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THESIS

A COMPUTER SIMULATION AND ANALYSIS OF THE FORWARD SURGICAL TEAM

by
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September 1995

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To meet the challenge of providing effective combat health care on the modern battlefield, the Army Medical Department is designing a unit that will provide far forward surgery to stabilize the most seriously injured casualties. A Forward Surgical Team (FST) can provide emergency surgery to casualties prior to evacuation to an Army hospital. The model documented in this thesis is a simulation of casualty flow through a FST that will help determine if the intended force structure is adequate to perform its mission. The model uses data from the Deployable Medical Systems Task-Time-Treater database to simulate medical treatment of surgical patients. The model is designed to measure the utilization rates of each member of the FST based upon expected casualty arrival rates and types. It also provides data on operating room times and casualty waiting times. This data can be used to analyze the effects changes in the force structure of the FST have on health care operations. By varying input parameters, medical planners can use the model to help determine resource requirements for specific missions. The model could be modified to simulate casualty flow through other units with similar missions or expanded to reflect other types of field medical units.

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A COMPUTER SIMULATION AND ANALYSIS OF THE FORWARD SURGICAL TEAM

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ABSTRACT

To meet the challenge of providing effective combat health care on the modern battlefield, the Army Medical Department is designing a unit that will provide far forward surgery to stabilize the most seriously injured casualties. A Forward Surgical Team (FST) can provide emergency surgery to casualties prior to evacuation to an Army hospital. The model documented in this thesis is a simulation of casualty flow through a FST that will help determine if the intended force structure is adequate to perform its mission. The model uses data from the Deployable Medical Systems Task-Time-Treater database to simulate medical treatment of surgical patients. The model is designed to measure the utilization rates of each member of the FST based upon expected casualty arrival rates and types. It also provides data on operating room times and casualty waiting times. This data can be used to analyze the effects changes in the force structure of the FST have on health care operations. By varying input parameters, medical planners can use the model to help determine resource requirements for specific missions. The model could be modified to simulate casualty flow through other units with similar missions or expanded to reflect other types of field medical units.

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EXECUTIVE SUMMARY

In the mid to high intensity conflicts of the future, the nature of the battlefield will likely be intense, chaotic, and highly destructive. Advances in the precision of weapons systems and the lethality of modern armaments would seemingly have created an even deadlier environment. The export of advanced military technology to Third World nations may create a similar type of environment on a smaller scale in a low intensity conflict. To adapt to changes in the capabilities of modern weapons systems, military doctrine has been continuously modified. Current United States Army doctrine published in Field Manual 100-5 stresses the need for rapid and destructive fires throughout the depth of a nonlinear battlefield.

The Army Medical Department (AMEDD) has the responsibility for providing health service support to the Army. The AMEDD is currently developing new types of units and procedures to support changing Army doctrine. In the past, the AMEDD has been very successful in providing high quality health care to US soldiers even as the dynamics of the battlefield have changed. While the percentage of casualties that are killed in action (die before entering a military hospital) has remained at 18-24% in each war the US has fought in since World War I, the number of casualties that die of their wounds (after entering a military hospital) has steadily decreased. One of the key factors in reducing this percentage has been the improvement in Level III (medical care provided at a military hospital) care the AMEDD has provided through advances in medical technology and casualty treatment. Although the percentage of casualties that die from their wounds has steadily decreased, there has not been a significant improvement on the percentage that are killed in action. The AMEDD is hoping to reduce this percentage by developing new types of units and doctrine that will provide rapid evacuation and more definitive care at Level II (medical care at the forward medical companies). While providing the high quality of care needed to treat the most seriously injured casualties, forward AMEDD units must remain integrated members of the combined arms team. Units must be mobile, agile, and flexible to support current and future Army operations.

One of the major initiatives in the AMEDD designed to reduce the number of soldiers killed in action is the Forward Surgical Team (FST). As currently envisioned, this unit will be able to provide the far forward surgical care needed to stabilize the most seriously wounded casualties prior to evacuation to hospitals outside the combat zone. The design of the FST was based upon experiences gained by units that performed similar missions in Panama and Iraq. The FST will be a small, highly-mobile unit capable of providing emergency surgical procedures as far forward as the Brigade Support Area.

The purpose of this thesis was to determine, using simulation methodology, whether the force structure developed for the FST is adequate to perform its wartime mission. The model provides data on the utilization rates of each member of the FST and estimates of operating table usage. The model allows medical planners to analyze the impact on forward medical care of such parameters as the number of casualties treated, the casualty arrival rate, and the design of the FST, and is a valuable tool to study the structure of the team and its capability to support various missions.

The results of the analysis provide many insights into FST operations. The simulation results indicate that operating room times for FST patients are highly variable. The results also showed the model was less sensitive to changes in the arrival distribution than anticipated. As expected, an increase in the number of arrivals caused a greater number of casualties to wait for treatment. The data showed there was a quadratic relationship between the number of arrivals and the number of casualties that waited for treatment. This result can be used by medical personnel to plan more accurately for support of future operations.

The final analysis conducted in this thesis was the comparison of various FST configurations. The results indicated there could possibly be potential force structure savings in the design of the FST. There was little effect on the number of casualties waiting longer than the established 120 minute threshold by eliminating an Advanced Trauma Management Section or even an Operating Room Section. The utilization rates of the members of the FST did not increase beyond acceptable levels when the number of personnel was reduced. In an era of shrinking budgets and declining force sizes, it is imperative that units be properly sized and equipped. This model provides a means to help evaluate proper manning levels and ensure dwindling resources are efficiently used.

I. INTRODUCTION

A. BACKGROUND

In the mid and high intensity conflicts of the future, the nature of the battlefield will likely be intense, chaotic, and highly destructive. Advances in the precision of weapons systems and the lethality of modern armaments would seemingly have created an even deadlier environment than has previously existed. The export of advanced military technology to Third World nations may create a similar type of environment, on a smaller scale, in a low intensity conflict. To adapt to changes in the capabilities of modern weapons systems, military doctrine has been continuously modified. Current United States Army doctrine stresses the need for rapid maneuver and destructive fires throughout the depth of a nonlinear battlefield [Ref. 1].

As a result, the ability to sustain modern combat operations has become increasingly complex. Logistical units must have the capabilities needed to perform the many types of combat service support required and at the same time be survivable on the modern battlefield. This requires forward logistical units to be highly mobile and responsive in order to provide continuous support to the combat forces.

The Army Medical Department (AMEDD) has the responsibility for providing health service support to the Army. The AMEDD is currently developing new types of units and procedures to support changing Army doctrine. In the past, the AMEDD has been very successful in providing high quality health care to US soldiers, even as the dynamics of the battlefield have changed. Since World War I, the percentage of casualties that have been killed in action (die before entering a military hospital) has remained at 18-24% in each war the US has fought. However, the percentage of casualties that have died of their wounds (after entering a military hospital) has steadily decreased. One of the key factors in reducing this percentage has been the improvement in Level III (medical care provided at a military hospital) care the AMEDD has provided through advances in medical technology and casualty treatment. The AMEDD is currently sponsoring several initiatives designed to reduce the percentage of casualties that are killed in action. They hope to reduce this percentage by developing new types of units and doctrine that will provide earlier intervention, rapid evacuation and more definitive care at Level II (medical care at the forward medical units). While providing the high quality of care needed to treat the most seriously injured casualties, forward AMEDD units must remain integrated members of the combined arms team. Units must be mobile, agile, and flexible to support current and future Army operations.

One of the AMEDD initiatives designed to reduce the number of soldiers killed in action is the Forward Surgical Team (FST). As currently envisioned, this unit will be able to provide the far forward surgical care needed to stabilize the most seriously wounded casualties prior to evacuation to hospitals outside the combat zone. Although the concept of forward surgery is not new, there are no units in the current Army force structure designed to accomplish this mission. The design of the FST was based upon experiences gained by units that performed similar missions in Panama and Iraq. The FST will be a small, highly-mobile unit capable of providing emergency surgical procedures as far forward as the Brigade Support Area (BSA). The Army Chief of Staff approved the FST concept in 1994, and unit fielding plans are now being developed by the major commands with anticipated fielding dates beginning in Fiscal Year 1997.

B. PURPOSE

The purpose of this thesis is to analyze the effectiveness of the FST by using a simulation model. Currently, no model is available to examine FST operations. A simulation model will provide AMEDD planners and combat developers a means to analyze the FST and gain insight into the factors that affect the FST's capability to perform its mission. A model which will allow medical planners to analyze the effects on forward medical care of such parameters as the number of casualties treated, the casualty arrival rate, and the design of the FST, will be a valuable tool to study the structure of the team and its capability to support various missions.

C. PROBLEM DESCRIPTION

The ability to test the capability of a FST during peacetime is severely constrained by the nature of its mission. The training necessary to treat the types of casualties the FST will see on the battlefield is seldom encountered in peacetime medical operations. Realistic situations in which the FST could perform its surgical mission can not possibly be constructed. Yet the importance of its combat mission necessitates the unit be properly staffed and equipped to function effectively on the battlefield. The approach of this thesis is to construct and analyze, by simulation methodology, a model to examine whether the force structure developed for the FST is adequate to perform its mission. Analyses will also be performed to determine the effect various parameters have on FST performance. The thesis will also examine other data critical to efficient health service support, such as operating table time, patient waiting times, and bed occupancy.

This thesis is the first stochastic model developed to study FST operations. The design of the FST has been based upon historical data and experiences gained by the AMEDD in fielding similar types of units in the past. This model represents the first attempt to incorporate the randomness of medical operations in the analysis of the FST.

D. SCOPE AND LIMITATIONS

The scope of this thesis is limited to modeling forward surgical operations using the mission profile for the FST developed by the AMEDD Center and School (AMEDDC&S). The tactics, techniques, and procedures used by the model to represent FST operations are based upon FM 8-10-25, *Forward Surgical Support.* Types of FST operations not covered in FM 8-10-25 are not within the scope of this thesis.

This thesis emphasizes the development of the FST simulation model using the MedModel simulation software system and its use as a tool to analyze FST operations. The use of this simulation software imposes several limitations on the structure and execution of the model. To capture the data necessary to determine utilization rates, individual resources were created within the simulation to represent each member of the

FST. Any changes in the structure of the FST therefore requires a working knowledge of the software language. Also, resources performing tasks within MedModel can be interrupted and assigned a new task. However, the software does not allow another resource to complete the task; instead it waits until that particular resource is available again. This limits the model's ability to represent actual medical operations, during which procedures are often interrupted in order to perform other, more urgent tasks.

II. EVOLUTION OF THE FORWARD SURGICAL TEAM CONCEPT

A. GENERAL

The mission of the Army Medical Department has remained basically unchanged since the revolutionary war. Its mission is to maintain the health of the Army and to conserve its fighting strength [Ref. 2]. To support this mission, the AMEDD developed five objectives [Ref. 2]. These objectives are:

- Save lives
- Evacuate casualties from the battlefield
- Reduce the incidence of disease and nonbattle injury (DNBI) through preventive medicine programs
- Examine, treat, and return soldiers to duty as far forward as possible
- Provide the utmost benefit to the maximum number of personnel by synchronizing health service support resources

The FST has been developed to help the AMEDD meet two of these objectives. A small, highly mobile team will enable surgical support to be provided much closer to the forward edge of the battle area. This will help to save lives and to reduce the distances evacuation assets must travel with critically injured patients before they are stabilized.

B. BATTLEFIELD SURGERY IN THE 20TH CENTURY

The AMEDD has developed the concept of the FST by examining the methods used to treat casualties throughout all of the wars in which the United States has participated during the 20th Century. In each conflict, the AMEDD identified a need to provide surgical care forward on the battlefield. The methods used to provide this type of treatment varied from conflict to conflict.

1. World War I

As the United States prepared to enter World War I in 1917, advance elements of the Army deployed to Europe to begin coordination with Allied forces. New tactics and procedures the Allies had developed in the three years since the war began were integrated into US Army doctrine. One development discovered by the Medical Department was a new type of unit found in the French service. The unit, called a "groupe complementaire", was a small mobile surgical unit designed to treat seriously wounded casualties close to the front. The success of these units impressed the American Expeditionary Forces (AEF) Surgeon and he requested to the Army Surgeon General that the Army form similar units. In May 1918, the AEF Surgeon published orders, which in part stated, "The developments of modern warfare have necessitated the adoption by the Medical Department of the AEF of two types of mobile sanitary formation which in the French Army are known as auto-chirs and groupes complementaires. These units have been designed in order that facilities for immediate surgical aid to the seriously injured may be brought to the man instead of removing any chance of recovery that the nontransportable wounded have by conveying them an uncertain distance to the hospital." [Ref. 3]

2. World War II

The first medical treatment facility capable of performing surgical procedures was located at the Division Clearing Station, where a surgical element of a supporting field hospital was usually attached. This positioning of surgical assets in the division area was instrumental in saving the lives of many casualties. This was especially evident in operations characterized by extensive maneuver, such as Patton's dash across France, or in operations where evacuation was difficult, such as operations in New Guinea. "Many men, wounded within the hour, were receiving emergency major surgical treatment in these installations. The forward disposition of these elements is responsible in large measure for the ... low mortality rate amongst our casualties." [Ref. 4] While the number of casualties killed in action (KIA) increased from 18% in World War I [Ref. 3] to 21% in World War II [Ref. 4], the number that died of wounds (DOW) was reduced from 9% [Ref. 3] to just 5% [Ref. 4].

3. Korean War

After World War II, the AMEDD established a table of organization and equipment (TO&E) for a 60-bed, mobile surgical hospital (MASH). It was designed to provide surgical care, pre- and post-operative care, pharmacy, x-ray, and patient holding services [Ref. 5]. Generally, the MASH was located 15-20 miles behind the Division rear. The MASH provided a forward location for surgical procedures throughout the war. One of the major problems in medical support during the war was casualty evacuation. Often, the typical litter carry to a wheeled evacuation vehicle took up to six hours [Ref. 5]. One partial solution to the evacuation problem was obtained in 1951, with the arrival of three medical helicopter units. These units teamed up with the MASHs to provide a much quicker surgical response. Later in the war, efforts were made to send surgical teams from the MASH units to the Division Clearing Companies to provide more rapid surgical response. Through these efforts, the number of casualties that died of wounds was reduced to less than 3%, a significant improvement considering the harsh conditions under which the Korean War was fought [Ref. 5].

4. Vietnam War

Forward surgery during the Vietnam War relied on stationary surgical hospitals and rapid aeromedical evacuation. Commenting on the relationship between the surgical hospital and the medical evacuation helicopters, Lieutenant Colonel Thomas Nelson, Medical Corps, stated, "... patients were moved directly from the battlefield either to a clearing station or a nearby hospital ... Most patients arrived at the hospital within 10 minutes of pickup, and some of these were in such critical condition, usually from internal bleeding or respiratory problems, that further evacuation even by helicopter would have been fatal ..." [Ref. 6] The hospital mortality rate for the Vietnam War was 3%, a slight increase over the figure from Korea. This slight increase was a result of a very rapid evacuation system that allowed many critically injured soldiers who would have been KIAs to survive until they reached a hospital. If the number of casualties that died within 24 hours of admittance to the hospital is subtracted, the rate is reduced to just 1% [Ref. 6].

5. Operations Urgent Fury, Just Cause, and Desert Storm

An emphasis on rapid evacuation and quick surgical intervention characterized all three of these operations. Airborne units in Operations Urgent Fury and Just Cause deployed with authorized surgical teams attached to their medical companies. In Operation Desert Storm, most divisional units were not authorized surgical teams. Instead, supporting MASH units and Combat Support Hospitals created ad hoc surgical units that deployed to the forward medical companies. This type of support reduced the percentage of patients that died of wounds to just 0.5% [Ref. 7].

6. Future Concepts

After Operation Desert Storm, the AMEDD conducted a study to develop methods to improve medical support. The study began by conducting an examination of historical casualty figures. The results are provided as Figure 1.

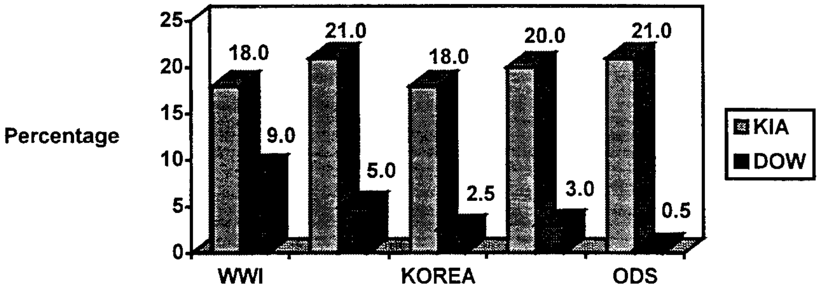

Figure 1. Percentage of Deaths Among US Army Casualties From Ref. [7].

From this data, it was determined that the major focus of future support must be to reduce the number of casualties listed as KIA. Further study indicated that 67% of all casualties listed as KIA die within 10 minutes of wounding [Ref. 7]. However, the remaining 33% die after surviving at least 10 minutes [Ref. 7]. While little can be done to save those that die within 10 minutes, casualties that can survive longer may be saved. Major efforts are now underway to develop methods to save some of the 33%. These efforts include such projects as the combat lifesaver program, blood expanders, and improved evacuation platforms. Another concept being developed that has proved highly successful in previous wars is the forward surgical team.

C. THE FORWARD SURGICAL TEAM

The FST concept and design was approved by the Chief of Staff, Army to compete in Total Army Analysis 2003. The mission, staffing, equipment, and the tactics, techniques, and procedures under which the team will operate have been developed with the goal of saving the lives of the most critically injured soldiers on the battlefield.

