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**MULTISTAGE DEPLOYMENT OF THE ARMY
THEATER HOSPITAL**

by

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December 2013

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MULTISTAGE DEPLOYMENT OF THE ARMY THEATER HOSPITAL

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ABSTRACT

We will never know the operational battle space of the future, so medical assets need to be flexible and agile to conform to a variety of environments and threats. We utilize a multistage optimization model and data from past contingency operations to analyze potential configurations of a robust theater-deployable hospital. The current Army theater-deployable hospital has 248 beds, and our analysis shows it is over-capacitated for the current brigade-centric force structure. Based on our analysis, the optimal role-3 medical treatment facility is between 44 beds and 124 beds, with smaller wards, and the ability to combine hospitals to create larger hospitals. The smaller role-3 medical treatment facility better suits the tactical and operational employment of medical assets and supports the strategic plans for regionally aligned forces.

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LIST OF ACRONYMS AND ABBREVIATIONS

AMEDD	Army Medical Department
ARFORGEN	Army Force Generation
BCT	brigade combat team
CASS	Center for AMEDD Strategic Studies
CONUS	continental United States
CSH	combat support hospital
CT	computed tomography
FASH	forward Army surgical hospital
FH	field hospital
FSH	forward surgical hospital
FST	forward surgical team
GAMS	Generalized Algebraic Modeling System
GH	general hospital
ICU	intensive care unit
ICW	intensive care ward
MASH	mobile Army surgical hospital
MCW	minimal care ward
MRI	Medical Reengineering Initiative
MTF	medical treatment facility
OCONUS	outside continental U.S.
OIF	Operations Iraqi Freedom
OOTW	operations other than war
OPLAN	operational plan
OR	operating room
VBC	Victory Base Complex

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EXECUTIVE SUMMARY

We will never know the operational environment of the future, so the Army Chief of Staff directed the planning of future forces to be flexible and agile so that it can conform to any hybrid environment and threat. The current role-3 medical treatment facility (MTF) is not 100% mobile, which hinders its agility. The current role-3 MTF was created to support division/corps-centric forces; however the Army has transitioned and invested in the agile and independently capable brigade-centric combatant force. In order to be an integrated and versatile combat multiplier that is adaptive to the current situation, the role-3 MTF asset doctrinally needs a flexible and agile task organization.

We introduce a multistage optimization model that serves as a support tool to determine the optimal hospital configuration at each phase of a combat scenario. We utilize parameter data for recent contingency operations from the Center for AMEDD Strategic Studies and include input parameters for the commander's assessment of the conflict development. We constrain the model to fixed sizes of medical wards and ensure we meet 95th percentile patient admission rates in each ward at each stage.

Based on our analysis, the current 248-bed role-3 MTF is over-capacitated for a brigade-centric force structure. If we sustain the current ward configurations, a hospital with 124-beds (84 beds and minimal care ward augmentation) would be sufficient to support a brigade-centric task force. However, the large ward sizes create unnecessary excess. If we created more flexible wards that are half the current sizes and optimally deploy our medical assets, we can reduce the deployment by 16 to 36 beds per deployment and hospital. Half-suite sizes provide a potential means to improve the rigidity and excess deployment of the current combat support hospital (CSH). A hospital minimally requires 44 beds to support 20,000 soldiers. If we saw twice the battle injury rates in Operation Iraqi Freedom (OIF), a 70-bed hospital would be optimal. The current 248-bed CSH far exceeds the capacity required to handle three times the OIF battle injury rates. Our multistage optimization model allows us to explore the ability of the CSH ward structure to adapt to a changing combat environment. We find that half-sized wards perform well in the notional combat scenarios we explore.

Our analysis shows that a robust role-3 MTF is between 44 beds and 124 beds, with smaller wards and the capability to independently deploy or combine to another hospital. The agile and flexible hospital we explore utilizes a constructive means to build an appropriate hospital size, rather than the current process of deconstructing a CSH to match the conflict. If the AMEDD utilized an optimized role-3 MTF of about 60 beds, similar to the mobile surgical hospital, the increased quantity of smaller efficient hospitals is capable of supporting the Army's evolution to a regionally aligned force. The current CSH configuration will not support a sustained regional alignment of role-3 MTF.

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I. INTRODUCTION

A. PROBLEM

In 2006, I was the Bravo Company Commander of the 21st Combat Support Hospital (CSH), staged to deploy in support of Operation Iraqi Freedom (OIF). The 21st CSH performed detainee healthcare in continuous split-based operations with our sister company who was deployed to Camp Bucca in southern Iraq. A CSH is not designed to perform sustained split based operations. Our company was established 500 kilometers north-west at Abu Ghraib, Iraq. About midway through the deployment, we deconstructed the Abu Ghraib treatment facility and reconstructed it at Victory Base Complex (VBC), Baghdad. We were not capable of moving ourselves the short 30 kilometers and required external unit and contract transportation support. In my mind, the austere conditions and lack of capability at Abu Ghraib warranted the large medical treatment force we initially deployed with, but with the change of location, additional capability on VBC, and the decrease in the primary medical treatment population, it was possible for us to downsize the deployed medical task force. However, I did not have a quantitative means to justify my intuition to the Hospital Commander who could authorize the change. Commanders do not willingly reduce their force size because of the unknown nature of their future assigned missions. Utilizing a multi-stage optimization and knowledge of the operational tactics, we can quantitatively analyze options for the optimal hospital task organization, based on the commander's future mission expectations. This process attempts to support proactive leadership planning and decisions, rather than reactive leadership actions after the change is required.

