and shorter wait times for all patients. (4)

In general one of the largest challenges with simulation in E.D.'s is accurately breaking the system down into observable processes. According to Blake and Carter "in an abstract sense, and emergency room can be thought of as a network of queues or waiting lines". As such it is very important to properly identify where the queues lie within the system. The ER room is a very fluid process with numerous entities and resources constantly moving in and out of the system. As such one of the biggest challenges in modeling the system is determine how to do it; what processes actually exist in the system and what resources these processes seize. (2)

2. METHODS

2.1 Data Collection and Verification

2.1.1 Process Times Data Collection

Process Time collection was split into the 3 main areas reflected in the earlier process maps: the entrance area where registration and triage took place, the Emergency Room, and the Fast Track. The first step in this collection was breaking each of the areas into workable processes such as assessment, initial treatment, wait time for testing, and secondary treatment. Process break downs were determined through observation and interview the staff. Once the system was broken down into workable pieces process times were collected over 6 weeks, at a variety of times and days. The times were collected on simple spread sheets and with a stop watch.

2.1.2 Arrival Time Data Collection

Arrival data was obtained directly from hospital records for an entire year. The data was received in an Excel file which contained arrival time, departure time, and category for each patient they hospital saw with in the year. For the purposes of this study we only considered arrivals from category 1 through 4.

2.1.3 Data Verification

For the patient arrival times no verification of data accuracy was performed as the data came directly from the hospitals own records. For the process times both the chosen layout for how to break down a patient visit and the times obtained from collection were confirmed with members of the E.D. staff to insure that the times and process layout were accurate. Only the average times were verified with the staff for different times of the day not each individual measurement.

2.2 Data Analysis

2.2.1 Analysis of Arrival Data

To analyze the process data to find a distribution fit the software EXPERT FIT was used. To use this software the data was first broken down by category, and then transformed into time between arrivals instead of just the time the patient entered the system. After this was performed the data was plugged into the solver until distributions which had at least a 90% Confidence according to a K-S test were found. In order to find these distributions for Category 3 and 4 the data had to be broken down into months and then further into shifts, which led to us having to run separate models for each of the 12 months.

Most of the arrival times followed a log normal or beta distribution. The exception being the Category 1 data which used a constant expression as the data was so limited that no good fit could be found. The constant was chosen such that the arrivals would occur during different times of the day each day, to try as closely mimic the process as possible.

2.2.2 Analysis of Process Data

Process data was analyzed by patient category and by process break down. For instance, sample processes were initial assessment, stabilization, primary treatment, tertiary treatment, delay for lab or x-ray, discharge, and triage time. The data was sorted and then plugged into the EXPERT FIT solver to obtain process times for each patient based on what their course of treatment was. These distributions were then used in the system to generate process times for the patients.

2.3 Model Development

It is important to note that developing models that are "dealing with patients rather than products places additional demands on the simulation". (1) This is because the patients are a much more fluid entity that can directly affect the simulation much more than standard products. The model developed in ARENA uses routing-sequence logic to move patients through five areas: beginning area, triage registration area, waiting area, fast track area, and emergency area. The patients move through the system differently based on their acuity level. There are 3 types of resources used in the system non human, human permanent, and human scheduled. The system was built using time distributions, determined by the data collected for processes. Kelton's book Simulation with Arena was used throughout the process as a reference. (5)

2.3.1 Beginning Area

This area of the model consists of creating the patient arrivals, assigning their category, and beginning their routing through the system. There are 5 creation modules used 1 each for category 1 and 2 and 3 for category 3 and 4 patients.

2.3.2 Registration and Triage

This area mimics the hospitals registration and triage procedures. It is visited by all, but category 1 patients. It utilizes 3 resources 2 secretaries and a triage nurse, along with calling regular nurses during non-triage hours.

2.3.3 Waiting Area

This is merely a holding area for patients much like the waiting area in the hospital it holds all non category 1 patients until they are sent to their rooms in the E.R. or Fast Track.

2.3.4 Emergency Room

This is set-up to mimic the main E.R. room it employs the majority of the human resources scheduled and non-scheduled and 13 rooms. Patients are treated here based on category and given different process flows depending on what their category is. For instance, category 2 patients receive additional treatment times when compared to category 3 and 4 patients. It is important to note that resource schedules mimic availability not actual people in the system. For instance there is 3 full time nurses scheduled, this is represented by a single resource with capacity to deal with 3 patients at a time not the 9 separate nurses it would actually be in a single day.