1. Mission

The mission of the FST is to provide a rapidly deployable, highly mobile unit capable of performing emergency resuscitative surgery to seriously injured casualties forward in the division area of operations [Ref. 7]. The FST is capable of providing:

- Continuous operations for up to 48 hours, in conjunction with a Level II unit.
- Urgent initial surgery for otherwise non-transportable patients.
- Emergency treatment to receive, triage and prepare incoming casualties for surgery; provide required surgery; and continue post-operative care for up to 20 patients over a period of 48 hours.
- Post-operative care for up to eight patients simultaneously.

2. Personnel

The FST is a 20-person team consisting of three general surgeons, one orthopedic surgeon, two nurse anesthetists, an operating room nurse, a medical surgical nurse, a critical care nurse, and a field medical assistant. Enlisted personnel consist of three practical nurses, three operating room specialists, and four medical specialists. These personnel form two Advanced Trauma Management (ATM) Teams, two operating room (OR) teams staffed for 24 operating room table hours per team, and an eight bed medical-surgical ward. These personnel are capable of performing up to 20 surgical procedures in 48 hours. The FST also has one Medical Service Corps officer and one noncommissioned officer (NCO) to provide administrative support to the FST and act as liaisons to the Medical Company. [Ref. 7]

3. Equipment

The FST is 100% mobile with their organic vehicles. Major items of equipment include lightweight surgical instrument sets, mobile electrosurgical apparatuses, refrigeration units for blood products, and other associated equipment. The FST does not possess lab or x-ray equipment, and relies on the medical company with which they co-locate for this support. The FST is designed to operate in a General Purpose, Large Tent. The FST has an estimated 48 hour supply of expendable medical supplies, after which resupply will be required. The unit has organic communications equipment to facilitate command and control. [Ref. 7]

4. Tactics, Techniques, and Procedures

The FST has been designed to co-locate with the divisional medical companies. The AMEDD has identified that 43 patient conditions (patient types) are candidates for forward surgery. The FST will provide surgical care for these 43 patient types prior to further evacuation. The medical company will provide support for other types of patients. The FST will consist of two ATM stations, two OR tables, and eight medical surgical ward beds. A typical FST operation is provided as Figure 2.

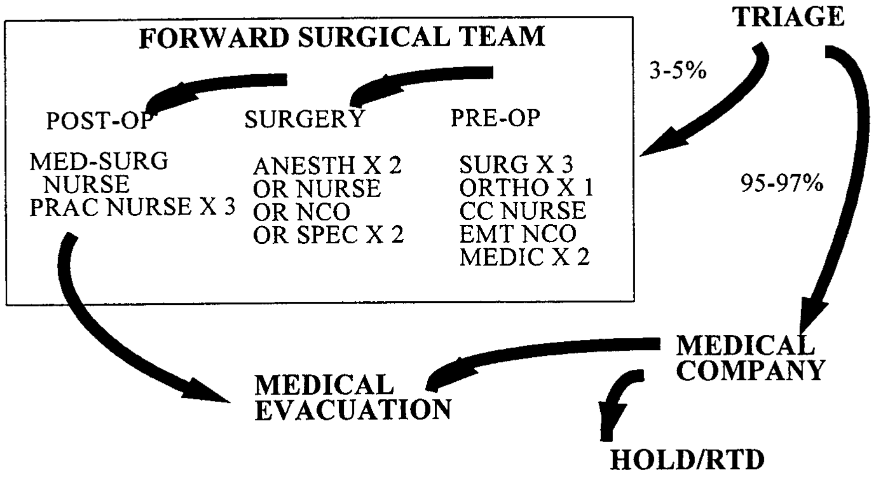

Figure 2. Typical FST Operations After Ref. [7].

D. DATA SOURCES

The primary source of data for this thesis was the Directorate of Combat and Doctrine Development (DCDD) of the AMEDD Center and School. Located at Fort Sam Houston, San Antonio, Texas, the Directorate is responsible for the development of future AMEDD doctrine. The FST is an example of initiatives developed at the AMEDD Center and School designed to support future Army operations.

One of the major data elements in the model is the Time- Task- Treater file of the Deployable Medical Systems (DEPMEDS) database. This database was originally developed to support the standardization of DOD field hospitals in the 1980's. As originally designed, the database contained a listing of patient conditions, medical tasks, medical requirements, estimated times, possible providers, and other information that would be required to treat each patient at a Level III or Level IV medical treatment facility. Using medical personnel with experience in forward surgical operations, the database was modified to include representation of Level II operations. This provides the information necessary to model the types of medical procedures that will be performed by the FST.

The Time- Task- Treater database contains the treatment procedures for each patient condition. Developed by the Army and modified for Joint Service standardization by the Defense Medical Standardization Board, the patient conditions are a listing of the types of patients military medical facilities can expect to treat during a conflict. Currently, there are 322 of these patient conditions. Of these patients, the AMEDD has identified 43 that are candidates for forward surgery. The 43 patient conditions identified for forward surgery are provided in Appendix A. The overall numbers of Army patients are generated by the Total Army Analysis (TAA) model. The data used for this thesis represent output from TAA 1995-2003. The frequency of occurrence for each type of patient is generated by an AMEDD specific model called the Patient Workload Generator Model (PATGEN). This model determines the percentage of battlefield casualties that fall into each of the 322 patient conditions. The patient condition frequencies used in this model are provided in Appendix B.

III. FORWARD SURGICAL TEAM SIMULATION

A. BASICS OF MEDMODEL

MedModel is a simulation software system designed to support the analysis and evaluation of healthcare systems. MedModel is a discrete event simulator created primarily to model discrete event healthcare systems. A model is constructed by creating an arrangement of locations (ATM site, OR table, etc.) to and from which casualties, supplies, or personnel move and are managed according to some type of processing logic. A typical model will include locations (triage, ATM site, etc.), paths for movement between locations (triage to ATM site), entities (casualties), supporting resources (doctors, nurses), processing and routing logic, and arrival information. Once the modelers have a clear understanding of the process they are modeling, MedModel uses a graphical interface to allow users to efficiently define the model. Other elements, such as variables, arrays, and subroutines can be created and referenced during processing logic. An important feature of the software is that it allows the assignment of attributes to entities and locations within the model. These attributes are numeric values directly assigned and associated with each individual system element. [Ref. 8]

B. MODEL DESIGN

The FST model uses the features of MedModel and the concept of forward surgical operations to model the FST. To accurately model FST operations, casualties had to be generated, moved from location to location, and have the required treatment performed. These are all critical components to understanding the design of the model.

1. Structure

The standard elements of the FST model are locations, entities, resources, path networks, and processing. These elements provide the necessary information to allow FST operations to be modeled.

a. Locations

Locations within MedModel are defined as places to which casualties travel to have some type of healthcare processing performed on them. For the FST model, there are 12 key locations. These locations are the two ATM Stations, the two OR Tables, and the eight medical-surgical ward beds. Other locations defined within the model include a triage site, a medical company treatment site, evacuation sites, and sleep areas. The 12 FST locations are all single capacity locations, meaning there can be only one casualty in each area. Other characteristics can be assigned to locations, such as downtimes, types of queues, and number of units. Data such as the number of times casualties enter each location, the time spent at each location, the percent of time each location or resource is in operation, and many other types of information can be collected for each location. Provided in Table 1 is an example of the location definition for the FST model.

Name	Capacity	Units	Statistics	Rules
ATM1	1	1	Basic	Oldest
ATM2	1	1	Basic	Oldest
OR1	1	1	Basic	Oldest
OR2	1	1	Basic	Oldest
Bed1	1	1	Basic	Oldest
Bed2	1	1	Basic	Oldest
Bed3	1	1	Basic	Oldest
Bed4	1	1	Basic	Oldest
Bed5	1	1	Basic	Oldest
Bed6	1	1	Basic	Oldest
Bed7	1	1	Basic	Oldest
Bed8	1	1	Basic	Oldest

Table 1. Example of Location Definition Within the FST Model

In the example provided in the above table, the 12 key FST locations are defined. The names of each location are provided, as well as the number of units of that type and the capacity. In these cases, the numbers of units and capacities are all one. Basic statistics are collected at each location and the rule for entry to the location is the entity that has been waiting longest.

b. Entities

Entities are the casualties created within the model to study the FST. Entities are defined by name within the model and have attributes that assign specific items of information to each casualty. For instance, within the FST model, casualties are assigned attributes such as patient condition, treatment times, and time to spend in post-operative recovery. These attributes can be changed as the model executes, allowing patients to update data as the simulation executes. Entities can also be assigned several types of graphics, allowing icons to change as different conditions are encountered, such as a patient going from a standing position (ambulatory) to lying down on a stretcher (litter).

c. Resources

Resources within the FST model are the personnel and equipment used to transport and treat the casualties. The key resources within the model are the 18 personnel of the FST that provide patient treatment. They consist of three General Surgeons, one Orthopedic Surgeon, one Critical Care Nurse, one Operation Room Nurse, two Nurse Anesthetists, one Medical-Surgical Nurse, three Medical Specialists, three OR Specialists, and three Practical Nurses. Information such as utilization rates, average time per treatment, and times used can all be collected for resources. Resources can be assigned downtimes to represent periods off duty. For this model, each resource is assigned a 16 hour work shift, with 8 hours of rest time. Resources can also be designated to perform healthcare tasks as they enter and exit a location, and several other features. Provided as Table 2 is an example of resource definition in the FST model.

Name	Units	Statistics	Work Search	Park Search	Path	Motion
LitterBearer	4	Summary	Closest	Closest	Casualty_Net	Home: Tent_Ent Full: 50 Empty: 100
Surg1	1	Summary	Closest	Closest	Casualty_Net	Home: ATM1_Rest Full: 100 Empty: 100
Surg2	1	Summary	Closest	Closest	Casualty_Net	Home: ATM1_Rest Full: 100 Empty: 100
Medic1	1	Summary	Closest	Closest	Casualty_Net	Home: ATM1_Rest Full: 100 Empty: 100 (Return)

Table 2. Example of Resource Definition Within FST Model

In the above example, four of the resources used in the model are defined. The first resource, defined as Litter_Bearer, consists of four units that move along the Casualty_Net path. Summary statistics are collected and the resource will search for entities that are closest to it to perform required tasks. The resource home is the Tent_Ent, which is the location the resource will go to if not performing any other task.

Also listed is the speed at which the resource travels, both empty and when carrying a casualty, in feet per minute.

d. Path Networks

Path networks within MedModel are the routes on which resources and entities travel during the simulation. In the FST model, there are routes for the evacuation vehicles and routes for the casualties as they are unloaded from ambulances. Casualties travel along the routes by litter bearers to locations indicated by processing logic within the model. These path networks interface with locations within the model to allow entities and resources to move along paths and execute logic at locations. Provided as Table 3 is an example of a path network in the FST model.

Name	From	To	BI	Dist/Time	Speed Factor
Casualty_Net	Drop_Off	Triage_Site	Bi	35.50	1
	Triage_Site	N4	Bi	68.62	1
	Tent_Entrance	N4	Bi	18.00	1
	ATM_Site1	ATM1_Rest	Bi	20.00	1
	N4	ATM_Site2	Bi	18.02	1
	N4	ATM2_Rest	Bi	23.02	1
	Tent_Exit	Evac_Out_Pick_Up	Bi	18.38	1
	Med_Co	Triage_Site	Bi	45.61	1
	Tent_Exit	Triage_Site	Bi	76.83	1
	Triage_Site	N1	Bi	120.72	1
	N2	Tent_Entrance	Bi	63.93	1

Table 3. Example of a Path Network in the FST Model

This table describes portions of the path network Casualty_Net. This network is the primary path through the model. The Table lists the locations the path connects, the distance between locations, and whether travel is uni-directional or bi-directional.

e. Processing

Processing is the logic within the model which defines the operations and routing for each casualty at a location. An example of the processing logic for a casualty at the triage site is provided as Table 4.

```
path=0
^ N(5,2)
Time_In = clock(min)
if pc=999 then Route 4
else if ATM1_Full = 0 and
FreeUnits(Surg1)=1 then begin
   Inc ATM1_Full
   Route 1
end
else if ATM2_Full=0  then begin
   Inc ATM2_Full
   Route 2
end
else if ATM1_Full=0 then begin
   Inc ATM1_Full
   Route 1
end
else
   Route 3
              Routes
1  Casualty                ATM1     FIRST 1    USE LitterBearer
2  Casualty                ATM2     FIRST 1    USE LitterBearer
3  Casualty                Bed7     FIRST 1    USE LitterBearer2
   Casualty                Bed8     FIRST      USE LitterBearer2
   Casualty                MedCo    FIRST      USE LitterBearer
4  Casualty                MedCo    FIRST 1    USE LitterBearer
```

Table 4. Processing Logic for Triage Site

At this site, the path attribute is initialized to zero, later this attribute will be used to determine which treatment teams are providing medical care. The casualty then waits at the triage site for approximately five minutes while medical personnel determine to which patient condition category the casualty belongs. Another attribute is assigned which is the simulation time at which the casualty enters the treatment system. If the casualty is not a surgical patient, the casualty moves along route 4 by litterbearer to the Medical Company. If the casualty is a surgical patient, the first ATM location is checked to see if it is occupied and the treatment team is available. If the location is unoccupied, the casualty moves along route 1. If ATM1 is occupied, ATM2 is checked and if unoccupied the casualty moves along route 2. If ATM2 is occupied, another check of ATM1 is made, and in this case if the location is unoccupied, the treatment team is off duty and the casualty moves to ATM1 and the team is recalled. If none of these conditions are met, then both ATM stations are occupied and the casualty moves along route 3 to one of the three overflow locations, Bed7, Bed8, or the Medical Company.

This is one example of the processing logic at a location. Each location has specific processing logic depending upon the tasks performed at that location.

2. Casualty Generation

Two of the most critical factors affecting the performance of the FST are the number of casualties that arrive in a given day and the arrival pattern of the casualties. These two factors will have a significant impact on the ability of the FST to perform its mission of prompt surgical intervention for the most seriously injured casualties.

a. Arrivals

The number of casualties that arrive at a medical treatment facility within a day is dependent upon many factors. Since this study is concerned with the treatment of casualties wounded in action, a primary factor affecting this will be how heavily the unit is engaged. For the purpose of this thesis, engagements will take place during a 48 hour time period, beginning at 2400 hours. Personnel loss rates for US Army units are estimated using tables published in Army manuals such as Field Circular 101-5-1, *Staff Officers Handbook.* This publication estimates that casualties for a unit attacking a defensive position will be between 3.8% and 6.3%. Of these casualties, 70% will be wounded in action. These figures will be used to determine the number of patient arrivals to be generated for the simulation. [Ref. 9]

The FST is designed to be capable of operating for a 48 hour period under peak workload conditions. After 48 hours, the team would be replaced with another surgical unit. To ensure the study analyzes FST operations under the least favorable conditions, the model assumes the number of casualties generated during the two days are approximately equal. The number of arrivals is based upon the figures for a brigade attacking a prepared defensive position. In actual operations, the number of casualties over a two day period will likely decrease the second day, as primary defensive positions are overrun.

b. Arrival Rate

The rate at which casualties will arrive at the FST will be dependent on many factors. Such factors may include the intensity of the engagement the supported unit is involved in, the availability of medical evacuation assets, terrain, weather, and many others. Since the FST is limited to performing only two surgical procedures at a time, the rate at which surgical patients arrive will be critical to analyzing the effectiveness of the FST.

The method the model uses to manage arrival rate is the construction of an arrival cycle. An arrival cycle is a defined pattern of casualty arrivals which occurs over a 24 hour time period. The percentage of casualties that arrive during each two hour period is used to create an arrival cycle table, which will be the basis for the distribution of arrivals for each of the two 24 hour periods the model simulates.

c. Patient Types

The patient types used in the model are based upon patient criteria and patient conditions developed by the AMEDD Center and School. A panel of subject matter experts met in 1987 and choose 43 of the 322 patient conditions as candidates for forward surgery. The criteria used to choose forward surgery candidates were:

- Acutely deteriorating level of consciousness with closed head injuries
- Despite Level II advanced trauma management:
    - Blood pressure equal or less than 90 mmHg systolic
    - Pulse equal to or greater than 120 per minute
    - Respiratory distress
- Visible or suspected continued significant active bleeding
- Rigid abdomen with or without distention
- Significant mortality expected at level II treatment facilities.

The data generated by the Patient Workload Generator Model consist of a finite number of patient conditions together with the probability of obtaining each outcome. The patient conditions and frequencies can then be represented by a probability mass function from a discrete distribution. The probability mass function can then be used within the model to form a distribution table consisting of the 44 possible patient conditions (43 types of surgical patients and all others) and the probability of obtaining each.

3. Casualty Movement

Casualty movement within the model is by ambulance or litter bearer. Casualties arrive at a triage site within the Forward Support Battalion Medical Company. At the triage site, it is determined whether the casualty is a surgical candidate or not. If not, the casualty is transported by litter bearer to the Medical Company. If the casualty is one of the 43 patient conditions requiring surgery, the patient is transported by litter to the FST. If both FST ATM or OR sites are occupied, the patient is transported to the medical-surgical ward. There are two overflow beds on this ward. If both of these beds are full, the patient is sent to the medical company. When an OR table becomes available, the longest waiting casualty is transported to the FST ATM site. After post operative treatment in the medical surgical ward, the patient exits the simulation by ambulance.

To model casualty flow through the FST, a series of locations were created within the model. The 12 primary locations were two ATM stations, two operating room tables, and eight medical-surgical ward beds. The model's representation of the FST is provided as Figure 3.