Today, Army combat medicine is challenged with more than one mission to support, in more than one environment, and treating more than one demographic of patient. Historically, we designed theater hospitalization to manage the healthcare of combat operations on a linear battlefield, for male soldiers ages 18–25. Today, it is not unreasonable for a medical unit to conduct small-scale contingency operations, humanitarian assistance support, combat casualty care, detainee care, and peacekeeping

operations in non-linear environments that traverse mountainous ranges to city streets, for a plethora of casualties to include women, children, and the elderly.

The ideal hospital configuration is dependent upon the patient demographic and operational environment. A hospital conducting combat support to a predominately reserve duty military force may expect higher disease and non-battle injuries than if supporting a predominately active duty military force, resulting in a higher need for sick-call capabilities and ICW beds. Whereas, a hospital conducting peacekeeping operations may expect a larger infectious disease patient population versus a hospital conducting initial entry combat operations that will have more blast injuries and need for surgical and burn care capabilities. Commanders have been given a modular set of medical assets to customize their medical task force contingency, but how does a commander decide when and what to take for uncertain future missions and patient demographics? We propose the use of a multi-stage optimization and analysis, to stimulate the decision process for a commander faced with this dilemma and to aid in establishing the configuration of the next generation role-3 medical treatment facility (MTF). By configuration, we mean specifically the total number of beds required in the operating room (OR), intensive care unit (ICU), intensive care ward (ICW), and minimal care ward (MCW).

B. RESEARCH QUESTIONS

We focus our research on the following questions.

1. What does the task organization for a robust deployable hospital look like?
2. Does our optimal robust hospital support the combatant commander's plan?

C. BACKGROUND OF ARMY THEATER HOSPITALIZATION

1. Health Services Support Levels of Care:

The Army Health System is the complete medical continuum that traverses from the forward edge of the battlefield through continental United States (CONUS) medical facilities (see Figure 1). Army Field Manual 4-02 Army Health System describes the doctrinal planning of deployable medical support. The Army Health System is tailored to the mission, size of force supported, projected patient workload, anticipated civic

programs, evacuation availability, and evacuation policy. The elements organic to the supported unit typically provide role-1 and role-2 care with capabilities for immediate lifesaving measures and stabilization for evacuation. They have minimal patient holding and ancillary support capabilities (i.e., x-ray, dental, and lab), however are 100% mobile. We primarily use role-1 and role-2 MTFs for emergency care and treatment with the expectation that patients will return to duty within 72 hours (Department of the Army, 2013).

Role-3 MTF care provided by the Combat Support Hospital is the focus of our study. It is the most comprehensive care provided in the deployed theater and expands on the support rendered. Role-3 medical treatment facilities include increased surgical capabilities to prepare patients for evacuation to CONUS hospitalization care and care for all types of patients.

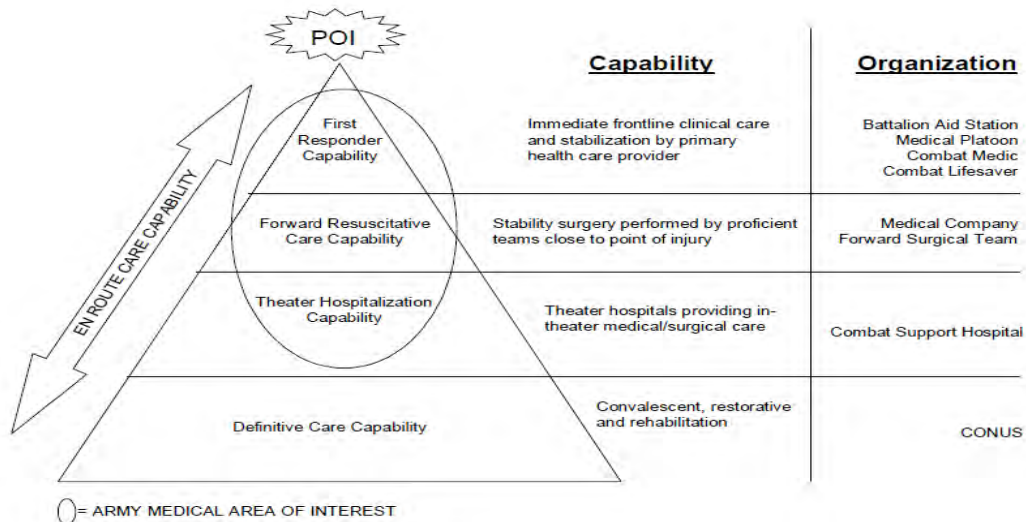


Figure 1. The capability and organization that provides each level of care (from Department of Army, 2007).

2. Task Organization History of Army Theater Hospitalization

The Army’s surgical capability has evolved through time. According to Nessen (2005), in World War I the Army had over 30,000 hospital beds deployed in large 1,000 bed hospitals in France. During World War II, we made the hospitals slightly smaller;

however they were still large bed deployable hospitals. By the Korean War, we recognized the need for more mobility and we created the mobile Army surgical hospitals (MASH). However, as Vietnam continued, we utilized semi-fixed establishments on relatively permanent bases. After Vietnam, we utilized semi-mobile hospitals that required corps transportation assets like the CSH. This formation worked in Operation Desert Storm and Shield, but faired less favorable in Operation Iraqi Freedom because corps transportation assets were not available (Nessen, 2005).