2.3.5 Fast Track

Set-up much like the E.R. this area mimics the Fast Track area of the E.D. It uses the remaining of the human and non-human resources, and allows Category 4 patients to be received during the appropriate door. If the Fast Track is not open patients are sent to the main E.R. where they undergo treatment.

2.4 Model Testing, Verification, and Validation

2.4.1 Testing

This consisted of 3 main things determining the amount of time it took for each month to reach steady state, determine how many replications were needed for each month to get an accurate result of system times and finally determine which if any models were statistically the same on average times in system

The first and second tests were done to insure that the times and recommendation reported were accurate and reasonable. The hospital is never entirely empty so it was important to allow the model to run long enough before analysis was started to insure that times would reflect reality as closely as possible. Similarly a single run of the model is not enough to determine how the system works. Since there is no set constant time for patients in treatment or arrival rate it is important to run the model multiple times before gathering any data.

The final test was done because in order to accurately model arrival data we had to break the model down into months. Hence following this we desired to see if we could eliminate any months from the final analysis because they were statistically the same as another. There were no months which were paired on system times for four or more patient categories, category 1, category 2, category 3, category for fast track, category 4 E.R., so all months were run.

2.4.2 Verification

The model was first verified to insure that the number of patients which entered the system was consistent with the number of patients which the hospital actually saw. Originally, the number in the system was higher so steps were taken to re-analyze and adjust the creation module distributions, so that outputs matched up with the actually data more closely. For each month's actual and theoretical patient outputs were within 75 of each other after the adjustments.

The model was also verified to insure both that resources were being properly seized and that patients were reflecting reasonable process times and times in system. To do this we looked at both overall patient times and times patients spent in individual processes. We looked at both the averages and the extremes to insure all were reasonable. For overall time in system we had the data from the hospital on entrance and discharge times for patients so we were able to verify whether or not our model times were matching up with the patient times reported by the hospital. Individual process times were verified with the data that had been collected.

One issue found for resource utilization was that patients were being trapped in the Fast Track area once it closed for the night and the workers went off staff. To fix this we merely added an extra 2 hours on to the P.A.'s scheduled availability, so all patients left the system before it closed for the day.

2.4.3 Validation

To insure the model was valid two steps were taken. One overlapping with the verification process in using the hospitals actual data for patient times and arrivals and insuring it matched up with what the model was producing.

The second method of validation took place in the form of asking workers in the E.D. what they felt were reasonable system times after explaining to them how we broke down the model, and also insuring that how we broke patient treatment times down was reasonable with what was actually occurring.

3 RESULTS

3.1 Bottle Necks and Under Utilized Workers

3.1.1 Bottle Necks

These are areas/processes where the model typically hard the largest waiting time. This can reflect one of two issues, either that the process is very inefficient and takes a long time compared to other processes or that the process calls on an overburdened resource.

The first major area of delay was the triage area; this seems to be primarily because of the process efficiency. This seems apparent because in later tests the addition of another worker or even 2 workers to the station did little to improve the wait time for resources at that station. This phenomena matches up with what was observed as triage times could become quite lengthy.

The second major areas of delay were processes which called for a professional worker, doctor, in the system. These were often a single treatment in Category 2 patients or optional consultations for other category patients, stabilization processes for category 1 also demanded a doctor. This was probably due to the doctor resource being overburdened as the addition of another doctor often significantly lowered times in all these processes and over all times for patients.

3.1.2 Under Utilized Workers

The most under-utilized worker in the system was the Techs. This probably reflects that many of their primary duties were not modeled as separate processes in the system. For instance, data entry and lab work and x-ray work was not modeled as separate processes it was simply added into general process times or seen as a delay in the system.

3.2 Scenarios

To determine what is needed during both general traffic times and high traffic times of specific patients several scenarios were run the results are summarized below.

3.2.1 Scenario 1 Base Model

The following table focuses on the current system in November. The base model shows 1 full time doctor, 3 full time nurses, 1 full time tech, and 1 triage nurse.