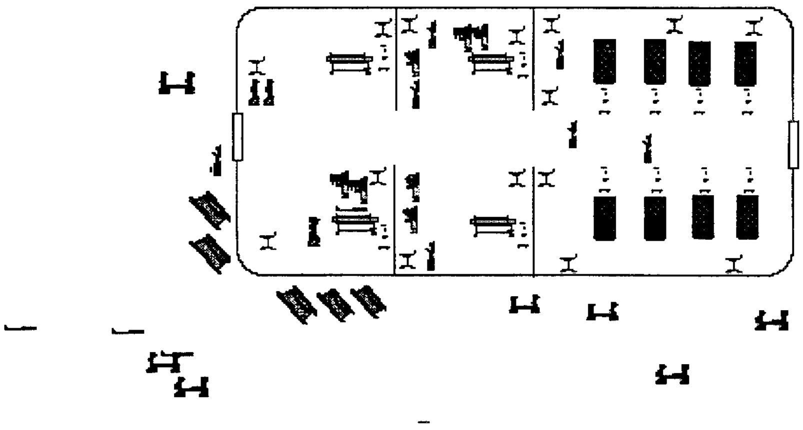

Figure 3. Screen Capture of the FST Model

The casualty flow through the model is similar to the movement described above. Each of the 12 primary locations have a capacity of one patient. The two ATM sections and two operating rooms have attributes which indicate whether the treatment team is occupied, which prevents casualties from being sent to locations where providers are not available.

4. Casualty Treatment

Casualty treatment in the model is based upon modifications made to the DEPMEDS Time-Task-Treater database. This database provides a listing of each task that must be conducted for each type of patient. The database also contains the average time each task is expected to take and personnel required to perform each task. Appendix C contains a listing of the tasks that the FST will perform during treatment of the 43 patient conditions. These tasks are grouped by functional area (ATM, OR, Medical-Surgical Ward) and further grouped into subsets of tasks that can be performed simultaneously. An example of a task grouping is provided as Table 5.

PC	Site	Task	Task Description	Time	Treater
163	ATM	002	Assessment of Patient Status	2	Nurse, Medic
163	ATM	010	Neurological Assessment	3	Nurse,Medic,MD
163	ATM	061	IV Infusion Medications	5	Nurse, MD
163	ATM	062	IV Infusion Blood	8	Nurse
163	ATM	071	Insert NG Tube	7	Nurse, Medic
163	ATM	079	Catheterization, Foley	4	Medic, Nurse
163	ATM	126	Seizure Care/Precautions	3	Medic, Nurse
163	ATM	145	Administer Medications	3	Medic, Nurse
163	ATM	165	Request Diagnostic Study	2	MD

Table 5. Example of Task Grouping

Each member of the FST is designated within the model as a resource. A resource within MedModel is defined as a person, piece of equipment, or some other object that is used to perform some type of processing logic at a location. Each member of the FST can then be designated to perform the specific tasks contained within a treatment group. The mean treatment times are represented within the model as normal random variables with the task time as the mean and the standard deviation as 10% of the mean. For example, the processing logic in Table 6 is an example of the logic required to perform the task grouping in Table 5.

Get Medic, Doctor, and Nurse	# This commands gets the required resources
Wait Normal (10,1)	# This command occupies each resource for the specified time.
Free Doctor	# The Doctor has completed Tasks 010,061,165
Wait Normal (3,.3)	# This command continues to occupy the Medic and Nurse
Free Nurse	# The Nurse has completed Tasks 002,062,126
Wait Normal (1,.1)	# This command continues to occupy the Medic
Free All	# This command frees the Medic, who has completed Tasks 071,079,145. This completes the treatment group

Table 6. Example of MedModel Code for Casualty Treatment

For the 43 types of surgical patients, there are over 350 different tasks. Each patient requires over 100 tasks to be performed during his treatment. Appendix D is an example of the information in the Time- Task- Treater file for one patient condition.

C. MODEL INPUT

The user is prompted to enter information on two of the model parameters. The first required input is the expected number of casualties. The user is prompted to enter the mean and standard deviation that will be used to generate a normal random variable. This will be the number of arrivals for each 24 hour period. The second input required is the arrival distribution that will be used. The user is required to enter the percentage of casualties that will arrive over each two hour segment of the day. It is critical that the time intervals sum to 24 hours and the percentages sum to 100.

D. MODEL EXECUTION

After the input parameters are entered, the simulation is ready to execute. The simulation will generate casualties for 48 simulation hours, and will terminate when the last patient exits the system. During the simulation, the operations of the FST will be graphically represented on the monitor. From the animation, the user is able to obtain a clear understanding of casualty flow within the model. Movements of casualties and resources along the path networks are represented by the movement of icons across the screen.

During the 48 hour period, each FST team member will be on duty for 32 hours and off duty for 16 hours. If during these off duty periods another casualty arrives, the off duty team will respond.

E. MODEL OUTPUT

The output of the model is stored in two locations. The first is the output module within MedModel. Within this module, the user can find the utilization of each member of the FST and also the utilization of each location within the FST. It also provides other data on variables, locations, entities, and resources.

The second output location is a data file that can be read into any statistical program or spreadsheet. This file gives the entry and exit time for each surgical patient, the ATM time, OR time, post-operative time, and the time waiting for surgery if both teams are busy. This output can then be used to perform further statistical analysis of the model results.

IV. SIMULATION ANALYSIS

A. ANALYSIS

The use of a stochastic model to represent FST operations is a valuable tool that can be used to perform many different types of analysis. The primary goals of this thesis was to construct a model of FST operations that could be used for three purposes. One purpose was to develop a stochastic model that could be used to estimate the operating room usage of forward surgical patients. This figure is often used as a basis for personnel authorizations, medical resupply figures, and medical evacuation planning. The second goal of the thesis was to determine the factors which have the most significant impact on FST performance. Key factors were varied to determine the sensitivity of the model to different parameters. The two parameters used for the analysis were the casualty arrival distribution and the total number of casualties. These two parameters are often the key factors in determining whether a medical unit is capable of continuing to provide quality healthcare under extreme circumstances. The third goal of the analysis was to determine if the currently envisioned design of the unit is the most efficient. To determine this, the effectiveness of six different FST configurations was analyzed.

Several assumptions were made concerning FST operations. These assumptions included:

- The FST was capable of performing 48 hours of continuous operation without resupply.
- Personnel assigned to the FST were capable of performing duties 16 hours per day, at a minimum, without any performance degradation, for the 48 hour period.
- Patient acuity remained unchanged for up to six hours, at which time the casualty died.
- Medical evacuation was not constrained by a lack of resources.

B. MEAN OPERATING ROOM TIMES

The mean operating table time is an important factor to medical planners. This factor is often used as a basis for personnel, equipment, and other requirements. However, the times required to perform the necessary types of medical procedures on individual patients vary. To ensure adequate resources are available, especially time sensitive requirements such as oxygen, the entire range of possible OR times must be considered.

1. Experimental Design

To compute the mean OR time for each of the 43 patient conditions supported by the FST, operating room times were recorded during each replication. The patient condition distribution tables within the model were modified to increase the numbers of surgical casualties. Since OR time is not affected by any other events in the model, this modification did not change the result. Data were collected on each of the 43 patient conditions until at least 15 samples were obtained for each condition.

2. Results

The mean, median, standard deviation, and standard error of the mean for the 43 patient conditions is provided in Appendix E. Also provided in Appendix E are the minimum and maximum values and the first and third quantiles for each patient condition. Figures 4a, 4b, 4c, and 4d are box plots of the OR times for each patient condition. The boxplot consists of a box, which represents the 1st and 3rd quantiles, a line drawn through the box representing the median, outliers represented by asterisks, and whiskers that define values within the region defined by the following limits:

Lower Limit: $\text{Quantile}_1 - 1.5\,(\text{Quantile}_3 - \text{Quantile}_1)$
Upper Limit: $\text{Quantile}_3 + 1.5\,(\text{Quantile}_3 - \text{Quantile}_1)$

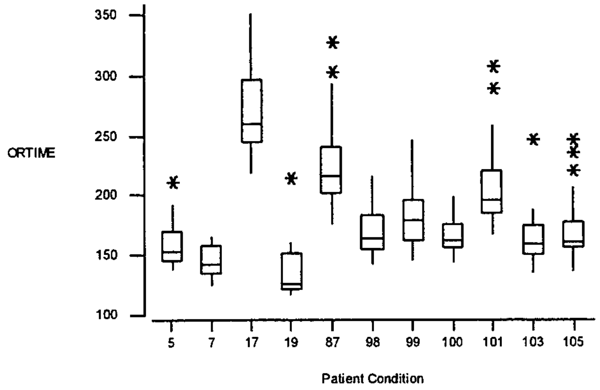

Figure 4a. Boxplots of Patient Conditions 5 through 115
Operating Room Time (in Minutes) Versus Patient Condition

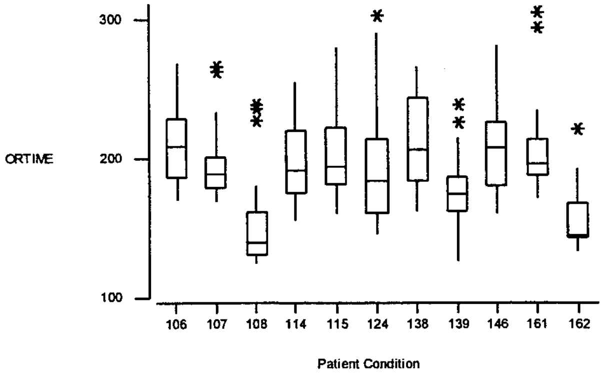

Figure 4b. Boxplots of Patient Conditions 106 through 162
Operating Room Time (in Minutes) Versus Patient Condition

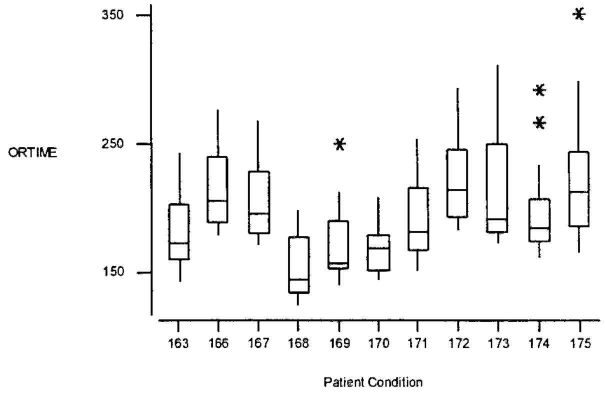

Figure 4c. Boxplots of Patient Conditions 163 through 175
Operating Room Time (in Minutes) Versus Patient Condition

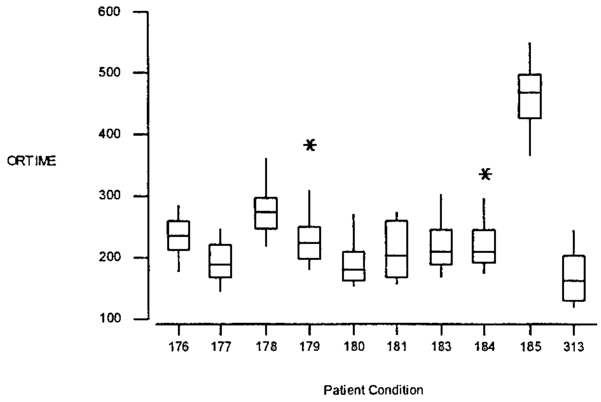

Figure 4d. Boxplots of Patient Conditions 176 through 313
Operating Room Time (in Minutes) Versus Patient Condition

This data indicates that the mean OR times for forward surgical patients range in value from a minimum of just under 120 minutes to a maximum of over 540 minutes. The mean times for the OR procedures range in value from 136 minutes to 460 minutes. Standard deviations are generally between 20 and 30 minutes. These figures indicate a high degree of variability between different types of surgical patients, and not much variability within a single type.

C. EFFECTS OF CHANGES IN CASUALTY ARRIVALS AND ARRIVAL RATE

Two factors that will have a significant impact on the effectiveness of the FST will be the pattern by which casualties arrive and the number of casualties treated. Since the FST is limited to two OR tables and the severity of the casualties require extensive treatment times, the arrival of more than two surgical patients within several hours severely taxes the team's resources. This part of the analysis will examine the affects of arrival patterns and number of casualties on FST operations.

1. Arrival Rate Fluctuations

The rate at which surgical patients arrive at the FST seriously impacts the waiting time of casualties. The distribution of arrivals at a forward medical unit throughout a 24 hour period is not well known. Although there have been extensive studies of casualty arrivals over the course of a campaign, the arrivals of casualties over the course of a 24 hour period has not been studied.

a. Experimental Design

To evaluate the effect of changes in the arrival rate on the FST, three types of distributions were chosen. The response variable was the average number of patients that waited more than 120 minutes for surgical care to begin. This figure is the clinically determined threshold for degradation at this level of care. The number of casualties that arrived per day at the Forward Support Battalion Medical Company was 100 and the patient condition distribution table generated by PATGEN was used for all replications. The expected number of surgical patients per day using these figures was 3.76. Each run represented a 48 hour time period.

The first distribution used in the model was the uniform distribution. Casualties arrived at the FST according to the distribution shown in Figure 5.

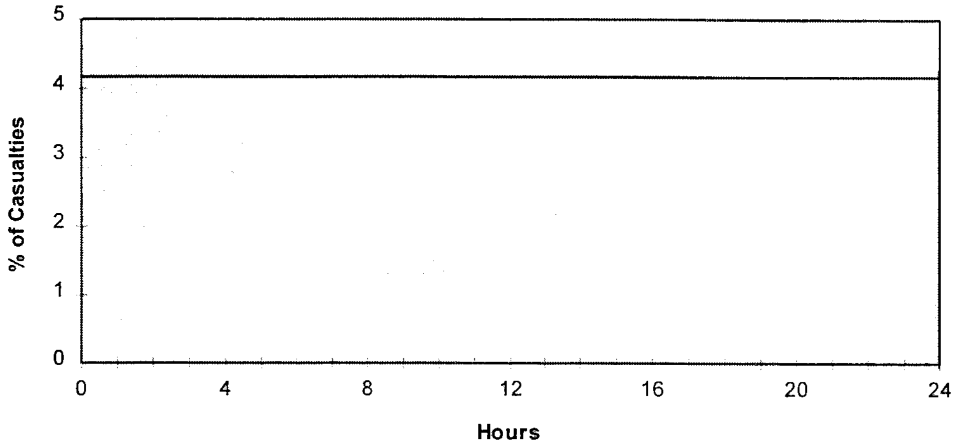

Figure 5. Uniform Arrival Rate of Casualties

This distribution represents an arrival pattern in which casualties arrive uniformly throughout the day. Using the MedModel arrival cycle table, this equates to 4.1667 percent of casualties arriving randomly throughout each hour.

The next distribution was a bimodal distribution. This distribution is often used to represent daily casualty arrival rates. Figure 6 is plot of the distribution.

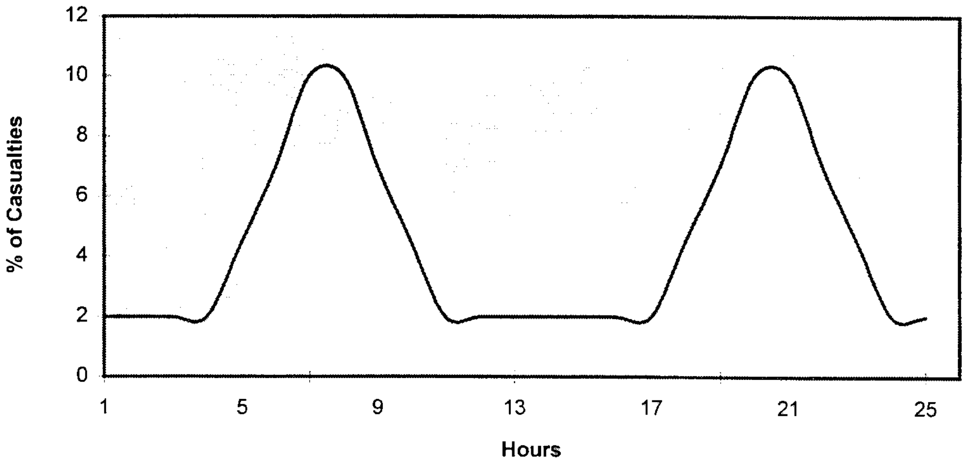

Figure 6. Bimodal Arrival Rate of Casualties

This distribution is commonly used in analysis done by the AMEDD. This distribution represents arrivals over a 24 hour period and is based upon historical casualty arrival patterns. Medical records from previous conflicts indicate that casualties wounded in action arrive at medical units during two peak time periods. This is due to the tendency of forces in the past to fight many battles at dawn or dusk. This allowed attacking forces to take advantage of natural lighting conditions and other factors. This results in the twin peaks of casualty arrivals centered around 0600 hours and 1800 hours.

The final distribution used for the analysis is pictured in Figure 7.