Through the Medical Force 2000 force concept, Army theater hospitalization was supported by the 296-bed combat support hospital, the 60-bed MASH, the 504-bed field hospital (FH), and the 1,000-bed general hospital (GH) (Lodi, 2003); all with a piece of the mission that sequentially moved patients through the echelons of care on a typically linear battlefield against opposition with near or similar capabilities (see Figure 2). As the environment evolved, the Army Medical Department (AMEDD) sought to improve its ability to quickly deploy medical assets by medically modularizing its units through a Medical Reengineering Initiative (MRI). The 248-bed combat support hospital (CSH) replaced the MASH, FH, and GH as a means to standardize the platforms to reduce familiarization and training requirements, logistics, and maintenance along with its ability to provide the full-spectrum of capability (Nessen, 2005). This reconfigured the force structure into modular elements and resulted in a modular formation of the combat support hospital to support theater hospitalization, instead of the three different formations of hospitals. We have 26 combat support hospitals (see Table 1) in the active and reserve Army force structure (Lewis, et al., 2010).

	Active	Reserve
Role 3 MTF Available	10	16
Total Personnel Req (Approx.)	5,000	8,000

Table 1. The Army currently has 26 CSHs totaling approximately 13,000 personnel in it (after Lewis, et al., 2010).

Currently, we depend on role-2 forward surgical teams (FSTs) to doctrinally provide 100% mobile surgical capability within the brigade and division areas (Edgar, 2009). The AMEDD created these teams as a means to fill the shortfall of the immobility of the CSH and to ensure patients received definitive care within the “golden hour” (a commonly known timeframe in the medical community where survivability exponentially increases if patients receive care before its end). While they have 100% mobility, they do not have the complete and advanced capability that the CSH has. Typically, we evacuate patients from the FST to the CSH for further surgery and stabilization before evacuation to CONUS.

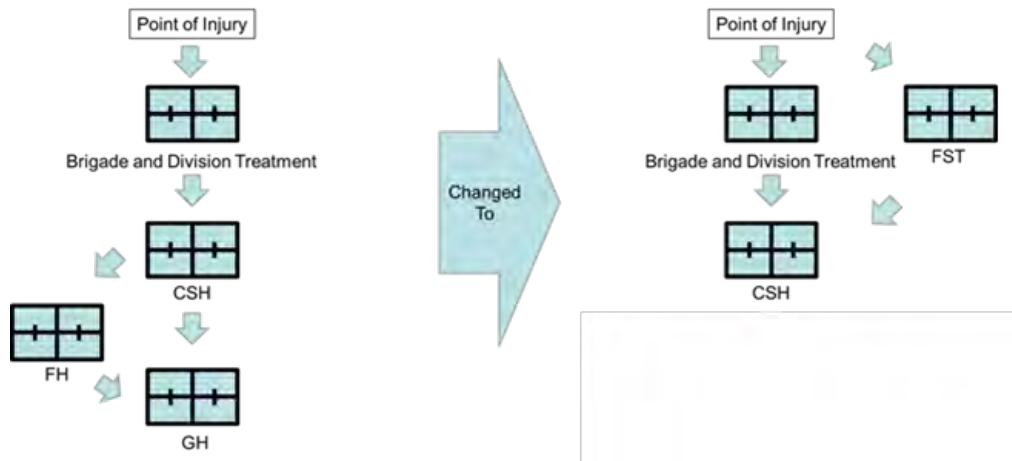


Figure 2. The AMEDD removed the field hospital (FH) and general hospital (GH) from unit inventory, replacing it with a combat support hospital to support echelons above corps areas and a fully mobile forward surgical team in the brigade and divisional areas on the battlefield.

3. The Combat Support Hospital:

According to the Army Training Publication 4-02.5 Casualty Care, the combat support hospital is a 248-bed unit that provides definitive care in the corps and echelons above corps areas of the battlefield. It has the most medical capability on the battlefield to include myriad surgical capacity, emergency treatment, pharmacy, psychiatry, community health, clinical laboratory, blood banking, radiology, physical therapy, nutrition care, dental care, and medical logistic reconstitution. Its design allows for split-

based operations for 72-hours with an 84-bed company (that has the capability for further modularization into a 44-bed early entry module) and a 164-bed company; all efforts to address the quick deployment and mobilization of theater hospitalization (see Figure 3) (Department of the Army, 2013).

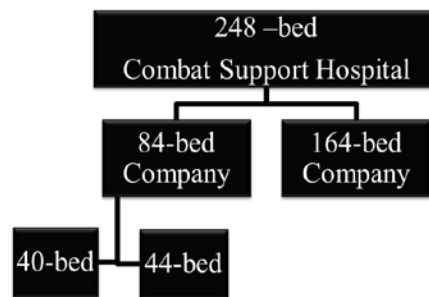


Figure 3. The task organization of the combat support hospital is modular to allow the deconstruction of it into smaller units to support phased or varying missions (after Department of the Army, 2013).

The Army Training Publication 4-02.5 also specifies logistical and administrative specifications of the CSH. The CSH has approximately 490 officers and enlisted soldiers assigned, of which 45% to 55% of the personnel consist of ancillary medical support, administrative/logistical support, and command structure. The 84-bed company is 35 percent mobile, and the 164-bed company is not mobile at all. It takes approximately six days to prepare for relocation and another six days to erect the facilities; doctrinally intended to conduct an average relocation occurrence every 25 days. A single unit of a CSH in its entirety doctrinally covers over nine acres of land upon its complete equipment and tent establishment. In addition, it also requires external evacuation assets to support the transport of patients to overseas/CONUS medical facilities (Department of the Army, 2013).

The CSH is the AMEDDs only deployable role-3 MTF capability. It has the most medical capability on the battlefield, but it lacks mobility and entails a large theater footprint.