					Total time in system (min)				
	Doct	Nurse	Tech	TriageNur	cat 1	cat 2	cat 3	cat 4 noFT	FastTrack
base	1	3	1	1	122.477	156.106	128.877	103.066	64.699
2 doct	2	3	1	1	109.221	130.75	112.444	92.627	60.361
2 FullNurses	1	4	1	1	120.085	154.217	128.616	101.739	64.616
2Full Techs	1	3	2	1	122.706	157.396	129.784	101.925	65.06
2Triage	1	3	1	2	122.477	156.106	128.877	103.066	64.699
2 docs 2 Nur	2	2	1	1	109.321	130.615	111.846	92.994	60.364

TABLE 1—Time in System (minutes) for Base Layout

From the different iteration, the highlighted sections show the most improvement. We conclude that when a professional staff member is added to the system, there is an improvement in the total time that the patient spends in the ER. Also, the 3rd full time nurse does not seem to be fully utilized in this model, and when removed the total time in system for all the categories stays the same as if there were three full time nurses. Although, before making any changes to staffing it is necessary to take a closer look at the system

3.2.2 Scenario 2 New Layout

Since the hospital is adding rooms to their recourses we have run our model with the additional 11 rooms. The following table shows similar results as the previous table even though we have added additional.

						Total time in system (min)				
	Doct	Nurse	Tech	TriageNur	ER rooms	cat 1	cat 2	cat 3	cat 4 noFT	FastTrack
NewLayout	1	3	1	1	12	122.1	156.8	129.0	102.1	65.2
NewLayDoc	2	2	1	1	12	110.0	131.0	112.3	93.2	60.3

TABLE 2—Time in System (minutes) for New Layout

The same type of patient arrival data was used for both iterations, so we can see that the additional rooms do not change the fact that the system needs a professional staff member added to the system in order to reduce the times for all the categories.

These tables show results for the month of November, but when we ran other months, the outcome was very similar.

3.2.3 Scenario 3 Overall System Flood

This scenario shows a high volume day all the patient arrival times were halved across the system doubling the number of patients in system

The following table shows results from an overall system flood. The arrival rates were doubled for all of the patient categories

						Total time in system (min)				
Doctor	Nurses	Techs	TriNurse	ER Rooms	N 9 to 11	cat 1	cat 2	cat 3	cat 4 noFT	FastTrk
1	3	1	1	1	1	158.9	274.3	256.7	131.9	111.6
1	3	1	1	12	2	149.3	281.4	247.5	131.9	128.8
2	3	1	1	12	2	125.2	159.6	133.9	94.9	79.2
2	4	1	1	12	1	122.9	158.7	133.8	93.1	79.4
2	4	1	1	12	1	122.9	158.7	133.8	93.1	79.4
2	3	1	1	12	1	125.2	159.6	133.9	94.9	79.2
2	2	1	1	12	1	126.1	179.5	145.0	105.6	80.4

TABLE 3—Time in System (minutes) for Overall System Flood

In this scenario it is clearly visible that an additional doctor would greatly decrease the total time spent in the system by a patient. Also adding another nurse does not seem to improve the system in any major way, but if a full time nurse is removed from the systems the time increases slightly.

3.2.4 Scenario 4 Category 1 System Flood

This scenario mimics what happens when a large influx of very serious patients enters the E.D., such as if a bad accident or crash occurs.

The following table shows Category 1 patient flood. In this scenario we flooded the system with 20X the normal category 1's patients.

							Total time in system (min)				
Doctor	Nurses	Techs	TriNurse	ER Rooms	FT Nurse	Nur 9 to 1130	cat 1	cat 2	cat 3	cat 4 noFT	FastTrk
2	3	1	1	12	0	1	123.5	170.8	146.1	100.3	74.0
1	3	1	1	12	0	2	136.4	294.6	279.4	145.6	108.7
2	3	1	1	12	0	2	123.5	170.8	146.1	100.3	74.0
1	3	1	1	1	1	1	153.6	292.1	281.8	144.2	111.0

TABLE 4—Time in System (minutes) for Category 1 System Flood

Once again the iterations revealed that in order to bring down the times, a professional staff member is required to be added to the current staff.

3.2.5 Scenario 5 Category 3 and 4 System Flood

This scenario reflects a day when a large number of low injury/illness patients enter the hospital. The number of category 3 and 4 patients was quadrupled for a day.

In the last scenario we flooded the system with a high volume of category three and four patients. The following table shows a few of the iterations that we have tested in our model.