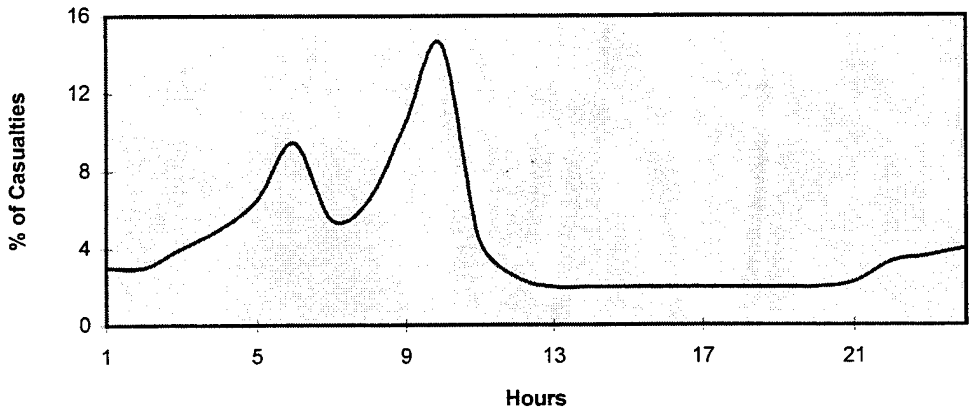

Figure 7. Baseline Arrival Rate of Casualties

This distribution was developed based on the US Army's transition to AirLand Battle doctrine. To take advantage of superior night fighting capabilities, US Army tactics have changed . The preferred time to engage enemy units today is during the hours of darkness. Most engagements fought by US Army units at the National Training Center at Fort Irwin, California, take place between 0200 hours and 0600 hours. Medical evacuation vehicles are used to evacuate casualties as the battle progresses, which is represented by the first peak in Figure 7. As the engagement ends and both sides begin rearming, refueling, and clearing the battlefield, non-medical vehicles are used to transport casualties. This is represented by the second, higher peak two to four hours later. This distribution may most accurately reflect casualty arrivals using current US Army doctrine. *This distribution will be used as the baseline distribution throughout much of this study.*

To compare the three systems, a paired-t confidence interval is constructed using

$$\overline{Z}(n) \pm t_{n-1,1-\alpha/2}\sqrt{\mathrm{Var}\left[\overline{Z}(n)\right]} \qquad (4.1)$$

an approximate 100(1-α) percent confidence interval. It is possible to compare each system and quantify the significant differences this way. Since the number of observations for each variable is 100, the use of the normal distribution is justified regardless of the underlying distribution of Z. [Ref. 10]

b. Model results

Provided as Appendix F are the means, medians, standard deviations, and standard error of the means of the average number of casualties that waited longer than 120 minutes for treatment. Also shown is a table containing the minimum, maximum, and 1st and 3rd quantiles of the results. The data shown in Appendix F indicate that extremely long waiting times occur with equal frequency when using the uniform or bimodal distribution. The mean values for each are 1.12, which is slightly lower than the mean of the baseline distribution. All of the means show significant variability, as indicated by the standard deviations of each. A graphical representation of this data is provided as boxplots in Figure 8.

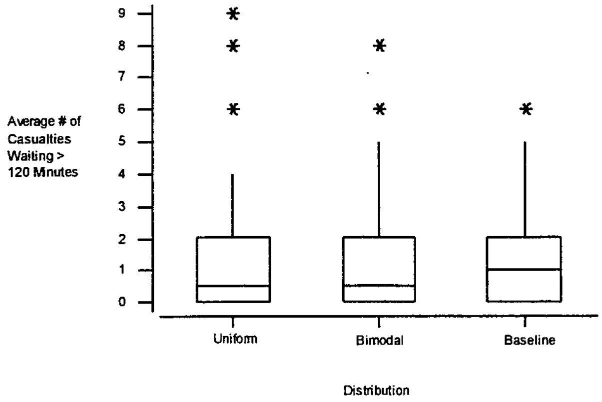

Figure 8. Boxplots of Arrival Distribution Data

The boxplots show the similarity between the results obtained for the uniform and bimodal distributions. The medians for the uniform and the bimodal distributions are equal, while the baseline median is twice as high. The values for the first and third quantiles are the same for each distribution. All of the mean values are highly variable, and each case contains data points outside the expected range.

Using equation 4.1 to construct paired-*t* confidence intervals yields the results provided in Appendix F. These results indicate that for 100 replications there is no statistically significant difference between the three arrival distributions used for the analysis. Although the values for the mean of the uniform and bimodal distribution are different from the baseline distribution, it is not significant at the 95% confidence level.

Appendix F also contains the mean and standard deviation for the percent operation for each of the critical locations in the model using the three arrival distributions. Percent operation is defined as the percentage of time that a casualty was processing at that location. These values are similar for all three of the distributions analyzed. In all three cases, six medical surgical ward beds would have been sufficient to handle the casualty workload. The use of beds 7 and 8 as overflow beds are also evident. The operating room table utilization, an important factor for medical planners, was similar in all cases, with values approaching 20% for OR table 1 and approximately 15% for OR table 2.

Appendix F also contains the percent in use for each member of the FST. Again, similar figures were obtained for all three distributions. The highest percentages were for the four physicians, who are involved throughout the treatment process. Values for the other members of the team varied greatly. The low figures for the practical nurses may indicate the medical surgical ward is overstaffed. The operating room personnel have the heaviest workloads, with the percent in use ranging from approximately 13% to 22%.

2. Arrivals

The total number of casualties that arrive at a medical unit in a 24 hour time period seriously impacts the effectiveness of the unit. As more casualties arrive, the ability of the unit to provide prompt, efficient care is degraded. This analysis will examine the effect of an increase in the total number of casualties treated by the FST.

a. Experimental Design

To test the effect that the number of arrivals has on the FST, an experiment was conducted varying the number of arrivals. Again, the response variable was the average number of patients that waited more than 120 minutes. Again, this figure is the maximum amount of time physicians feel a surgical patient can wait at this level of care before the surgical procedure begins without experiencing a significant increase in mortality and morbidity. During this waiting time, the patient is receiving ATM care from other members of the FST. The number of arrivals used in the experiment were 10, 20, 40, 60, 80, 100, 120, 140, and 160 casualties per day. Thirty replications were conducted at each level. The objective of the experiment was to examine the effect of the number of casualties on waiting time and to determine if a relationship exists between the parameter and the response variable; if a relationship does exist between waiting time and the number of arrivals, to determine an equation that could estimate the average number of casualties that waited greater than 120 minutes for surgery based upon arrival numbers.

b. Model results

Provided in Appendix G are the results of the experiment at each level. The information includes the mean, median, standard deviation, and standard error of the mean for the varied number of casualty arrivals. Also found in Appendix G are the minimum, maximum, first and third quantiles.

The mean values of the response variable indicate a steady increase as the number of casualties exceeds 40. The standard deviation also increases as the casualty workload increases. Boxplots of the data are provided as Figure 9.

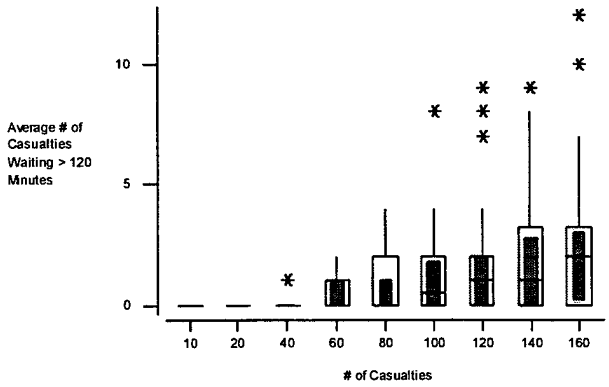

Figure 9. Boxplots of Average Number of Casualties Waiting Greater Than 120 Minutes Versus Number of Casualties

The boxplots again indicate that as the number of casualties increases beyond 40, the mean and standard deviation of the response variable increases. The FST is essentially a 2-server system, therefore as the number of arrivals increases, so does the probability that no server will be available when a new casualty arrives. This accounts for the increase in both the mean and standard deviation. To determine if there is any relationship between the response and predictor variable, a plot of the mean versus the number of casualties can be constructed. A scatter plot of the average number of casualties waiting greater than 120 minutes versus the number of casualties is provided as Figure 10.

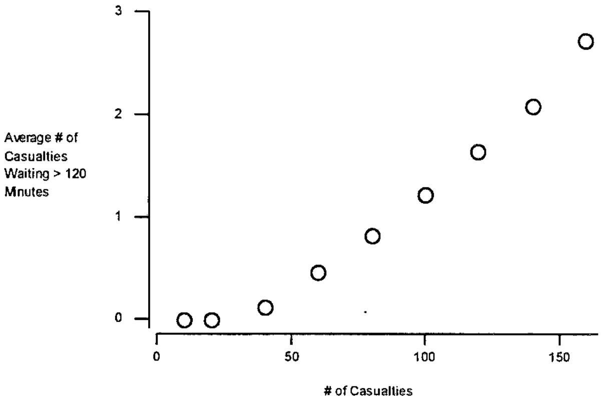

Figure 10. Scatter Plot of Average Number of Casualties Waiting Greater Than 120 Minutes Versus Number of Casualties

This plot indicates that a relationship between the response and predictor does exist. The scatter plot indicates that a simple linear regression model is not appropriate for this data. If the standard linear regression model is expanded by the addition of terms that are powers of the predictors, a polynomial regression model can be used. The model used to fit this data is

$$Y = \beta_0 + \beta_1 X + \beta_2 X^2 + \varepsilon$$

where Y = the average number of casualties waiting greater than 120 minutes
β_0 = intercept
β_1 = slope, rate of change in Y for a unit change in X
β_2 = slope, rate of change in Y for a unit change in X^2
X = predictor variable, number of casualties
X^2 = predictor variable, (number of casualties)^2

To fit this model, several assumptions must be made. The first assumption is that the errors, represented by ε, are independent. Another assumption is that the expected value of the errors is zero with constant variance equal to σ^2. This type of polynomial model can then be used as an approximation for the number of casualties that must wait for treatment.

The regression analysis and analysis of variance tables for the model are given in Appendix G. The t-ratios and the associated p-values indicate the X and X^2 are significant predictors. The estimated standard deviation about the regression line is 0.05333. The adjusted R^2, coefficient of determination, value for the model is 99.7%. This implies that 99.7% of the variability in the observed values of the response variable is explained by the predictor variables.

The analysis of variance table provides an F-test statistic that tests the hypothesis:

NH: $Y = \beta_0 + \varepsilon$

AH: $Y = \beta_0 + \beta_1 X + \beta_2 X^2 + \varepsilon$

The large value of the F-statistic provides evidence against the null hypothesis in favor of the alternate hypothesis. This indicates support for the quadratic model. A lack of fit test can be conducted using the residual sum of squares, which in this case is 0.0171. The lack of fit test produces a p-value > .1, indicating there is no evidence of a lack of fit of the model to the data. [Ref. 11]

Figure 11 is a plot of the fitted regression line.

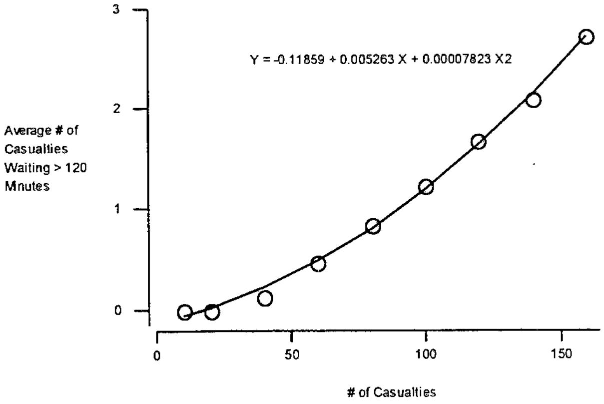

Figure 11. Plot of Fitted Regression Line

As can be seen in the fitted regression line, the quadratic model provides a good estimation of the data. The equation for the fitted regression line is given by

$$Y = -0.11859 + 0.005263\ X + 0.00007823\ X^2 \qquad (4.2)$$

Residuals, the differences between the observed and fitted values, are often used to assess the quality of fit of a model. Residual plots graphically illustrate whether the assumptions of normally distributed errors with constant variance have been met. Provided as Figure 12 is a residual plot of the regression. The figure includes a normal probability plot, a histogram of the residuals, a plot of the individual observations, and a plot of the residuals versus fits.

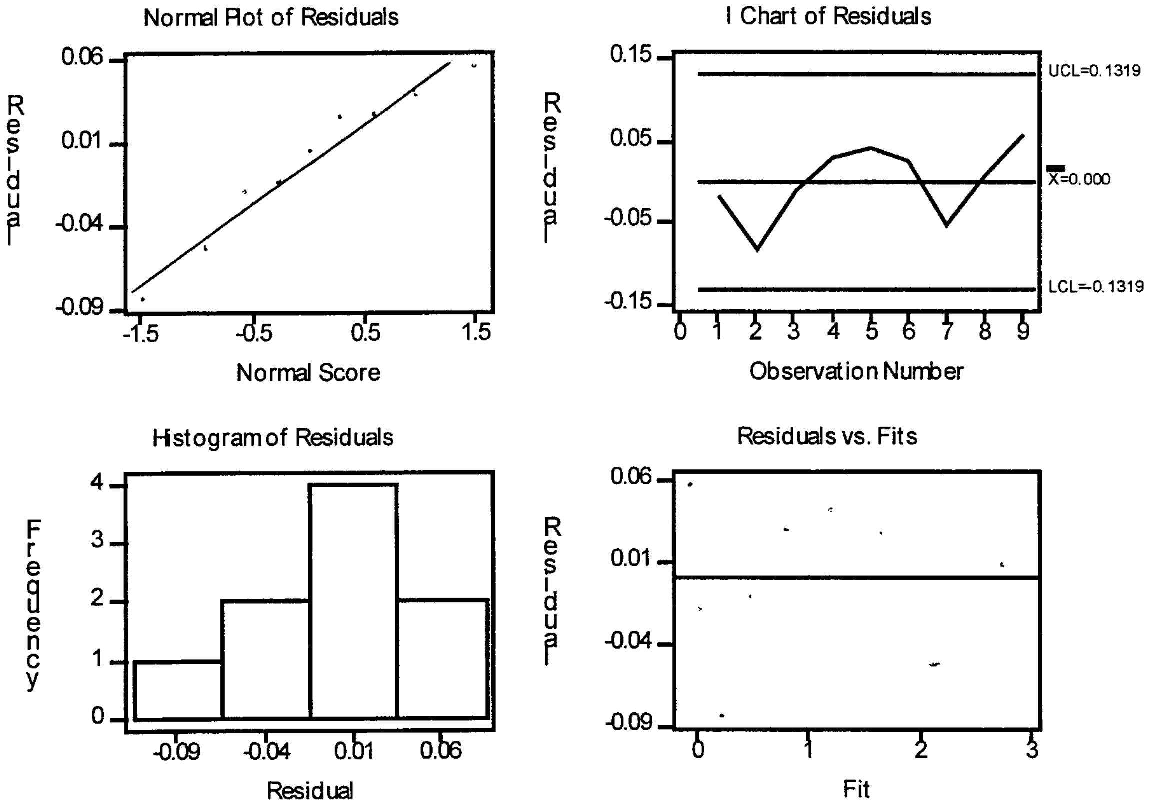

Figure 12. Analysis of Residuals

The residual plots indicate no evidence of a lack of fit of the model to the data. The residuals versus normal score is a plot of the ordered observations against their expected value, if the underlying distribution of the observations is normal. The plot can be approximated by a straight line, indicating normality. The histogram also indicates the residuals are normally distributed. The I chart of residuals and the residuals versus fit plot indicate a randomness in the residuals, with scatter about the value 0. This indicates that the variance of the errors is constant and does not depend on the predictors.

D. EFFECTS OF CHANGES IN THE TABLE OF ORGANIZATION

The final part of the analysis was to determine the effects of changes in the Table of Organization and Equipment (TO&E). There were five different configurations that were compared to the FST as it is currently structured. The first modification was the elimination of the physician support personnel from one ATM Section. This reduced the FST by two personnel, one EMT NCO and one medical specialist. The second configuration was the elimination of one OR Section. This reduced the FST by three personnel, one nurse anesthetist, one OR NCO, and one OR specialist. The third configuration was the deletion of two practical nurses from the medical-surgical ward. The fourth configuration reduced the FST by one ATM Section and one OR Section. This reduced the FST by five personnel, one EMT NCO, one medical specialist, one anesthetist, one OR NCO, and one OR specialist. The final configuration was to reduce the FST by 50%, eliminating two physicians, one EMT NCO, one medical specialist, one anesthetist, one OR NCO, one OR specialist, and two practical nurses. By comparing these modifications to the FST as it is currently configured, insight can be obtained into the correctness of the team's structure.

1. Experimental Design

The baseline arrival distribution was used for the experiment. One hundred casualties arrived per 24 hour period, and each replication consisted of a 48 hour run. The patient condition table generated by PATGEN was used for all the runs. The expected number of surgical patients generated was 3.76 per day. These parameter settings most closely approximate the conditions expected on the battlefield by medical planners.

The response variable used was the average number of patients waiting longer than 120 minutes for surgery. One hundred replications were run for each configuration.

2. Model Results

Provided as Appendix H are the results of 100 replications for each of the six TO&E configurations. Included are the mean, median, standard deviation, and the standard error of the mean for each of the six TO&E configurations. The appendix also includes values for the minimum, maximum, and the first and third quantiles.

A boxplot of the data is provided as Figure 13. As can be seen from the figure, the data for five of the configurations are similar. The 1st quantiles and the 3rd quantiles are the same for the full FST and the FST with only one OR Section.

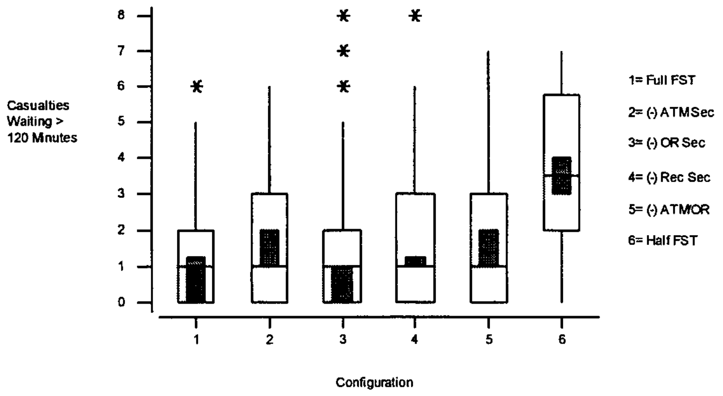

Figure 13. Boxplots for each of the Six TO&E Configurations

To test the hypothesis that the means of the six systems are the same, pairwise comparisons between the systems were made constructing the paired-*t* confidence intervals using equation 4.1. The results of the pairwise comparisons are provided in Appendix H.