4. Principles of Health Service Support:

In FM 4-02, the Army Medical Department clearly and purposefully identified “enduring fundamentals – upon which the delivery of health care in a field environment is founded” (p. 1-5). These principles “guide medical planners in developing OPLANs (operations plans) which are effective, efficient, flexible, and executable” (p. 1-5). In order for medical planners to do this, the medical units including the CSH must have the capability to support the principles of the Army Health System as well. According to the Field Manual 4–02, the Principles of the Army Health System are:

a. Conformity

Medical planning must support the theater combat operations plan at the right time and place (Department of the Army, 2013). The CSH is an enormous logistic package that takes at least six days to establish and covers over nine acres. Although its modularized 44-bed early entry asset is capable of early establishment, it is not self-sufficient. During the first phase of Operation Iraqi Freedom, the AMEDD had to utilize the older generation MASH hospitals to support the combat forces movement into Baghdad. The battle was moving so quickly, that the MRI CSH was not capable of sustaining the mobility to geographically and tactically conform to the operational area in continuous split based operations. The medical capability must conform and support the combat operational plan; the combat operational plan should not alter to the available medical capability.

b. Continuity

There must not be a break in patient care. We created the CSH as a necessary package to stabilize and hold patients for evacuation out of theater. However, many times in Iraq we circumvented the CSH in the evacuation process because of redundant capability on the battlefield. We sometimes evacuate patients receiving FST surgical care without the requirement of utilizing CSH capabilities. In recent past engagements, the CSH was not capable of situating itself on the battlefield to support continuity of care so we skipped its capability altogether.

c. Control

The CSH commander must have control and the ability to proactively manage the medical resources. He must have the ability to tailor the resources in order to fully support theater operations and ensure a responsive system. The lack of mobility of the modular CSH components and the inability for sustained split based operations does not allow CSH commanders the intended control of resources to maintain a responsive system.

d. Proximity and Mobility

Proximity and Mobility in this instance go hand in hand. The CSH needs to be as close to combat operations and evacuation resources as tactically possible. The CSH must be capable of maintaining viable distances that do not drain the evacuation lines. Especially during early entry operations as a battle physically progresses, we must safely minimize the evacuation distance between role-2 assets and the CSH to allow evacuation assets to clear the battlefield. The CSH currently needs non-organic additional assets to sustain proximity to the operational units. The CSH must have the ability to move its own personnel and equipment with organic transportation or immediate patient evacuation.

e. Flexibility

The redistribution or relocation of medical resources is essential in an ever-changing operations area, however resources should only be committed as required to support the expected patient densities. A modular construct allows a commander the flexibility to support the operational battle as needed. In order to support and follow the Army Health System principles, the CSH must conform to the combatant plan, be mobile and agile, reconfigurable, and allow medical commanders the control to provide continuous care. Currently, the CSH is capable of care, but does not have effective mobility and has limited reconfiguration options, which reduces the medical commander's control and ability to conform to the combatant commander's tactical plan.

D. MOTIVATION FOR CHANGE

The CSH is a major force multiplier on the battlefield; however its current configuration has enormous logistical requirements in training, maintenance, mobilization, and during theater operations has a significant effect on logistic support. A combat service support asset should not be a major combat service support drain. The incredible drain of theater hospitalization requires a robust system that can withstand the ever changing requirements, and modularly optimize itself through command decisions in its resourced task organization (Davis, Hosek, Tate, Perry, Hepler, & Steinberg, 1996).

The AMEDD needs a viable theater hospitalization option to support the requirements of Joint Forces 2020, which “stresses the military’s agility and flexibility as the United States faces unclear and unknown threats in the future” (Garamone, 2012, p. 1). The force management process takes minimally two years to create, and many more to resource with actual trained and capable leaders. It is not a process that quickly adapts to the changing mission. Army Force Management seeks depth and versatility, adaptive and innovative, and flexible and agile characteristics for the future force (Army Force Management School, 2012). This also includes reversibility and expansibility components that allow strategic depth of the force. Leaders accept the fact that we will not have a predetermined and set solution ideal for all scenarios; therefore, an adaptive force that is modularly constructed has become the means to a robust future force.

Although the theater hospital construct was extremely successful during Operation Iraqi Freedom with survival rates of over 90% (Horoho, 2012b), the opportunity for improvement is still present. As stated in a report to the Congressional Committees in 2011, as recommendations for Executive Action concerning the opportunities for AMEDD support in Iraq and Afghanistan:

To enhance medical units’ preparedness to conduct current and future operations given the changing use of combat support hospitals and forward surgical teams in Iraq and Afghanistan, we recommend that the Secretary of the Army direct the Army Medical Department to update its doctrine and the organization of medical units concerning their size, composition, and use. (United States Government Accountability Office, 2011, p. 21).

Although doctrinally the CSH has a fully mobile and self-sustaining component and decomposes modularly to a required element size, it does not support any long-term operational tempo, nor does it functionally support long-term split based operations (Nessen, 2005). Due to the construct of the command structure, a CSH cannot deploy to two theaters of operation at the same time; for example a portion of the hospital cannot be conducting humanitarian assistance in Haiti while the remaining hospital conducts detainee operations in Iraq. Therefore, when we utilize a modular portion of the hospital, the remainder becomes essentially non-deployable. Since its inception as a modular CSH, it has not deployed its full capability to any contingency or operation (Nessen, 2005).

Therefore, although the CSH is modular to support robust deployment, the design is not optimal for force management because it utilizes a deconstruction method of unit formation. We currently take a large unit and make it smaller when necessary, leaving everything not used as non-deployable. The proposed optimal theater hospital construct would entail minimizing the personnel deployed while simultaneously minimizing the amount of organizational change required that meets the expected patient load. This results in a unit that minimizes the variance of changes necessary to meet the required mission. We can then take these smaller hospitals and if necessary construct and combine hospitals, or add modules to them to create a larger unit when necessary for an increased mission requirement.