Doctor	Nurses	Techs	TriNurse	ER Rooms	FT Nurse	Nur 9 to 1130	Total time in system (min) cat 1	cat 2	cat 3	cat 4 noFT	FastTrk
3	5	1	2	12	1	2	153.4	254.8	287.2	302.8	223.2
2	5	1	1	12	1	2	180.7	277.5	344.6	157.5	251.4
2	5	1	2	12	0	2	180.7	277.5	344.6	157.5	251.4
3	5	1	1	12	0	2	153.4	254.8	287.2	302.8	223.2
2	4	1	2	12	1	2	175.4	285.8	347.7	159.1	257.4
2	3	1	1	12	1	2	177.3	305.8	354.6	154.2	264.6
1	3	1	1	12	0	2	142.6	374.2	482.5	177.6	353.2
2	3	1	1	12	0	2	177.3	305.8	354.6	154.2	264.6

TABLE 5—Time in System (minutes) for Category 3 and 4 System Flood

Once again adding additional doctors, and also in this case, additional nurse is a must in order to keep the patient total time in system within reasonable boundaries.

4. CONCLUSION

4.1 Final Recommendations

From our findings across all the months it appears that the addition of a doctor or P.A. to the staff could greatly help in reducing patients wait times across the board. The model itself only tested for doctors; as P.A.'s were not modeled in the main E.R. area.

However, the reason doctors are so effective at reducing patient wait times is most likely because they are very flexible in what services they can perform when compared to other employees. As such it may be nearly or as effective to add a P.A. into the actual system as they can perform many of the same services that a full doctor can when compared to a nurse.

An additional finding was the overall techs were highly underutilized in the system. However, as mentioned in the design many of the Techs primary duties were not accurately modeled; however, it is worth looking into either the reduction or perhaps reassignment of duties to techs to see how they can be more effectively utilized.

Another set of very under-utilized worker were the registration clerks. This makes sense as their process is very short and they are only used at most twice by any patient, and usually only once. It is our belief that moving to a bed side registration and eliminating the need for these workers to just be in charge of taking patient data at the front could help speed processes along. Relocating them to the main E.R. and allowing them to perform additional services within the E.D. could improve both their utilization and the overall, patient experience.

A final assignment to look at is the number of nurses in the hospital throughout the day. When reducing the number of nurses by one, utilization was improved, although not to such an extent to lead to overburdening, and patient wait times were not significantly changed. It is possible that one fewer nurses during standard operation could be effective in treating patients. However, it is important to note that not all duties of workers were modeled in this simulation, much of the clerical and data entry work was not accurately modeled and so more information must be collected to insure that patients could still be effectively serviced.

The triage process is perhaps the most inexplicable delay which occurs for patients. It has some of the longest wait times, but the addition of workers did little to eliminate these times. It is our recommendation that the triage process be further examined to see if steps within it could be eliminated or moved the main ward, to allow patients to move more quickly into the E.D. for treatment.

4.2 Concluding Remarks

Overall, this simulation helped pinpoint where many of the problem areas were and give insight into how staffing could be adjusted to help improve the patients' experience and keep the E.D. efficient. The final findings require further research before any drastic changes are made as when dealing with human lives it's important to sure that the quality of care not only the efficiency and speed of the care is not affected by the changes implemented.

5. REFERENCES

1. Braly, Damon. "Seek alternative via simulation software." *Health Management Technology* 16.13 (1995): NIU Library Database. n. pag. Web. 31 Sep. 2009.

2. Blake, Jonn T. and Carter, Michael W. "An Analysis of Emergency Room Wait Time Issues Via Computer Simulation." *INFOR* 34.4 (1996): NIU Library Database n. pag. Web. 31 Sep. 2009.

3. Seireich, David and Marmor, Yariv. "Emergency department operations: The basis for developing a simulation tool." *IIE Transactions* 37.3 (2005): NIU Library database. n. pag. Web 31 Sep. 2009.

4. Gonzalez, Carlos J., Ganzalez, Merbil, and Rios, Nilda. "Improving the quality of service in an emergency room using simulation-animation and total quality management." *Computers and Industrial Engineering* 33.1-2 (1997): NIU Library database. n. pag. Web. 31 Sep. 2009.

5. Kelton, David W., Randall P. sadowski, and David T. Sturrock. *Simulation with Areana Fourth Edition*. NewYork: McGraw-Hill, 2007. Print.