The results of the test indicate that for 100 replications there is a statistically significant difference between the half FST and all the other configurations. The FST minus one ATM Section and one OR Section also differs significantly from the full FST. All other comparisons indicate there is not a statistically significant difference between the configurations. These results indicates that if waiting time is a key factor in determining the structure of the FST, alternate configurations should be considered that would reduce the size of the FST.

Also provided in Appendix H is the percent operation for the key locations in the model for each of the six configurations. The figures for the ATM Stations are consistent throughout the six configurations, with values between 10% and 12%. The values for beds 7 and 8 are also similar in five of the six configurations, with only the values for the half FST significantly different. This indicates more casualties must wait for treatment. This also explains the similarity in ATM station figures, for casualties in the half FST are having many of the ATM tasks performed in the overflow beds. The percent utilization of the operating room tables increases from approximately 15% -20% when two tables are available to over 30% when only one table is available. Again, results indicate that the number of medical surgical beds could be reduced.

Appendix H also provides the percent in use figures for each member of the FST for the six different configurations. The use rates for each of the team members varies between the six configurations, but use rates never exceed 40% in any configuration.

V. CONCLUSION AND RECOMMENDATIONS

A. CONCLUSION

The mission of the Army Medical Department has remained unchanged since the Revolutionary War. The success of the AMEDD has depended upon the ability to adapt medical operations to changing military doctrine. To support the rapid maneuver and nonlinearity of the modern tactics, the AMEDD has designed teams capable of providing immediate, lifesaving surgery to casualties far forward on the battlefield. The addition of the FST to the Army force structure provides a capability that will save the lives of seriously wounded casualties. The types of casualties the FST has been designed to treat requires a team that is highly mobile, survivable, and properly staffed to provide prompt, emergency medical services. The design of the team is therefore critical to the success of the mission.

The purpose of this thesis was to develop a model, using simulation methodology, of the FST. This model would provide medical planners with an ability to examine FST operations and the effects various parameters have on the FST. The mission of the FST and the types of casualties it is designed to treat are not reproducible in peacetime operations. Alternate methods must be developed to ensure the FST is adequately staffed and equipped to perform its critical mission. The simulation model provides analysts and force development personnel a tool to help analyze such critical questions as: "Is the FST adequately staffed to perform its mission?" and "How do changes in casualty arrival patterns affect FST operations?".

The model developed for this thesis provides a tool which allows the user to input the expected number of casualties and how they will arrive at the FST. Using the output of the model, various team configurations can be compared to determine the optimal design of the team. The model can also be used to provide insight on medical support of different types of operations. The output could be used to determine evacuation requirements or whether additional surgical assets are required.

The simulation results indicate that operating room times for FST patients are highly variable. The use of the mean operating room time to determine staffing levels and equipment requirements may not ensure the FST is always prepared to perform its mission. When determining the need for such time sensitive items as oxygen, requirements may be better estimated using factors that also account for the range of possible operating room times.

The results of the analysis provide many insights into FST operations. The results showed the model was less sensitive to changes in the arrival distribution than anticipated. As expected, an increase in the number of arrivals caused a greater number of casualties to wait for treatment. The data showed there was a quadratic relationship between the number of arrivals and the number of casualties that waited for treatment. This result can be used by medical personnel to plan more accurately for support of future operations.

The final analysis conducted in this thesis was the comparison of various FST configurations. The results indicated there could possibly be potential force structure savings in the design of the FST. There was little effect on the number of casualties waiting longer than the established 120 minute threshold by eliminating an ATM Section or even an OR Section. The utilization rates of the members of the FST did not increase beyond acceptable levels when the number of personnel was reduced. In an era of shrinking budgets and declining force sizes, it is imperative that units be properly sized and equipped. This model provides a means to help evaluate proper manning levels and ensure dwindling resources are efficiently used.

B. RECOMMENDATIONS

The results of this thesis are just a first step in understanding the use of stochastic models to analyze FST operations. Other parameters must be examined and different response variables used in order to obtain a more accurate representation of forward surgical operations.

The FST model has several limitations that must be considered when analyzing the results. The model assumes that the condition of each patient remains the same as they wait for treatment. Realistically, patient acuity changes over time, resulting in different conditions and treatments. Changes in patient acuity can be modeled and as the treatment database evolves the model should be updated to include such changes. The simulation is also limited by the ability of the software to accurately model some types of medical procedures. Revisions in the software are expected soon that will enable more accurate modeling of the movement of medical personnel between patients. This will allow the model to more accurately represent actual medical operations.

APPENDIX A. PATIENT CONDITIONS SUITABLE FOR FAR FORWARD SURGERY

This appendix contains a listing of the 43 patient conditions that have been identified as candidates for forward surgery. The list contains the assigned patient condition number and a brief description of the types of wounds.

PATIENT CONDITION	DESCRIPTION
5	Cerebral contusion (closed), with intracranial hematoma, with or without nondepressed linear skull fracture - severe- large hematoma (including epidural hematoma with rapid deterioration of comatose patient
7	Cerebral contusion (closed) with depressed skull fracture - severe - with associated intracerebral hematoma and/or massive depression
17	Wound - face, jaws, and neck, open, lacerated with associated fractures (excluding spinal fractures) - severe - with airway obstruction
19	Wound - face and neck, open, lacerated, contused without fractures - severe- with airway obstructions and/or major vessel involvement
87	Wound - thorax (anterior or posterior) open, penetrating with associated rib fractures and pneumohemothorax, acute, severe respiratory distress
98	Wound - liver, closed, acute (crush, fracture) - major liver damage
99	Wound - liver, closed, acute (crush, fracture) - minor liver damage
100	Wound - spleen, closed, acute (crush, fracture) - all cases
101	Wound - abdominal cavity, open with lacerating, penetrating, perforating wound to the large bowel
103	Wound - abdominal cavity, open with penetrating, perforating wound of liver, major damage
105	Wound - abdominal cavity, open with penetrating, perforating wound to spleen - severe - all cases
106	Wound - abdominal cavity, open, with lacerated, penetrating, perforating wound with shattered kidney
107	Wound - abdominal cavity, open, with lacerated, penetrating, perforating wound with lacerated kidney, initially repaired, but subsequent nephrectomy
108	Wound - abdominal cavity, open, with lacerated, penetrating, perforating wound with shattered bladder
114	Wound - abdomen, open, with pelvic fracture and penetrating, perforating wounds to multiple pelvic structures (male or female)

115	Wound - abdomen, open, with pelvic fracture and penetrating, perforating wounds to pelvic colon only (male or female)
124	Wound - thigh, open, lacerated, penetrating, perforating with fracture and nerve/vascular injury, limb
138	Crush injury, lower extremity, limb not salvageable
139	Crush injury, lower extremity, limb salvageable
146	Amputation above knee, traumatic, complete, requiring hip disarticulation
161	Multiple injury wound, brain and abdomen with penetrating, perforating wound, kidney
162	Multiple injury wound, brain and abdomen with penetrating, perforating wound, bladder
163	Multiple injury wound, brain and abdomen with shock and penetrating, perforating wound, spleen
166	Multiple injury wound chest (with pneumohemothorax) and abdomen (with penetrating wound, colon)
167	Multiple injury wound chest (with pneumohemothorax) and abdomen (with penetrating, perforating wound, kidney)
168	Multiple injury wound chest (with pneumohemothorax) and abdomen (with perforating wound, bladder)
169	Multiple injury wound chest (with pneumohemothorax) and abdomen (with penetrating, perforating wound, spleen)
170	Multiple injury wound chest (with pneumohemothorax) and abdomen (with penetrating, perforating wound, liver)
171	Multiple injury wound chest (with pneumohemothorax) and limbs (with fracture and vascular injury)
172	Multiple injury wound abdomen with penetrating, perforating wound of colon and bladder
173	Multiple injury wound abdomen with penetrating, perforating wound of colon and spleen
174	Multiple injury wound abdomen with penetrating, perforating wound of colon and liver
175	Multiple injury wound abdomen and limbs with penetrating, perforating wound of colon and open fracture and neurovascular wound of salvageable lower limb
176	Multiple injury wound abdomen and pelvis with penetrating, perforating wound of liver and kidney
177	Multiple injury wound abdomen and pelvis with penetrating, perforating wound of spleen and bladder
178	Multiple injury wound abdomen, pelvis, limbs with fracture and neurovascular damage (salvageable) and penetrating wound, kidney
179	Multiple injury wound abdomen, pelvis, limbs without fracture or

	neurovascular damage (limbs) and penetrating wound, bladder
180	Multiple injury wound abdomen and limbs (lower) with fracture and nerve injury of limb and with spleen damage
181	Multiple injury wound abdomen and limbs without fracture or nerve injury to limbs, with liver damage
183	Multiple injury wound chest, upper limbs and abdomen, with simple pneumohemothorax, soft tissue injury to limbs, and wound of colon
184	Multiple injury wound abdomen, chest and pelvis with pneumohemothorax, wound of colon and bladder
185	Multiple injury wound abdomen and chest with multiple organ damage
313	Wound, abdominal cavity open, with lacerated, penetrating, perforating wound, kidney, moderate - lacerated kidney, kidney salvageable

APPENDIX B. TOTAL ARMY ANALYSIS 2003 DISTRIBUTIONS FOR FORWARD SURGERY PATIENT CONDITIONS

This appendix contains the frequencies for the 43 forward surgical patient conditions generated by PATGEN. The table contains the patient condition, the percentage of that patient condition that dies at Level II, and the expected number of arrivals of that patient condition per day at a FST. The total number of forward surgical candidates per day is estimated to be 3.760101. The remaining patients will be treated at the Forward Support Battalion Medical Company.

Patient Condition	Die% - Echelon 2	#/Day/FST
5	10	0.013333
7	4	0.002222
17	8	0.335556
19	0	0.035556
87	2	0.337778
98	2	0.002222
99	0	0.04
100	0	0.095556
101	0	0.246667
103	0	0.037778
105	0	0.044444
106	0	0.002222
107	0	0.013333
108	0	0.006667
114	0	0.1
115	0	0.073333
124	0	0.86
138	0	0.02
139	0	0.028889
146	0	0.008889
161	0	0.026667
162	0	0.044444
163	0	0.033333
166	0	0.022222
167	0	0.02
168	0	0.017778
169	0	0.017778
170	0	0.02
171	2	0.315556
172	1	0.015556
173	3	0.0001
174	7	0.002222
175	0	0.171111
176	0	0.002222
177	0	0.004444
178	0	0.08
179	0	0.086667
180	2	0.117778
181	0	0.075556
183	0	0.291111
184	0	0.042222
185	0	0.028889
313	0	0.02
Total		3.760101

APPENDIX C. TYPES OF TASKS PERFORMED BY THE FST

This appendix contains a listing of all the tasks the FST will perform during treatment of the 43 forward surgical candidates. The listing includes the task number, the location where it is performed, a description, possible treaters, and the average time to complete the task.

TASK	LOC	TASK DESCRIPTION	TREATER	TIME
001	E	TRIAGE	66H/MD	2
002	E	ASSESSMENT AND EVALUATION OF PATIENT STATUS	91B/66H	2
002	O	ASSESSMENT AND EVALUATION OF PATIENT STATUS	66E/66F/MD	2
002	R	ASSESSMENT AND EVALUATION OF PATIENT STATUS	91C/66H	2
006	E	ESTABLISH ADEQUATE AIRWAY	91B/66H	2
006	R	ESTABLISH ADEQUATE AIRWAY	91C/66H	2
007	E	EMERGENCY CRICOTHYROIDOTOMY (PHYS)	66H/MD	6
007	O	EMERGENCY CRICOTHYROIDOTOMY (PHYS)	MD	6
007	R	EMERGENCY CRICOTHYROIDOTOMY (PHYS)	MD	6
008	E	EMERGENCY CRICOTHYROIDOTOMY (ASSIST PHYS)	91B/66H	6
008	O	EMERGENCY CRICOTHYROIDOTOMY (ASSIST PHYS)	66E/66F	6
008	R	EMERGENCY CRICOTHYROIDOTOMY (ASSIST PHYS)	91D/66H	6
009	E	ENSURE ADEQUATE AIRWAY	91B/66H	1
009	O	ENSURE ADEQUATE AIRWAY	66E/66F	1
009	R	ENSURE ADEQUATE AIRWAY	91C/66H	1
010	E	NEUROLOGICAL ASSESSMENT	91B/66H/MD	3
010	O	NEUROLOGICAL ASSESSMENT	66E/66F/MD	3
010	R	NEUROLOGICAL ASSESSMENT	91C/66H	3
017	E	SUCTION (ORAL/TRACH/ENDO)	91B/66H	3
017	O	SUCTION (ORAL/TRACH/ENDO)	66F	3
017	R	SUCTION (ORAL/TRACH/ENDO)	91C/66H	3
018	E	RECOGNIZE AND RESPOND TO HEMORRHAGE	91B/66H	2
018	O	RECOGNIZE AND RESPOND TO HEMORRHAGE	91D/66E	2
018	R	RECOGNIZE AND RESPOND TO HEMORRHAGE	91C/66H	2
019	E	EMERGENCY CONTROL OF HEMORRHAGE	91B/66H/MD	10
019	O	EMERGENCY CONTROL OF HEMORRHAGE	91D/66E/MD	10
019	R	EMERGENCY CONTROL OF HEMORRHAGE	91C/66H/MD	10

020	E	APPLY ANTI-SHOCK MEASURES	91B/66H	5
020	O	APPLY ANTI-SHOCK MEASURES	91D/66E	5
020	R	APPLY ANTI-SHOCK MEASURES	91C/66H	5
022	E	O2 ADMINISTRATION SETUP	91B/66H	2
022	O	O2 ADMINISTRATION SETUP	91D/66E	2
022	R	O2 ADMINISTRATION SETUP	91C/66H	2
023	E	O2 ADMINISTRATION CONTINUOUS (NASAL/MASK)	91B/66H	1
023	O	O2 ADMINISTRATION CONTINUOUS (NASAL/MASK)	66F	1
023	R	O2 ADMINISTRATION CONTINUOUS (NASAL/MASK)	91C/66H	1
024	E	VITAL SIGNS	91B/66H	3
024	O	VITAL SIGNS	66F	3
024	R	VITAL SIGNS	91C/66H	3
025	E	CARDIAC MONITOR SETUP AND CONNECT TO PATIENT	91B/66H	5
025	O	CARDIAC MONITOR SETUP AND CONNECT TO PATIENT	66F	5
025	R	CARDIAC MONITOR SETUP AND CONNECT TO PATIENT	91C/66H	5
026	E	CARDIAC MONITOR CONTROL	91B/66H	1
026	O	CARDIAC MONITOR CONTROL	66F	1
026	R	CARDIAC MONITOR CONTROL	91C/66H	1
029	E	PHYSICAL INSPECT/ASSESS/RE-EVAL	91B/66H/MD	3
029	O	PHYSICAL INSPECT/ASSESS/RE-EVAL	66E/66F	3
029	R	PHYSICAL INSPECT/ASSESS/RE-EVAL	91C/66H/66F/MD	3
030	E	RHYTHM STRIP/ECG FOR MONITORED PATIENT	91B/66H	1
030	O	RHYTHM STRIP/ECG FOR MONITORED PATIENT	91D/66E	1
030	R	RHYTHM STRIP/ECG FOR MONITORED PATIENT	91C/66H	1
031	E	MAINTAIN ON CARDIAC MONITOR (EQUIP TSK)	91B/66H	1
031	O	MAINTAIN ON CARDIAC MONITOR (EQUIP TSK)	66E/66F	1
031	R	MAINTAIN ON CARDIAC MONITOR (EQUIP TSK)	91C/66H	1
032	E	SET-UP PULSE OXIMETER	91B/66H	2
032	O	SET-UP PULSE OXIMETER	66F	2
032	R	SET-UP PULSE OXIMETER	91C/66H	2
033	E	PULSE OXIMETER CONTROL	91B/66H	1
033	O	PULSE OXIMETER CONTROL	66F	1
033	R	PULSE OXIMETER CONTROL	91C/66H	1
034	E	PULSE OXIMETER (EQUIP TSK)	91B/66H	1
034	O	PULSE OXIMETER (EQUIP TSK)	66F	1
034	R	PULSE OXIMETER (EQUIP TSK)	91C/66H	1