In January 2012, General Ray Odierno, 38th Chief of Staff of the Army published his *Marching Orders*, directing future force generation to support the following characteristics: depth and versatility, adaptive and innovative, flexible and agile, integrated and synchronized, and lethal and discriminate (Odierno, 2012). The force needs the depth and versatility to be able to quickly deploy in a myriad of “complex, dynamic, and uncertain global environments” (p. 5) while allowing its leaders to innovatively adapt their formation and employment to the changing situation. Therefore, the force needs to be flexible and agile to dominantly respond in any operational environment against any conventional or hybrid threat. In an integrated joint, interagency, and multinational effort, the entire force needs to synchronously maximize combat power

through all efforts in time, space, and purpose, so that we maintain the maximum lawful and discriminate lethal force (Ordierno, 2012).

Odierno (2012) clearly specified that because the operational environment is continuously changing and always unknown, flexibility and adaptability to the mission was essential. Since theater hospitalization fills a combat service support role, majority of its ability to remain flexible and adaptable lies in its balance of mobility and capability.

Organizationally, the CSH has not modernized itself to medically support the changes that occurred to the operational organization of combat forces. As the Army evolved from facing large conventional peer to peer opposition forces to hybrid guerilla opposition forces, its task organization changed from large division centric units to brigade centric combat units. This allowed a faster deployment under a smaller single command and more simultaneous missions by the division under three self-sustaining brigades. This also removed the need for additional coordinated efforts for combat support requirements by making the combat support assets organic to the brigade. This increases the potential geographic dispersion of combat units and their rate of movement. The area and rate of medical support required of the CSH increases while their mobility further decreases as corps transportation assets are no longer available on the battlefield (the availability of corps transportation assets were a critical assumption in the development of the CSH).

Organizationally, the CSH has not modernized itself to support the improvement and investment of the tactical mobility of combat forces. There is a fine balance that occurs between mobility and capability (see Figure 4). A highly mobile medical treatment facility has to forsake aspects of capability to sustain its quick agility. Highly mobile medical facilities can quickly and best conform to the tactical plans of the combat forces, and are located close to the forward line of troops to allow rapid acquisition, stabilization, and evacuation of casualties. Smaller mobile units also empower the medical commanders to shift and reallocate their medical resources on the battlefield because of the ease of movement. In contrast, a fully capable facility like the current CSH takes long to move and requires vast non-organic support to transport. However, the

increased capability in equipment and ancillary services supports the collaboration of physicians individual specializations increasing the pool of knowledge, allows them to sustain better work rest cycles, and allows a collaboration of command, administrative, and logistical support. A CSH will have a multiple physician and specialization network on-hand and far better equipment; a CSH may have a computed tomography (CT) scanner versus a FST having a simple and portable X-ray machine.

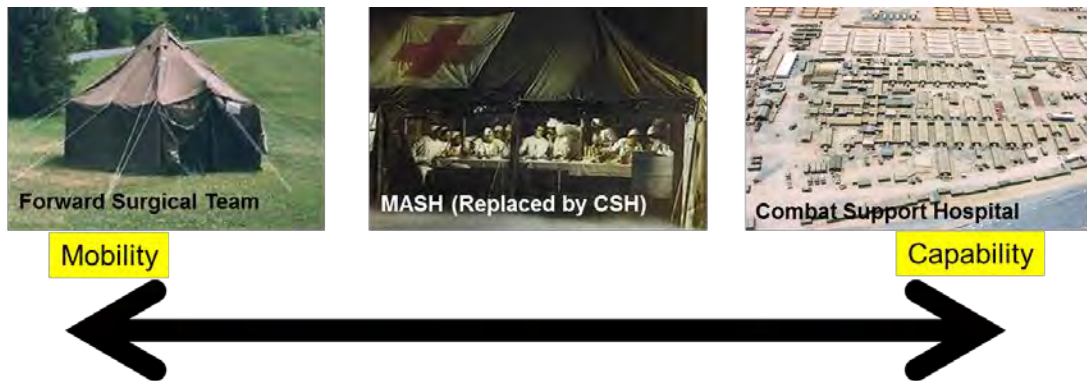


Figure 4. A forward surgical team has appropriate mobility, but lacks in the most desirable capability (from, left to right, California Army Navy Surplus website, Twenty Four Frames Word Press website, and Nessen, 2005).

Organizationally, the CSH has not modernized itself to support the full spectrum of operations. Separate from the issue of a CSH's mobility is the understanding that the operational environment has changed. The once patient demographic of 17- to 25-year-old healthy males, now includes women soldiers and civilian contractors, local national civilian women, children, and elderly, and larger quantities of detainees.

This study aims to find a task organization solution within the constraints of the current personnel allocations. This study does not look at follow on logistical and evacuation resource requirements. Although resourcing is essential to success, this study looks at the range of optimal solutions plausible for follow-on studies in actual resourcing. In following the principles of health service support and the Chief of Staff of the Army's guidance, we aim to use multi-stage stochastic optimization to identify a robust task organization for theater hospitalization that is capable of supporting the

changing mission as a unit traverses the full spectrum of operations. We look at supply and demand of units and its capability for a sustained operational tempo.

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II. LITERATURE REVIEW

A. AMEDD SPONSORED STUDIES

The AMEDD has conducted numerous studies to improve its theater hospitalization assets and the shortfalls of the CSH. The AMEDD has studied new configurations of the combat support hospital based on OIF/OEF lessons learned. However, they have not yet developed an improved role-3 medical treatment facility that has fulfilled the requirements of the Total Army Analysis process as a viable and functional facility within the current constraints.