035	E	ARTERIAL PUNCTURE	66H/MD	8
035	O	ARTERIAL PUNCTURE	66E/66F/MD	8
038	E	MAINTAIN ON VENTILATOR (EQUIP TSK)	91B/66H	15
038	O	MAINTAIN ON VENTILATOR (EQUIP TSK)	66F	15
038	R	MAINTAIN ON VENTILATOR (EQUIP TSK)	91C/66H	15
039	E	PERFORM VENTILATION CONTROL	91B/66H	2
039	O	PERFORM VENTILATION CONTROL	66F	2
039	R	PERFORM VENTILATION CONTROL	91C/66H	2
041	E	PULMONARY ASSESSMENT	66H/MD	2
041	O	PULMONARY ASSESSMENT	66F	2
041	R	PULMONARY ASSESSMENT	91C/66H/66F	2
046	E	MAINTAIN CHEST TUBE SUCTION (EQUIP TSK)	91B/66H	5
046	O	MAINTAIN CHEST TUBE SUCTION (EQUIP TSK)	66E/66F	5
046	R	MAINTAIN CHEST TUBE SUCTION (EQUIP TSK)	91C/66H	5
047	E	PERFORM CHEST TUBE SUCTION CONTROL	91B/66H	2
047	O	PERFORM CHEST TUBE SUCTION CONTROL	66E/66F	2
047	R	PERFORM CHEST TUBE SUCTION CONTROL	91C/66H	2
048	E	ASSESS IV REQUIREMENTS	66H/MD	2
048	O	ASSESS IV REQUIREMENTS	66F	2
048	R	ASSESS IV REQUIREMENTS	66H/66F/MD	2
049	E	START/CHANGE IV INFUSION SITE	91B/66H	5
049	O	START/CHANGE IV INFUSION SITE	66E/66F	5
049	R	START/CHANGE IV INFUSION SITE	91C/66H	5
050	E	IV INFUSION CHANGE BOTTLE (MAINTAIN)	91B/66H	2
050	O	IV INFUSION CHANGE BOTTLE (MAINTAIN)	66E/66F	2
050	R	IV INFUSION CHANGE BOTTLE (MAINTAIN)	91C/66H	2
061	E	IV INFUSION MEDICATIONS (Push Volutrol Administer)	66H/MD	5
061	O	IV INFUSION MEDICATIONS (Push Volutrol Administer)	66E/66F	5
061	R	IV INFUSION MEDICATIONS (Push Volutrol Administer)	91C/66H	5
062	E	IV INFUSION BLOOD PRODUCTS HYPERAL	66H	8
062	O	IV INFUSION BLOOD PRODUCTS HYPERAL	66E/66F	8
062	R	IV INFUSION BLOOD PRODUCTS HYPERAL	66H	8
063	E	VENOUS CUTDOWN (PHYS)	MD	15
063	O	VENOUS CUTDOWN (PHYS)	66F/MD	15
063	R	VENOUS CUTDOWN (PHYS)	MD	15
064	E	VENOUS CUTDOWN (ASSIST PHYS)	91B/66H	15
064	O	VENOUS CUTDOWN (ASSIST PHYS)	66E/66F	15

065	E	INSERT CENTRAL VENOUS LINES (PHYS)	MD	10
065	O	INSERT CENTRAL VENOUS LINES (PHYS)	66F/MD	10
065	R	INSERT CENTRAL VENOUS LINES (PHYS)	MD	10
066	E	INSERT CENTRAL LINES (ASSIST PHYS)	91B/66H	10
066	O	INSERT CENTRAL LINES (ASSIST PHYS)	66E/66F	10
066	R	INSERT CENTRAL LINES (ASSIST PHYS)	91C/66H	10
068	O	IV INFUSION TERMINATE	66E/66F	2
068	R	IV INFUSION TERMINATE	91C/66H	2
070	E	BOWEL SOUNDS ASSESS	91B/66H/MD	2
070	O	BOWEL SOUNDS ASSESS	66E/MD	2
070	R	BOWEL SOUNDS ASSESS	91C/66H/66F/MD	2
071	E	INSERT NG TUBE	91B/66H	7
071	O	INSERT NG TUBE	66E/66F	7
073	E	MAINTAIN NG SUCTION (EQUIP TSK)	91B/66H	15
073	O	MAINTAIN NG SUCTION (EQUIP TSK)	66E/66F	15
073	R	MAINTAIN NG SUCTION (EQUIP TSK)	91C/66H	15
074	E	PERFORM NG CONTROL	91B/66H	1
074	O	PERFORM NG CONTROL	66E/66F	1
074	R	PERFORM NG CONTROL	91B/66H	1
075	E	IRRIGATE NG TUBE	91B/66H	3
075	O	IRRIGATE NG TUBE	66E/66F	3
075	R	IRRIGATE NG TUBE	91C/66H	3
078	O	REMOVE NG TUBE	91D/66F	2
078	R	REMOVE NG TUBE	91C/66H	2
079	E	CATHETERIZATION FOLEY	91B/66H	4
079	O	CATHETERIZATION FOLEY	91D/66E	4
082	E	MEASURE/RECORD INTAKE/OUTPUT	91B/66H	2
082	O	MEASURE/RECORD INTAKE/OUTPUT	66E/66F	2
082	R	MEASURE/RECORD INTAKE/OUTPUT	91C/66H	2
084	E	SHAVE AND PREP	91B/66H	5
084	O	SHAVE AND PREP	91D/66E	5
085	E	WOUND IRRIGATION	91B/66H	10
085	O	WOUND IRRIGATION	91D/MD	10
085	R	WOUND IRRIGATION	91C/66H	10
086	E	CLEAN AND DRESS WOUND	91B/66H	8
086	O	CLEAN AND DRESS WOUND	91D/66E	8
086	R	CLEAN AND DRESS WOUND	91C/66H	8

088	E	DRESSING REINFORCEMENT	91B/66H	2
088	R	DRESSING REINFORCEMENT	91C/66H	2
093	E	EXTREMITY ELEVATION	91B/66H	1
093	R	EXTREMITY ELEVATION	91C/66H	1
096	E	APPLY SLING	91B/66H/MD	3
096	O	APPLY SLING	91D/66E	3
096	R	APPLY SLING	91C/66H/MD	3
098	E	APPLY SPLINT IMMOBILIZE INJURED EXTREMITY	91B/66H/MD	8
098	O	APPLY SPLINT IMMOBILIZE INJURED EXTREMITY	91D/66E	8
098	R	APPLY SPLINT IMMOBILIZE INJURED EXTREMITY	91C/66H/MD	8
103	E	CIRCULATION CHECK	91B/66H	1
103	O	CIRCULATION CHECK	66E	1
103	R	CIRCULATION CHECK	91C/66H	1
105	E	DOPPLER ASSESSMENT (ORTHO/GEN SURG)	MD	2
105	O	DOPPLER ASSESSMENT (ORTHO/GEN SURG)	MD	2
105	R	DOPPLER ASSESSMENT (ORTHO/GEN SURG)	MD	2
106	E	ESCHAROTOMY W/O GEN ANESTH (GEN SURG)	MD	20
106	O	ESCHAROTOMY W/O GEN ANESTH (GEN SURG)	MD	20
106	R	ESCHAROTOMY W/O GEN ANESTH (GEN SURG)	MD	20
121	E	EYE IRRIGATION	91B/66H	8
121	O	EYE IRRIGATION	66E/MD	8
121	R	EYE IRRIGATION	91C/66H	8
122	E	EYE DROPS INSTILLATION	91B/66H	1
122	O	EYE DROPS INSTILLATION	66E/MD	1
122	R	EYE DROPS INSTILLATION	91C/66H	1
125	E	SPONGE/HYPOTHERMIA/HYPERTHERMIA TREATMENT	91B/66H	20
125	R	SPONGE/HYPOTHERMIA/HYPERTHERMIA TREATMENT	91C/66H	20
126	E	SEIZURE CARE/PRECAUTIONS	91B/66H	3
126	O	SEIZURE CARE/PRECAUTIONS	91D/66E	3
126	R	SEIZURE CARE/PRECAUTIONS	91C/66H	3
128	E	PATIENT RESTRAINT 4 POINT LEATHER (COMBATIVE PATIENT)	91B/66H	10
128	O	PATIENT RESTRAINT 4 POINT LEATHER (COMBATIVE PATIENT)	91D/66E	10
128	R	PATIENT RESTRAINT 4 POINT LEATHER (COMBATIVE PATIENT)	91C/66H	10
129	E	PERFORM RESTRAINED PATIENT CONTROL	91B/66H	2
129	O	PERFORM RESTRAINED PATIENT CONTROL	91D/66E	2
129	R	PERFORM RESTRAINED PATIENT CONTROL	91C/66H	2

130	E	INCONTINENT CARE	91B/66H	10
130	O	INCONTINENT CARE	91D/66E	10
130	R	INCONTINENT CARE	91C/66H	10
131	E	PERFORM DETAILED CLINICAL EXAM	66H/MD	5
132	E	OBTAIN AND RECORD MEDICAL HISTORY	91B/66H/MD	5
132	O	OBTAIN AND RECORD MEDICAL HISTORY	66F/MD	5
132	R	OBTAIN AND RECORD MEDICAL HISTORY	91C/66H/MD	5
142	E	ORDER AND DOCUMENT APPROPRIATE MEDS/TREATMENT	91B/66H/MD	2
142	O	ORDER AND DOCUMENT APPROPRIATE MEDS/TREATMENT	66E	2
142	R	ORDER AND DOCUMENT APPROPRIATE MEDS/TREATMENT	91C/66H/66F/MD	2
145	E	ADMINISTER APPROPRIATE MEDICATION	91B/66H	3
145	O	ADMINISTER APPROPRIATE MEDICATION	66E/66F	3
145	R	ADMINISTER APPROPRIATE MEDICATION	91C/66H	3
148	E	OBTAIN SPECIMEN FOR LABORATORY ANALYSIS	91B/66H	3
148	O	OBTAIN SPECIMEN FOR LABORATORY ANALYSIS	91D/66E	3
149	E	BLOOD DRAWING VENOUS	91B/66H	4
149	O	BLOOD DRAWING VENOUS	66E/66F	4
165	E	REQUEST DIAGNOSTIC STUDIES (EMT PHYS)	MD	2
165	O	REQUEST DIAGNOSTIC STUDIES (EMT PHYS)	MD	2
165	R	REQUEST DIAGNOSTIC STUDIES (EMT PHYS)	MD	2
179	E	PLACEMENT OF PACEMAKER TRANSCUTANEOUS (EMT PHYS)	MD	5
179	O	PLACEMENT OF PACEMAKER TRANSCUTANEOUS (EMT PHYS)	MD	5
180	E	PLACEMENT OF PACEMAKER TRANSCUTANEOUS (ASSIST EMT PHYS)	66H	5
180	O	PLACEMENT OF PACEMAKER TRANSCUTANEOUS (ASSIST EMT PHYS)	66E/MD	5
191	E	GIVE A BEDPAN	91B/66H	3
191	R	GIVE A BEDPAN	91C/66H	3
195	E	ACCOMPANY PATIENT TO SPECIAL STUDIES/X-RAY/WARD	91B/66H/MD	10
195	O	ACCOMPANY PATIENT TO SPECIAL STUDIES/X-RAY/WARD	91D/66F/MD	10
195	R	ACCOMPANY PATIENT TO SPECIAL STUDIES/X-RAY/WARD	91C/66H/MD	10

196	E	POSITION FOR X-RAY (ASSIST X-RAY TECH)	91B/66H	4
196	O	POSITION FOR X-RAY (ASSIST X-RAY TECH)	91D/66E	4
196	R	POSITION FOR X-RAY (ASSIST X-RAY TECH)	91C/66H	4
197	E	CHARTING & PAPERWORK - PATIENT SPECIFIC	91B/66H	1
197	O	CHARTING & PAPERWORK - PATIENT SPECIFIC	66E	1
197	R	CHARTING & PAPERWORK - PATIENT SPECIFIC	91C/66H	1
202	E	ADMIT NEW PATIENT TO WARD	91B/66H	10
202	O	ADMIT NEW PATIENT TO WARD	66E	10
202	R	ADMIT NEW PATIENT TO WARD	91C/66H	10
203	R	RECOVERY ROOM ROUTINE	91C/66H	60
223	E	CVP (MANUAL)	66H	2
223	O	CVP (MANUAL)	66F	2
223	R	CVP (MANUAL)	91C/66H	2
242	E	BLADDER IRRIGATION CONTINUOUS	91B/66H	3
242	O	BLADDER IRRIGATION CONTINUOUS	66E	3
242	R	BLADDER IRRIGATION CONTINUOUS	91C/66H	3
244	E	HEMACULT TEST FECES EMESIS GASTRIC SUCTION	91B/66H/MD	1
244	O	HEMACULT TEST FECES EMESIS GASTRIC SUCTION	91D/66E	1
244	R	HEMACULT TEST FECES EMESIS GASTRIC SUCTION	91C/66H/MD	1
245	E	URINE TESTING	91B/66H	3
245	O	URINE TESTING	91D/66E	3
245	R	URINE TESTING	91C/66H	3
252	E	ADJUST PATIENT BED POSITION	91B/66H	2
252	O	ADJUST PATIENT BED POSITION	91D/66E	2
252	R	ADJUST PATIENT BED POSITION	91C/66H	2
253	E	ENFORCE BEDREST	91B/66H/MD	1
253	R	ENFORCE BEDREST	91C/66H	1
264	E	PARTIAL BATH ORAL PERINEAL SKIN (UNASSISTED)	91B/66H	5
264	R	PARTIAL BATH ORAL PERINEAL SKIN (UNASSISTED)	91C/66H	5
267	E	LINEN CHANGE	91B/66H	3
267	R	LINEN CHANGE	91C/66H	3
268	E	CHUCKS CHANGE	91B/66H	2
268	R	CHUCKS CHANGE	91C/66H	2
278	R	ARRANGE FOR PATIENT EVACUATION	91C/66H/MD	5
327	R	PREPARE EVAC DISCHARGE OR TRANSFER SUMMARY	91C/66H/MD	10
339	O	MINOR ROOM PREPARATION	91D/66E	5

343	O	PATIENT MOVEMENT ONTO OR TABLE	91D/66E	3
344	O	PATIENT PREPARATION IN THE OR	91D/66E	5
345	O	POSITION FOR PROCEDURE	66E	5
346	O	CIRCULATING DUTIES	66E	
349	O	SCRUB TECHNICIAN DUTIES	91D	
351	O	OR TEAM PREPARATION (SURGICAL HAND SCRUB)	MD	5
354	O	MINOR ROOM CLEAN-UP	91D/66E	
356	O	OR TABLE TIME (EQUIP TSK)	91D	
358	O	TRACHEOSTOMY (GEN SURG)	MD	30
364	O	DEBRIDE W/O NERVE AND/OR VASCULAR REPAIR (GEN SURG)	MD	60
372	O	OPERATION TO LIVER (NOT RESECTION) (GEN SURG)	MD	60
373	O	SPLENECTOMY (GEN SURG)	MD	60
374	O	COLOSTOMY/ILEOSTOMY (GEN SURG)	MD	90
377	O	ABDOMINAL EXPLORATION (GEN SURG)	MD	30
386	O	GASTROSTOMY (GEN SURG)	MD	30
387	O	MULTIPLE ABDOMINAL INJURIES REPAIR (GEN SURG)	MD	330
403	O	BURR HOLE PROCEDURE	MD	40
461	O	DEBRIDE WOUND (ORTHO/GEN SURG)	MD	90
467	O	FASCIOTOMY (ORTHO/GEN SURG)	MD	15
488	O	REPAIR WOUND NECK STRUCTURES OPEN (OTOLARY/GEN SURG)	MD	168
494	O	THORACOTOMY (THOR/GEN SURG)	MD	120
508	O	COMPLETE NEPHRECTOMY (UROL/GEN SURG)	MD	30
509	O	REPAIR URINARY BLADDER (UROL/GEN SURG)	MD	45
528	O	SELECT ANESTHETIC AGENT/ASSESS PATIENT	66F	10

530	O	INDUCE GENERAL ANESTHESIA	66F	10
531	O	MAINTAIN ON GENERAL ANESTHESIA (EQUIP TSK)	66F	
533	O	INDUCE AXILLARY BLOCK	66F	20
534	O	MONITOR AND MAINTAIN AXILLARY BLOCK	66F	60
535	O	INDUCE SPINAL ANESTHESIA	66F	15
536	O	MONITOR AND MAINTAIN SPINAL BLOCK	66F	40
537	O	RECOVERY/RELEASE FROM ANESTHESIA	66F	7
551	O	CMS PPD CONSUMABLES	91D	60
563	E	INTERPRET ELECTROCARDIOGRAM (CARDIO)	MD	2
563	O	INTERPRET ELECTROCARDIOGRAM (CARDIO)	MD	2
563	R	INTERPRET ELECTROCARDIOGRAM (CARDIO)	MD	2
595	E	BLOOD GAS ESTIMATION	91B/66H	5
595	O	BLOOD GAS ESTIMATION	66F	5
595	R	BLOOD GAS ESTIMATION	91C/66H	5
596	E	ELECTROLYTE LEVELS (Na K Cl CO2)	91B/66H	6
596	R	ELECTROLYTE LEVELS (Na K Cl CO2)	91C/66H	6
599	E	SERUM CREATININE LEVEL	91B/66H	13
599	R	SERUM CREATININE LEVEL	91C/66H	13
600	E	SERUM AMYLASE LEVEL	91B/66H	13
600	R	SERUM AMYLASE LEVEL	91C/66H	13
614	E	HEMATOCRIT LEVEL	91B/66H	2
614	O	HEMATOCRIT LEVEL	66F	2
614	R	HEMATOCRIT LEVEL	91C/66H	2
620	E	URINALYSIS W/SPECIFIC GRAVITY	91B/66H	3
620	R	URINALYSIS W/SPECIFIC GRAVITY	91C/66H	3
666	E	FOOT SERIES (AP OBLIQUE LATERAL WEIGHT BEARING)	91P	10
667	E	ANKLE SERIES (AP OBLIQUE LATERAL)	91P	10
668	E	LEG TIBIA/FIBULA SERIES (AP LATERAL)	91P	10
672	E	FEMUR SERIES (AP LATERAL)	91P	15
674	E	PELVIS AP	91P	10

676	E	CHEST AP/PA	91P	10
676	R	CHEST AP/PA	91P	10
677	E	CHEST LATERAL	91P	10
679	E	ABDOMEN SERIES (AP/ AP UPRIGHT/ PA CHEST)	91P	10
680	E	ABDOMEN AP (SUPINE FLAT OR KUB)	91P	10
683	E	CERVICAL SPINE SERIES (AP OPEN MOUTH LATERAL BOTH OBLIQUES)	91P	20
686	E	SKULL SERIES (PA BOTH LATERALS CHAMBER-TOWNE SUBMEN TO VERTICA)	91P	15
687	E	SKULL PA	91P	7
688	E	SKULL LATERAL	91P	7
693	O	INTERPRETATION OF FILM STUDIES	MD	3
693	R	INTERPRETATION OF FILM STUDIES	MD	3
700	E	CYSTOGRAM (RADIOL/X-R SPEC)	91P/PA/MD	10
700	R	CYSTOGRAM (RADIOL/X-R SPEC)	91P/PA/MD	10
701	E	URETHROGRAM (RADIOL/X-R SPEC)	91P/PA/MD	10
702	E	EXTREMITY ARTERIOGRAM (UPPER) (RADIOL/X-R SPEC)	91P	30
703	E	EXTREMITY ARTERIOGRAM (LOWER) (RADIOL/X-R SPEC)	91P	30
738	E	BANDAGE STUMP	91B/66H	7
738	O	BANDAGE STUMP	91D/MD	7
738	R	BANDAGE STUMP	91C/66H	7
744	E	APPLY VELPEAU DRESSING	91B/66H	3
744	R	APPLY VELPEAU DRESSING	91C/66H	3
747	E	CAST/DRESSING/SPLINT CARE	91B/66H	3
747	R	CAST/DRESSING/SPLINT CARE	91C/66H	3
748	E	ASSEMBLE MATERIAL/CLEAN UP	91B/66H	15
748	R	ASSEMBLE MATERIAL/CLEAN UP	91C/66H	15
751	E	ADMIN	66H	3
751	O	ADMIN	66E	3
751	R	ADMIN	66H	3

998	E	O2 CONSUMPTION - VENTILATOR - TIME VARIABLE (EQUIP TSK)	91B/66H	15
998	O	O2 CONSUMPTION - VENTILATOR - TIME VARIABLE (EQUIP TSK)	91D/66F	15
998	R	O2 CONSUMPTION - VENTILATOR - TIME VARIABLE (EQUIP TSK)	91C/66H	15
999	E	MORGUE CARE	91B	10
999	O	MORGUE CARE	91D	10
999	R	MORGUE CARE	91C	10
Z014	E	INTUBATION (PHYS)	MD	5
Z014	R	INTUBATION (PHYS)	66F/MD	5
Z015	E	INTUBATION (ASSIST PHYS)	91B/66H	5
Z015	R	INTUBATION (ASSIST PHYS)	91C/66H	5
Z019	O	SURGICAL CONTROL OF HEMORRHAGE	MD	
Z027	E	CARDIO ARREST RESUSCITATION (PHYS)	66H/MD	30
Z027	O	CARDIO ARREST RESUSCITATION (PHYS)	66F/MD	30
Z027	R	CARDIO ARREST RESUSCITATION (PHYS)	66H/MD	30
Z028	E	CARDIO ARREST RESUSCITATION (ASSIST PHYS)	91B/66H	30
Z028	O	CARDIO ARREST RESUSCITATION (ASSIST PHYS)	91D/66E	30
Z028	R	CARDIO ARREST RESUSCITATION (ASSIST PHYS)	91C/66H	30
Z036	E	VENTILATOR SETUP/MONITOR	91B/66H	5
Z036	O	VENTILATOR SETUP/MONITOR	66F	5
Z036	R	VENTILATOR SETUP/MONITOR	91C/66H	5
Z037	E	BVM SETUP	91B/66H/MD	5
Z037	O	BVM SETUP	66F	5
Z037	R	BVM SETUP	91C/66H/MD	5
Z038	E	MAINTAIN ON BVM	91B/66H	15
Z038	O	MAINTAIN ON BVM	66F	15
Z038	R	MAINTAIN ON BVM	91C/66H	15
Z039	E	PERFORM VENTILATION WITH BVM	91B/66H	15
Z039	O	PERFORM VENTILATION WITH BVM	66F	15
Z039	R	PERFORM VENTILATION WITH BVM	91C/66H	15
Z042	E	INSERT CHEST TUBE (PHYS)	MD	10
Z042	O	INSERT CHEST TUBE (PHYS)	MD	10
Z042	R	INSERT CHEST TUBE (PHYS)	MD	10
Z043	E	INSERT CHEST TUBE (ASSIST PHYS)	91B/66H	10
Z043	O	INSERT CHEST TUBE (ASSIST PHYS)	91D/66E	10
Z043	R	INSERT CHEST TUBE (ASSIST PHYS)	91C/66H	10

Z044	E	SETUP DRAINAGE SYSTEM (GASTRIC/CHEST)	91B/66H	2
Z044	O	SETUP DRAINAGE SYSTEM (GASTRIC/CHEST)	66E	2
Z044	R	SETUP DRAINAGE SYSTEM (GASTRIC/CHEST)	91C/66H	2
Z045	E	CHANGE DRAINAGE SYSTEM (GASTRIC/CHEST)	91B/66H	3
Z045	O	CHANGE DRAINAGE SYSTEM (GASTRIC/CHEST)	66E	3
Z045	R	CHANGE DRAINAGE SYSTEM (GASTRIC/CHEST)	91C/66H	3
Z083	E	EXPOSE PATIENT FOR EXAM	91B/66H	7
Z083	O	EXPOSE PATIENT FOR EXAM	66E	7
Z083	R	EXPOSE PATIENT FOR EXAM	91C/66H	7
Z089	E	COLOSTOMY/ILEOSTOMY/GASTROSTOMY DSG REINFORCE	91B/66H	2
Z089	O	COLOSTOMY/ILEOSTOMY/GASTROSTOMY DSG REINFORCE	91D/MD	2
Z089	R	COLOSTOMY/ILEOSTOMY/GASTROSTOMY DSG REINFORCE	91C/66H	2
Z177	E	DIAGNOSTIC PERITONEAL LAVAGE (PHYS)	MD	30
Z178	E	DIAGNOSTIC PERITONEAL LAVAGE (ASSIST PHYS)	91B/66H	30
Z277	R	PREPARE FOR EVAC GROUND/AIR	91C/66H	5
Z378	O	VASCULAR REPAIR TEMPORARY/LIGATE	MD	60
Z641	E	ISSUE GROUP O PACKED RBCs (1 UNIT)	66H	5
Z641	O	ISSUE GROUP O PACKED RBCs (1 UNIT)	66E	5
Z641	R	ISSUE GROUP O PACKED RBCs (1 UNIT)	66H	5
ZZ04	E	INTERPRET LAB RESULTS	66H/MD	1
ZZ04	O	INTERPRET LAB RESULTS	66F/MD	1
ZZ04	R	INTERPRET LAB RESULTS	66H/MD	1
ZZ11	E	STABILIZE NECK (COLLAR/SPINE BOARD) ASSIST	91B/66H	8
ZZ14	R	EXTUBATION POST-OP (PHYS)	66F/MD	3
ZZ15	R	EXTUBATION POST-OP (ASSIST PHYS)	91C/66H	3

APPENDIX D. TREATMENT FILE FOR PATIENT CONDITION 100

This appendix is an example of the Time- Task- Treater database for a patient condition. In this example, the file for patient condition 100, a casualty with a closed, acute wound of the spleen, is provided. Included is the task number, the location the task is performed (E= ATM, O= OR, R= Recovery), the task description, the possible treaters, and the average time required to perform the task. The tasks are grouped together into sets of tasks that can be performed simultaneously. All the tasks in a group must be completed before performing any tasks in another group.

Task	Echelon	Task Description	Treater	Time
001	E	TRIAGE	66H/MD	2
009	E	ENSURE ADEQUATE AIRWAY	91B/66H	1
131	E	PERFORM DETAILED CLINICAL EXAM	66H/MD	5
Z027	E	CARDIO ARREST RESUSCITATION (PHYS)	66H/MD	30
Z028	E	CARDIO ARREST RESUSCITATION (ASSIST PHYS)	91B/66H	30
025	E	CARDIAC MONITOR SETUP AND CONNECT TO PATIENT	91B/66H	5
032	E	SET-UP PULSE OXIMETER	91B/66H	2
022	E	O2 ADMINISTRATION SETUP	91B/66H	2
023	E	O2 ADMINISTRATION CONTINUOUS (NASAL/MASK)	91B/66H	1
041	E	PULMONARY ASSESSMENT	66H/MD	2
024	E	VITAL SIGNS	91B/66H	3
048	E	ASSESS IV REQUIREMENTS	66H/MD	2
049	E	START/CHANGE IV INFUSION SITE	91B/66H	5
149	E	BLOOD DRAWING VENOUS	91B/66H	4
063	E	VENOUS CUTDOWN (PHYS)	MD	15
064	E	VENOUS CUTDOWN (ASSIST PHYS)	91B/66H	15
Z641	E	ISSUE GROUP O PACKED RBCs (1 UNIT)	66H	5
002	E	ASSESSMENT AND EVALUATION OF PATIENT STATUS	91B/66H	2

061	E	IV INFUSION MEDICATIONS (Push Volutrol Administer)	66H/MD	5
062	E	IV INFUSION BLOOD PRODUCTS HYPERAL	66H	8
071	E	INSERT NG TUBE	91B/66H	7
079	E	CATHETERIZATION FOLEY	91B/66H	4
145	E	ADMINISTER APPROPRIATE MEDICATION	91B/66H	3
165	E	REQUEST DIAGNOSTIC STUDIES (EMT PHYS)	MD	2
029	E	PHYSICAL INSPECT/ASSESS/RE-EVAL	91B/66H/MD	3
148	E	OBTAIN SPECIMEN FOR LABORATORY ANALYSIS	91B/66H	3
596	E	ELECTROLYTE LEVELS (Na K Cl CO2)	91B/66H	6
614	E	HEMATOCRIT LEVEL	91B/66H	2
Z083	E	EXPOSE PATIENT FOR EXAM	91B/66H	7
026	E	CARDIAC MONITOR CONTROL	91B/66H	1
030	E	RHYTHM STRIP/ECG FOR MONITORED PATIENT	91B/66H	1
033	E	PULSE OXIMETER CONTROL	91B/66H	1
075	E	IRRIGATE NG TUBE	91B/66H	3
031	E	MAINTAIN ON CARDIAC MONITOR (EQUIP TSK)	91B/66H	1
034	E	PULSE OXIMETER (EQUIP TSK)	91B/66H	1
050	E	IV INFUSION CHANGE BOTTLE (MAINTAIN)	91B/66H	2
074	E	PERFORM NG CONTROL	91B/66H	1
142	E	ORDER AND DOCUMENT APPROPRIATE MEDS/TREATMENT	91B/66H/MD	2
196	E	POSITION FOR X-RAY (ASSIST X-RAY TECH)	91B/66H	4
620	E	URINALYSIS W/SPECIFIC GRAVITY	91B/66H	3
680	E	ABDOMEN AP (SUPINE FLAT OR KUB)	91P	10
197	E	CHARTING & PAPERWORK - PATIENT SPECIFIC	91B/66H	1
999	E	MORGUE CARE	91B	10
339	O	MINOR ROOM PREPARATION	91D/66E	5
343	O	PATIENT MOVEMENT ONTO OR TABLE	91D/66E	3
351	O	OR TEAM PREPARATION (SURGICAL HAND SCRUB)	MD	5
065	O	INSERT CENTRAL VENOUS LINES (PHYS)	66F/MD	10
066	O	INSERT CENTRAL LINES (ASSIST PHYS)	66E/66F	10
344	O	PATIENT PREPARATION IN THE OR	91D/66E	5
528	O	SELECT ANESTHETIC AGENT/ASSESS PATIENT	66F	10
345	O	POSITION FOR PROCEDURE	66E	5
530	O	INDUCE GENERAL ANESTHESIA	66F	10
085	O	WOUND IRRIGATION	91D/MD	10
346	O	CIRCULATING DUTIES	66E	
349	O	SCRUB TECHNICIAN DUTIES	91D	
356	O	OR TABLE TIME (EQUIP TSK)	91D	
373	O	SPLENECTOMY (GEN SURG)	MD	60

531	O	MAINTAIN ON GENERAL ANESTHESIA (EQUIP TSK)	66F	
693	O	INTERPRETATION OF FILM STUDIES	MD	3
537	O	RECOVERY/RELEASE FROM ANESTHESIA	66F	7
354	O	MINOR ROOM CLEAN-UP	91D/66E	
002	R	ASSESSMENT AND EVALUATION OF PATIENT STATUS	91C/66H	2
009	R	ENSURE ADEQUATE AIRWAY	91C/66H	1
017	R	SUCTION (ORAL/TRACH/ENDO)	91C/66H	3
022	R	O2 ADMINISTRATION SETUP	91C/66H	2
023	R	O2 ADMINISTRATION CONTINUOUS (NASAL/MASK)	91C/66H	1
024	R	VITAL SIGNS	91C/66H	3
025	R	CARDIAC MONITOR SETUP AND CONNECT TO PATIENT	91C/66H	5
029	R	PHYSICAL INSPECT/ASSESS/RE-EVAL	91C/66H/66F/MD	3
032	R	SET-UP PULSE OXIMETER	91C/66H	2
203	R	RECOVERY ROOM ROUTINE	91C/66H	60
Z027	R	CARDIO ARREST RESUSCITATION (PHYS)	66H/MD	30
Z028	R	CARDIO ARREST RESUSCITATION (ASSIST PHYS)	91C/66H	30
Z036	R	VENTILATOR SETUP/MONITOR	91C/66H	5
010	R	NEUROLOGICAL ASSESSMENT	91C/66H	3
038	R	MAINTAIN ON VENTILATOR (EQUIP TSK)	91C/66H	15
041	R	PULMONARY ASSESSMENT	91C/66H/66F	2
070	R	BOWEL SOUNDS ASSESS	91C/66H/66F/MD	2
142	R	ORDER AND DOCUMENT APPROPRIATE MEDS/TREATMENT	91C/66H/66F/MD	2
202	R	ADMIT NEW PATIENT TO WARD	91C/66H	10
033	R	PULSE OXIMETER CONTROL	91C/66H	1
039	R	PERFORM VENTILATION CONTROL	91C/66H	2
223	R	CVP (MANUAL)	91C/66H	2
050	R	IV INFUSION CHANGE BOTTLE (MAINTAIN)	91C/66H	2
061	R	IV INFUSION MEDICATIONS (Push Volutrol Administer)	91C/66H	5
998	R	O2 CONSUMPTION - VENTILATOR - TIME VARIABLE (EQUIP TSK)	91C/66H	15
ZZ14	R	EXTUBATION POST-OP (PHYS)	66F/MD	3
ZZ15	R	EXTUBATION POST-OP (ASSIST PHYS)	91C/66H	3
075	R	IRRIGATE NG TUBE	91C/66H	3
145	R	ADMINISTER APPROPRIATE MEDICATION	91C/66H	3
026	R	CARDIAC MONITOR CONTROL	91C/66H	1
030	R	RHYTHM STRIP/ECG FOR MONITORED PATIENT	91C/66H	1

031	R	MAINTAIN ON CARDIAC MONITOR (EQUIP TSK)	91C/66H	1
034	R	PULSE OXIMETER (EQUIP TSK)	91C/66H	1
073	R	MAINTAIN NG SUCTION (EQUIP TSK)	91C/66H	15
074	R	PERFORM NG CONTROL	91B/66H	1
082	R	MEASURE/RECORD INTAKE/OUTPUT	91C/66H	2
191	R	GIVE A BEDPAN	91C/66H	3
196	R	POSITION FOR X-RAY (ASSIST X-RAY TECH)	91C/66H	4
197	R	CHARTING & PAPERWORK - PATIENT SPECIFIC	91C/66H	1
252	R	ADJUST PATIENT BED POSITION	91C/66H	2
267	R	LINEN CHANGE	91C/66H	3
268	R	CHUCKS CHANGE	91C/66H	2
751	R	ADMIN	66H	3
278	R	ARRANGE FOR PATIENT EVACUATION	91C/66H/MD	5
327	R	PREPARE EVAC DISCHARGE OR TRANSFER SUMMARY	91C/66H/MD	10
Z277	R	PREPARE FOR EVAC GROUND/AIR	91C/66H	5

APPENDIX E. RESULTS- MEAN OR TIMES

This appendix contains the results from the analysis of mean OR time. Provided as Table 7 is the resulting mean, median, standard deviation, and standard error of the mean of the operating room times (in minutes) for each patient condition. Provided as Table 8 is the minimum, maximum, and 1st and 3rd quantiles for operating room times (in minutes).