In 2001, RAND performed an assessment of the AMEDD's deployable medical operations to identify key areas needing improvement (Cecchine, Johnson, Bondanella, Polich, & Sollinger, 2001). The authors identified four problems, two of which directly relate to this thesis. For one, the AMEDD needed to conduct further risk analysis on the effects warfare tactics, casualty timing, and casualty types had on the medical treatment facility (Cecchine et al., 2001). This proved true in years to come with the challenges the CSH faced in conventionally utilizing its force to deal with an asymmetrical battlefield, guerilla tactics, and a higher prevalence of civilian casualties in Iraq and Afghanistan. During OIF, the AMEDD had to turn to an increased and sustained utilization of forward surgical teams to support the large blast and burn injuries throughout the operational area, and the use of the last mobile army surgical hospital for the fast paced initial offensive operation into Baghdad instead of the modularized CSH (Nessen, 2005). The authors (Cecchine et al., 2001) also identified the need for medical operations planning of the medical force structure and technologies to support the future transformation concepts of the operational combat force. Based on future war-game scenarios, the AMEDD will face a mission with a larger number of casualties and a larger dispersion of combat forces on the battlefield. The AMEDD identified its solution to bridge the gap of supporting the future combat force on improving medical capabilities that would increase the survivability and immunity of the soldier, resulting in less casualties of war. "Such technologies included biostasis "pods," artificial blood, and multivalent vaccines" (p. 31). However, RAND suggested additional means to support the expected future force and

environment, because the economic, political, and scientific support for the medical advances may not be feasible. One mean to bridge the gap in supporting the future force is to make the deployable theater hospital more robust and agile to support the changing need (Cecchine et al., 2001).

RAND (Johnson & Cecchine, 2006) also performed an assessment to highlight medical concerns the AMEDD should address as the Army transformed to its Future Force. Utilizing the Caspian Sea 2.0 scenario, RAND simulated a 100-hour battle and the participants of the study assessed the casualties that resulted to assist in the design of medical assets above the brigade level for a highly dispersed battlefield. They concluded through their series of workshops, that a 44-bed CSH's surgical capability would often reach its maximum capacity to support the Future Force design even when augmented by the forward surgical teams. They suggested that a 44-bed facility was not enough to support the scenario utilized. They noted that the improved survivability of soldiers on the battlefield will actually create a higher surgical demand to support patients that immediately died of wounds in previous conflicts. They also identified the need for more evacuation assets to support the longer evacuation lines because of the inability of surgical capabilities to push forward as the battle progressed (Johnson & Cecchine, 2006).

Johnson and Cecchine (2006), identified the 44-bed mobile portion of the current CSH was potentially inadequate to support approximately four brigades in an asymmetrical warfare scenario. If the Army operates with a four brigade task force, then we will likely need a 100% mobile hospital larger than 44-beds. The simulation by RAND provides a starting point and lower limit for a viable role-3 MTF.

In 2010, the Center for AMEDD Strategic Studies (CASS) analyzed the optimized ratio of medical wards (Intensive Care Unit, Intensive Care Ward, and Operating Room) based on pre-determined suite capability bundles planned in a modular combat support hospital (Fulton, Perry, Wood, & Bewley, 2010). The study identified an optimal ratio of 1:3:11 (OR:ICU:ICW) suites, when the scenarios (stability operations through combat operations) are equally weighted, but was limited on the pre-determined capability

bundles available. Our multi-stage optimization model expands on this study by removing the suite capability bundle constraints and adds a stochastic element to the subsequent states of the system.

In 2010, RAND also performed an analysis of the CSH equipment strategy, and concluded that the Army owned more CSH medical equipment than it needed to support units through the ARFORGEN cycle and more than it had the maintenance resources to maintain and update in good condition (Lewis, et al., 2010). RAND provided various potential equipping and maintenance strategies to address these problems, but was constrained on the required equipment of the CSH. A decrease in the size of the CSH is also a potential alternative to improve the failing maintenance of CSH equipment. A decrease in the size of the CSH into a 100% mobile unit with organic transportation assets will potentially result in logistically manageable units.

The AMEDD has put in the time and effort to investigate the shortfalls and issues of the CSH. The studies support the fact that theater hospitalization is not optimal for the execution of robust and flexible medical support and identify it as a still relevant and important issue in deployable medical operations.

B. SUPPORTING FULL SPECTRUM OPERATIONS

In 1996, RAND conducted a case study analysis on recent operations other than war (OOTW), to identify differences in medical support to combat operations and recommendations to improve response efforts (Davis, Hosek, Tate, Perry, Hepler, & Steinberg, 1996). RAND concluded that one issue common to OOTW missions is termed “mission creep” or an expanding medical mission due to incomplete mission planning, changes in the operation, and an excess capacity in theater. OOTW missions tend to have relatively low patient load demand, resulting in medical commanders to depart from their original mission and take on more missions to keep soldiers busy which encourage a circular additional requirement at the tactical level. The presence of excess capability also encourages outside government and non-government agencies to pressure the non-doctrinal use of military medical assets. RAND also concluded that the patient population served and the associated medical services in OOTW missions is different than combat

operations resulting in a different type and mix of medical personnel needed. One of RAND's recommendations was the construct of a robust and flexible medical structure that is modular to allow tailored structures for changing demand and missions.

While the MRI CSH aimed to meet these recommendations, it has not fulfilled the expectations of medical operators of the CSH. In 2003, Major Derek Cooper, conducted comparative qualitative research of the MRI CSH, the 84-bed hospital company of the MRI CSH, the MASH, and the 25+ EMEDS (the Air Force modular medical capability). His qualitative analysis resulted in the MASH as the best asset based on his criteria of flexibility, deployability, mobility, full spectrum capability, and economy of footprint; however he concluded that all of the assets were not ideal. Major Cooper recommended we “design the CSH with an EMEDS building block structure” with the possibility of using the MASH as the core base structure to build upon (Cooper, 2003, p. 70).