PC	N	Mean	Median	Standard Deviation	Standard Error of Mean
5	34	158.41	152.13	17.54	3.01
7	27	144.27	141.73	13.15	2.53
17	42	269.98	260.45	31.9	4.92
19	17	136.89	125.53	24.58	5.96
87	39	224.78	216.22	32.29	5.17
98	28	169.13	163.7	20.52	3.88
99	33	181.07	178.79	26.87	4.68
100	30	166.25	161.43	15.38	2.81
101	46	207.08	196.12	29.73	4.38
103	24	164.28	159.19	22.2	4.53
105	32	170.74	160.42	25.78	4.56
106	23	213.5	209.33	30.38	6.33
107	23	196.62	188.8	26.37	5.5
108	27	150.86	138.65	32.91	6.33
114	38	198.73	192.02	29.14	4.73
115	21	205.81	194.33	32.04	6.99
124	71	190.66	184.44	35.07	4.16
138	16	211.76	206.38	32.39	8.1
139	27	173.13	173.79	29.06	5.59
146	23	209.31	207.67	33.11	6.9
161	29	205.07	196.43	30.92	5.74
162	31	154.85	144.27	22.01	3.95
163	20	181.6	172.79	30.68	6.86
166	16	214.24	205.33	31.86	7.97
167	19	203.2	195.75	29.08	6.67
168	22	153.48	143.71	24.38	5.2
169	26	171.15	156.88	26.47	5.19
170	24	168.98	168.42	18.52	3.78
171	31	191.66	181.33	32.19	5.78
172	21	221.34	214.4	34.04	7.43
173	15	217.3	190.8	48.5	12.5
174	23	195.91	184.72	32.62	6.8
175	23	224.01	212.59	47.77	9.96
176	23	232.05	233.57	36.04	7.51
177	23	191.53	188.71	32.12	6.7
178	19	281.76	274.44	39.07	8.96
179	29	227.56	222.98	44.02	8.17
180	29	189.77	179.43	36.05	6.69
181	21	209.74	202.32	43.15	9.42
183	42	219.99	208.24	38.34	5.92
184	27	224.13	208.41	45.55	8.77
185	25	460.9	467	52.2	10.4
313	21	166	161.01	41.84	9.13

Table 7. Table of Mean, Median, Standard Deviation, and Standard Error of the Mean for OR Times in Minutes

PC	Minimum	Maximum	First Quantile	Third Quantile
5	137.43	211.82	144.84	170.12
7	123.66	165.53	135.16	158.06
17	218.78	351.91	244.3	296.6
19	115.95	213.43	121.24	150.57
87	175.5	327.02	202.47	240.18
98	142.17	215.44	153.82	184.18
99	145.44	245.88	161.7	196.01
100	143.25	199.16	155.38	176.14
101	167.38	307.42	185.55	219.69
103	134.99	245.74	149.74	174.77
105	136.02	246.32	155.21	177.01
106	169.98	269.1	186.22	229.49
107	169.55	266.18	178.95	201.58
108	124.64	238.58	130.92	161.21
114	155.83	255.51	175.12	220.75
115	160.41	279.52	181.78	223.16
124	145.11	302.61	160.77	214.09
138	161.1	266.25	183.7	243.96
139	125.98	239.31	162.31	186.56
146	159.98	281.41	180.33	226.43
161	171.37	305.25	187.32	214.51
162	132.86	220.96	142.67	168.38
163	142.57	241.92	159.56	202.74
166	178.15	276.46	188.18	239.76
167	170.91	267.83	179.29	228.41
168	124.88	198.71	134.21	176.5
169	140.03	249.28	152.26	189.51
170	145.06	208.99	150.83	178.47
171	151	253.96	166.99	214.75
172	182.79	293.61	192.18	245.76
173	172.6	312.4	181.7	249.4
174	161.83	292.19	174.02	206.66
175	165.22	351.44	185.58	243.41
176	174.02	286.23	210.4	259.58
177	143.48	247.43	165.6	220.89
178	218.11	362.56	247.59	297.08
179	178.13	381.17	194.83	248.01
180	153.23	271.51	161.14	207.54
181	154.48	274.36	166.02	259.34
183	168.01	303.9	188.55	244.24
184	171.1	333.82	189.96	242.98
185	363.4	550.2	425.5	497.4
313	117.02	244.52	126.97	200.67

Table 8. Table of Minimum, Maximum, and 1st and 3rd Quantiles for OR Times in Minutes

APPENDIX F. RESULTS- CHANGES IN ARRIVAL DISTRIBUTION

This appendix contains the results from the analysis of changes in the arrival distribution. Provided as Table 9 is the resulting mean, median, standard deviation, and standard error of the mean of the average number of casualties that waited greater than 120 minutes for surgery to begin. Table 10 contains the minimum, maximum, and 1st and 3rd quantiles for each distribution. The results of the pairwise comparisons are provided in Table 11. Tables 12 and 13 contain the percent in operation for each FST location and the percent in use for each resource, respectively.

Distribution	N	Mean	Median	Standard Deviation	Standard Error of Mean
Uniform	100	1.120	0.500	1.659	0.166
Bimodal	100	1.120	0.500	1.565	0.157
Baseline	100	1.360	1.000	1.521	0.152

Table 9. Table of Mean, Median, Standard Deviation, and Standard Error of the Mean for the Average Number of Casualties Waiting Greater Than 120 Minutes for Surgery for Each Distribution

Distribution	Minimum	Maximum	First Quantile	Third Quantile
Uniform	0.000	9.000	0.000	2.000
Bimodal	0.000	8.000	0.000	2.000
Baseline	0.000	6.000	0.000	2.000

Table 10. Table of Minimum, Maximum, and 1st and 3rd Quantiles for the Average Number of Casualties Waiting Greater Than 120 Minutes for Surgery for Each Distribution

	Bimodal Distribution	Baseline Distribution
Uniform Distribution	0.000 ± .433	0.240 ± .444
Bimodal Distribution		0.240 ± .386

Table 11. Individual 95 Percent Paired-*t* Confidence Intervals for All Pairwise Comparisons Between the Distributions

	Uniform Distribution	Bimodal Distribution	Baseline Distribution
ATM1	12.20 (3.80)	12.75 (3.45)	11.99 (3.1)
ATM2	10.38 (3.43)	11.20 (3.22)	9.79 (3.48)
OR1	19.49 (7.28)	19.77 (7.71)	19.41 (6.4)
OR2	15.07 (6.10)	15.34 (6.98)	14.23 (6.0)
BED 1	28.21 (8.61)	27.72 (9.25)	27.26 (7.2)
BED 2	12.25 (7.49)	13.87 (8.25)	12.41 (7.3)
BED 3	2.23 (4.00)	3.47 (5.19)	2.74 (3.6)
BED 4	0 (0)	.1390 (.848)	.10 (.68)
BED 5	0 (0)	0 (0)	0 (0)
BED 6	0 (0)	0 (0)	0 (0)
BED 7	1.46 (1.38)	1.838 (1.46)	1.15 (1.0)
BED 8	.3739 (.681)	.6009 (.871)	.673 (.72)

Table 12. Mean (Standard Deviation) of the Percent Operation for Each Location for Each Arrival Distribution

	Uniform Distribution	Bimodal Distribution	Baseline Distribution
GenSurg1	28.15 (8.53)	28.33 (8.85)	28.53 (7.4)
GenSurg2	28.25 (8.86)	29.09 (9.88)	28.52 (7.7)
GenSurg3	22.41 (7.45)	23.28 (7.96)	20.45 (7.7)
Ortho	22.88 (8.20)	23.76 (8.68)	20.91 (7.9)
CCNurse	10.37 (3.63)	12.21 (4.03)	9.50 (3.7)
EMT NCO	12.69 (4.37)	13.49 (4.39)	11.74 (3.6)
Medic1	14.81 (4.96)	16.51 (4.78)	14.44 (4.1)
Medic2	12.82 (4.62)	14.76 (4.43)	11.62 (4.3)
OR Nurse	20.25 (7.54)	20.94 (7.98)	20.03 (6.6)
OR NCO	15.80 (6.85)	16.31 (7.44)	14.93 (6.3)
OR Spec1	17.77 (6.78)	18.26 (7.28)	17.36 (5.9)
OR Spec2	13.72 (6.0)	14.35 (6.79)	12.87 (5.6)
Anesth1	20.64 (7.63)	21.33 (8.15)	20.50 (6.6)
Anesth2	16.05 (6.60)	16.45 (7.43)	14.93 (6.3)
MedSurg Nurse	21.20 (7.22)	21.86 (7.72)	19.19 (6.0)
PracNurse1	7.88 (5.16)	8.11 (5.78)	7.31 (4.8)
PracNurse2	9.19 (4.47)	11.17 (5.59)	11.29 (4.6)
PracNurse 3	3.24 (3.17)	4.37 (3.92)	4.51 (4.0)

Table 13. Mean (Standard Deviation) of the Percent In Use for Each FST Member for Each Arrival Distribution

APPENDIX G. RESULTS- CHANGES IN ARRIVALS

This appendix contains the results from the analysis of changes in the number of arrivals. Provided as Table 14 is the resulting mean, median, standard deviation, and standard error of the mean of the average number of casualties that waited greater than 120 minutes for surgery to begin. Table 15 contains the minimum, maximum, and 1st and 3rd quantiles for each distribution. Tables 16 and 17 contain the results of the regression analysis of the data.

# of Casualties	# of Replications	Mean	Median	Standard Deviation	Standard Error of Mean
10	30	0	0	0	0
20	30	0	0	0	0
40	30	0.1333	0	0.3457	0.0631
60	30	0.467	0	0.681	0.124
80	30	0.833	0	1.289	0.235
100	30	1.233	0.5	1.794	0.328
120	30	1.667	1	2.44	0.445
140	30	2.1	1	2.618	0.478
160	30	2.733	2	3.29	0.601

Table 14. Table of Mean, Median, Standard Deviation, and Standard Error of the Mean for the Average Number of Casualties Waiting Greater Than 120 Minutes for Surgery for Each Distribution

# of Casualties	Minimum	Maximum	1st Quantile	3rd Quantile
10	0	0	0	0
20	0	0	0	0
40	0	1	0	0
60	0	2	0	1
80	0	4	0	2
100	0	8	0	2
120	0	9	0	2
140	0	9	0	3.25
160	0	12	0	3.25

Table 15. Table of Minimum, Maximum, and 1st and 3rd Quantiles for the Average Number of Casualties Waiting Greater Than 120 Minutes for Surgery for Different Arrival Numbers

Predictor	Coefficient	Standard Deviation	t-Ratio	p value
Constant	-0.11859	0.05066	-2.34	0.058
X	0.005263	0.001462	3.60	0.011
X^2	0.00007832	0.00000852	9.18	0.000

Table 16. Regression of Waiting Time > 120 Minutes on Number of Casualties and (Number of Casualties)^2

Source	DF	SS	MS	F	p
Regression	2	7.7555	3.8777	1363.39	0.000
Error	6	0.0171	0.0028		
Total	8	7.7725			
Source	DF	SEQ SS			
X	1	7.5158			
X^2	1	0.2397			

Table 17. Analysis of Variance for Regression

APPENDIX H. RESULTS- CHANGES IN FORCE STRUCTURE

This appendix contains the results from the analysis of changes in the force structure of the FST. Provided as Table 18 is the resulting mean, median, standard deviation, and standard error of the mean of the average number of casualties that waited greater than 120 minutes for surgery to begin for each TOE configuration. Table 19 contains the minimum, maximum, and 1st and 3rd quantiles. The results of the pairwise comparisons are provided in Table 20. Tables 21 and 22 contain the percent in operation for each FST location and the percent in use for each resource, respectively.

	N	**Mean**	**Median**	**True Mean**	**Standard Deviation**	**Standard Error of the Mean**
Full FST	100	1.360	1.000	1.233	1.521	0.152
(-) ATM Section	100	1.680	1.000	1.578	1.510	0.151
(-) OR Section	100	1.450	1.000	1.244	1.783	0.178
(-) Rec Section	100	1.610	1.000	1.467	1.693	0.169
(-) ATM & OR	100	1.840	1.000	1.678	1.927	0.193
Half FST	100	3.690	3.500	3.700	2.048	0.205

Table 18. Table of Mean, Median, Standard Deviation, and Standard Error of the Mean for the Average Number of Casualties Waiting Greater Than 120 Minutes for Surgery for Each TOE Configuration

	Minimum	**Maximum**	**First Quantile**	**Third Quantile**
Full FST	0.000	6.000	0.000	2.000
(-) ATM Section	0.000	6.000	0.000	3.000
(-) OR Section	0.000	8.000	0.000	2.000
(-) Rec Section	0.000	8.000	0.000	3.000
(-) ATM & OR	0.000	7.000	0.000	3.000
Half FST	0.000	7.000	2.000	6.000

Table 19. Table of Minimum, Maximum, and 1st and 3rd Quantiles for the Average Number of Casualties Waiting Greater Than 120 Minutes for Each Configuration

	(-) ATM Section	**(-) OR Section**	**(-) Recovery Section**	**(-) ATM/OR Sections**	**1/2 FST**
Full FST	.320 ± .408	.090 ± .451	.250 ± .465	**.480 ± .463**	**2.320 ± .484**
(-) ATM Section		-.230 ± .473	-.070 ± .455	.160 ± .475	**2.000 ± .510**
(-) OR Section			.160 ± .463	.390 ± .517	**2.230 ± .493**
(-) Recovery Section				.230 ± .537	**2.070 ± .495**
(-) ATM/OR Sections					**1.840 ± .550**

Table 20. Individual 95 Percent Paired-*t* Confidence Intervals for All Pairwise Comparisons Between the Different TOE Configurations

	Full FST	**(-) ATM Sec**	**(-) OR Sec**	**(-) Rec Sec**	**(-) ATM/OR**	**Half FST**
ATM1	11.99 (3.1)	11.54 (3.0)	10.81 (2.8)	11.54 (2.8)	10.90 (3.2)	11.67 (2.0)
ATM2	9.79 (3.48)	9.26 (3.56)	8.46 (2.82)	10.10 (3.5)	8.21 (2.85)	0 (0)
OR1	19.41 (6.4)	20.27 (7.3)	32.91 (10.4)	20.28 (7.2)	32.1 (10.9)	31.62 (8.4)
OR2	14.23 (6.0)	13.01 (5.7)	0 (0)	14.82 (6.7)	0 (0)	0 (0)
BED 1	27.26 (7.2)	28.93 (8.1)	29.68 (8.4)	28.72 (9.1)	29.33 (9.3)	31.80 (8.5)
BED 2	12.41 (7.3)	11.97 (7.2)	10.98 (7.0)	13.83 (7.7)	9.53 (6.3)	6.99 (6.2)
BED 3	2.74 (3.6)	2.41 (3.6)	.1226 (.87)	3.305 (4.1)	.2481 (1.2)	.168 (.84)
BED 4	.10 (.68)	.1296 (.97)	0 (0)	.194 (1.18)	0 (0)	0
BED 5	0 (0)	.0451 (.45)	0 (0)	0 (0)	0 (0)	0
BED 6	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
BED 7	1.15 (1.0)	1.39 (.95)	1.85 (1.5)	1.57 (1.4)	1.63 (1.2)	2.53 (1.1)
BED 8	.673 (.72)	.714 (.70)	.675 (.82)	.604 (.73)	.737 (.80)	1.30 (.88)

Table 21. Mean (Standard Deviation) of the Percent Operation for Each Location for Each TOE Configuration

	Full FST	(-) ATM Sec	(-) OR Sec	(-) Rec Sec	(-) ATM/OR	Half FST
GenSurg1	28.53 (7.4)	28.90 (8.0)	27.66 (6.4)	29.20 (8.1)	27.54 (7.2)	38.97 (7.2)
GenSurg2	28.52 (7.7)	29.23 (8.6)	27.81 (6.6)	29.31 (8.8)	27.65 (7.6)	39.68 (8.0)
GenSurg3	20.45 (7.7)	19.33 (7.7)	19.37 (7.7)	20.82 (8.2)	18.68 (7.4)	0 (0)
Ortho	20.91 (7.9)	19.57 (8.0)	20.08 (8.1)	21.70 (8.8)	18.76 (7.7)	0 (0)
CCNurse	9.50 (3.7)	0 (0)	8.986 (3.6)	10.16 (4.3)	0 (0)	0 (0)
EMT NCO	11.74 (3.6)	22.07 (6.4)	12.0 (3.6)	12.49 (4.1)	22.38 (7.3)	16.49 (3.2)
Medic1	14.44 (4.1)	26.55 (6.5)	14.44 (3.6)	15.18 (4.3)	25.19 (6.4)	18.81 (3.1)
Medic2	11.62 (4.3)	0 (0)	11.07 (3.9)	12.40 (4.7)	0 (0)	0 (0)
OR Nurse	20.03 (6.6)	20.66 (7.4)	33.25 (10.1)	20.99 (7.6)	32.12 (10.8)	31.26 (7.9)
OR NCO	14.93 (6.3)	13.51 (5.9)	0 (0)	15.36 (6.7)	0 (0)	0 (0)
OR Spec1	17.36 (5.9)	17.97 (6.6)	29.56 (9.1)	18.40 (6.8)	28.69 (9.8)	27.70 (7.4)
OR Spec2	12.87 (5.6)	11.76 (5.3)	0 (0)	13.35 (6.0)	0 (0)	0 (0)
Anesth1	20.50 (6.6)	21.20 (7.4)	33.01 (9.5)	21.42 (7.5)	32.14 (10.3)	31.77 (8.0)
Anesth2	14.93 (6.3)	13.65 (6.0)	0 (0)	15.55 (6.7)	0 (0)	0 (0)
MedSurg Nurse	19.19 (6.0)	20.37 (7.0)	21.56 (7.0)	25.56 (7.9)	21.09 (8.0)	23.69 (6.9)
PracNurse 1	7.31 (4.8)	5.997 (4.4)	5.68 (4.1)	19.42 (4.4)	4.31 (3.4)	15.2 (4.8)
PracNurse 2	11.29 (4.6)	11.39 (4.8)	10.29 (4.0)	0 (0)	10.92 (4.3)	0 (0)
PracNurse 3	4.51 (4.0)	4.844 (4.0)	2.876 (2.5)	0 (0)	2.32 (2.3)	0 (0)

Table 22. Mean (Standard Deviation) of the Percent In Use for Each FST Member for Each TOE Configuration

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