Also in 2003, Major Paula Lodi (now Colonel Lodi, 14th Combat Support Hospital Commander, Fort Bragg, NC) conducted a case study of a series of OOTW missions. She concluded that a “MASH, FASH (forward army surgical hospital), or FSH (forward surgical hospital) would provide adequate mobility and flexibility to meet the needs of full spectrum operations, particularly small-scale contingency operations below the Corps level” (Lodi, 2003, p. iii). The FASH was a concept hospital that used a FST as the base hospital and the FSH was a concept hospital that used a MASH as the base hospital, with both adding modular components to the base as needed. She identified the design of the CSH as a viable asset to support Major Theater War operations; however it is not a suitable organization for small-scale contingency operations below corps level (Lodi, 2003). The combat support hospital has the largest medical capability on the battlefield and has the capacity to support MTW operations in which quick deployment, mobility, and logistical strain are not a key measure of combat service support performance. Recently however, as the battlefield morphs asymmetrically, the CSH has been required to perform long-term split based operations on a large demographic of patients and varying environments.

Most recently in 2005, Major Shawn Nessen conducted a qualitative case study analysis by comparing various hospital configurations in different operations. He

concluded that the Role-3 MTF capability needs to be within ground evacuation range and must be fully mobile to support the Unit of Employment (UEX and UEy) concept. He also concluded that the current practice of sustained split-based operations put severe limitations on the hospital and essentially makes it incapable of tactical operations. He recommended a modular hospital with the basic structure similar to the MASH, noting that the AMEDD would be able to build more of these smaller hospitals to allow a more flexible and sustainable medical force.

C. EFFECTS OF NON-DOCTRINAL UTILIZATION OF CSH

Based on lessons learned during Operation Iraqi Freedom and Operation Enduring Freedom, the construct of theater hospitalization still requires changes. We often utilize medical assets with less capability like forward surgical teams, but more flexibility and mobility for employment resulting in the underutilization of CSH assets on the battlefield and the overutilization FSTs and medical evacuation (Edgar, 2009). This has second and third order effects on retention, as the abundance of capability requires a higher frequency of deployment for physicians while at the same time leaving surgeons searching for board certification minimum requirements due to sporadic caseloads during the deployment (Edgar, 2009). “When the military health care system is purchasing civilian care and hiring contractors to take care of its beneficiary population at home, every decision to deploy a surgeon or keep one deployed must be a valid one” (Edgar, 2009, p. 11).

D. COMBAT SERVICE SUPPORT ASSETS DRAINING SUPPORT ASSETS

The combat support hospital has incredible capabilities with vulnerable assets and limited mission operability. A CSH is so large and dependent on non-organic transportation and logistics assets, that it diverts combat support from the priority of combat units; a major combat multiplier becomes a combat drain. For example, a 248-bed hospital needs over 13,000 gallons of water per day for full operation (Department of the Army, 2013) along with fuel to run generators to sustain blood products, sterilizers, and an air controlled temperature environment. All of which, requires additional logistic support personnel for sustenance and competes with combat unit requirements. In

addition, desired equipment items like a CT scanner that is available in a CSH, provides improved capabilities, but is extremely sensitive to operational changes and can severely diminishes the effective mobility of the hospital.

In Keith Ho's Naval Postgraduate School thesis analysis (2001), he identified the distribution of naval combat systems and its increased force effectiveness on the fleet. He utilized quantitative analysis with Lanchester and Hughes-Salvo models to show that "combat potential concentrated in a few ships has an inferior force effectiveness when compared to a fleet in which the same amount of combat potential is spread among many smaller ships" (Ho, 2001). The distribution of combat power resulted in better stability and robust capabilities. Similarly, it is possible that the distribution of medical combat power also results in better stability and robust medical capability.

Ho (2001) also cited historical examples like guerrilla organizations and the Yom Kippur War to show the benefits of distribution. He identified lessons learned where large ships with incredible capability were not invulnerable, and because of its great capability, required its focus to transition to defense of its assets. The focus on defense resulted in the consumption of valuable assets from the main mission of offense. He also discussed the mission planning aspect of combinations and permutations available with a distributed force which allows commanders the ability to make calculated risks. Similarly, the combat support hospital is such a large and critical asset, that the simple maintenance and movement of it drains the logistical system and training time of assigned personnel.

E. EFFECT OF CHANGING THE STAFFING OF MEDICAL PERSONNEL

In a 2006 study, Vaughan utilized simulation and data farming to analyze the balance of force protection space, force protection success, and time. He concluded that the tactical employment of the force protection force was essential and key to overcoming the reduction of force size. He showed simulated success of smaller forces projection of presence with the use of an increased dispersion of smaller tactical units (Vaughan, 2006). Therefore, the success of a smaller unit requires a larger dispersion

between units to sustain the overall same mission set. If we make the CSH smaller, the new capability must have the ability to sustain a larger dispersion to maintain the current expected mission.

F. UNCERTAINTY

Decision makers primarily cope with uncertainty by reduction, assumption-based reasoning, and weighing pros and cons (Lipshitz & Strauss, 1997). When a decision maker has an inadequate understanding of a situation they manage it with reduction by extrapolating based on available information, making the written doctrine and training critical in the decision making process. So, although a commander may have the leniency to mold a modular task force, if there is uncertainty, they will favor following the normal mode of doctrine or past utilization methods. When a decision maker has incomplete information they manage it by assumption based reasoning to fill the incomplete information. Our model attempts to assist the decision maker in an objective and quantitative assumption based decision.

A formal quantitative method to decision analysis helps a decision maker overcome and analyze risk by explicitly accounting for uncertainty in the process (Peterman & Anderson, 1999). Peterman and Anderson (1999) identified that “the resulting optimal decision is often different from the one that would have been chosen had the uncertainties not been taken into account quantitatively” (p. 231). In analyzing the employment of a CSH, operators can benefit from a decision support tool to support attaining an optimal solution.

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III. DATA AND METHODOLOGY

A. MODEL DESCRIPTION

We present a multi-stage optimization model. It takes historical hospital admissions data from previous military operations along with a medical commander's mission expectations and assessments to provide a quantitative analysis of the optimal hospital configuration for a role-3 MTF. The goal of this model is to minimize the number of beds initially deployed while considering the optimal configurations of potential future missions.

If we look specifically at combat operations, we can break it into three significant phases of operations; initial entry operations, combat operations, and stabilization operations. The model takes into account the operations of the hospital over the entire lifetime of the engagement. We divided the engagement into stages, for example each stage could be a period of three months. We assign each stage a type of operation, one of: initial entry operation, combat operation, stabilization operation. The commander builds a probabilistic scenario tree of how the operation might develop (see Figure 5). The tree describes the likelihood of transition from one type of operation to another, as the engagement develops. For example, in Figure 5, we begin with initial entry operations, and have a probability p_e we will remain in initial entry operations at the end of the stage 1 time period. Similarly, with probabilities p_e and p_s , we will transition to combat and stabilization operations respectively at the end of stage 1. Furthermore, given we remain in initial entry operations at the end of stage 1, we will transition to combat operations at the end of stage 2 with probability $p_{e,c}$.

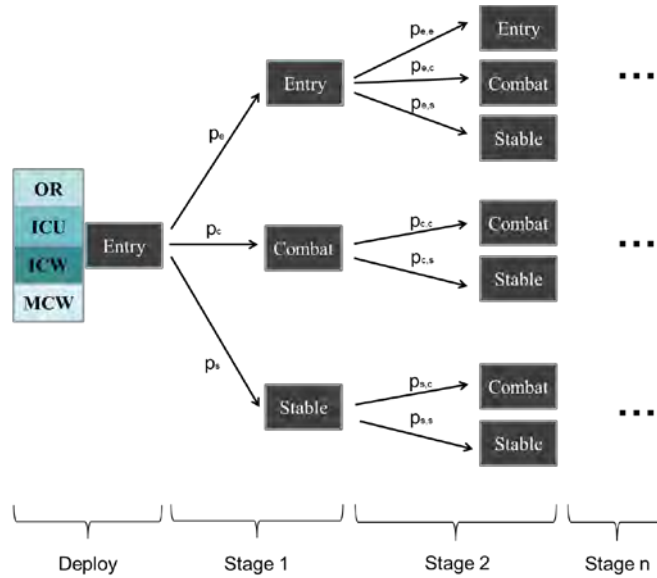


Figure 5. A pictorial description of the scenario over time. The conflict starts in entry operations, with probability p_e it will remain in entry operations at the end of stage 1 time period. Similarly, with probabilities p_c and p_s it transitions to combat or stability operations respectively. The multi-stage tree describes the probabilistic development of the entire engagement that the hospital faces.

The stages of the scenario tree come from the commander's intuition and from directed operations orders that provide the planned timeline and potential future missions. We can proactively plan and optimize our initial deployment package based on our best assessment of the probability of the follow-on mission in the timeline stage. We can optimize our initial deployment package and plan the phased addition of our assets at the optimal time, instead of reactively making the changes if and when the order occurs. The mathematical model to determine the optimal deployment of the hospital is as follows:

B. INDEX

$w \in \text{ward}$	type of ward capability [~4]
$p \in \text{patient}$	type of patients [~7]
$i \in \text{injury}$	category of injury [~3]
$h \in \text{history}$	history to the current stage [~11]
$p(h) \in \text{history}$	parent history of h , the scenario preceding h [1]
$op \in \text{operations}$	types of military operations [~6]
$op(h) \in \text{operations}$	the current operation type for history h [1]

Our ward set is based on the major wards available and utilized in a role-3 MTF where $w \in \text{ward}$ includes the operating room (OR), intensive care unit (ICU), intensive care ward (ICW), and minimal care ward (MCW). We could extend this set to include other wards like physical therapy and pediatrics as desired. We identify the types of patients that visit these wards by our set $p \in \text{patient}$ that includes demographic groups of patients like U.S. Army soldiers, Other U.S. military, coalition forces, U.S. government civilians, contract employees, indigenous population, and prisoners of war. Our injury set is based on the available data where $i \in \text{injury}$ includes disease, non-battle injury, and battle injury. The prevalence of the injury type is different based on the type of patient. We assume the treatment time in a ward is the same across patient types, but differs according to injury types. The $op \in \text{operations}$ set are all operation types studied. The types of operations could expand to include other things like peacekeeping operations, detainee operations, humanitarian missions, and defensive operations. The $op(h) \in \text{operations}$ set is the current operation type for history h . For example, in Figure 6, $op(h)$ is Stab.

The $h \in \text{history}$ set includes names for the paths in the scenario tree. We can extend this set out infinitely to include the number of stages desired in our model. In Figure 6, for the highlighted path, the h is InitComStab. The $p(h) \in \text{history}$ set is the parent history or scenario preceding h . For example, in Figure 6, $p(h)$ is InitCom.

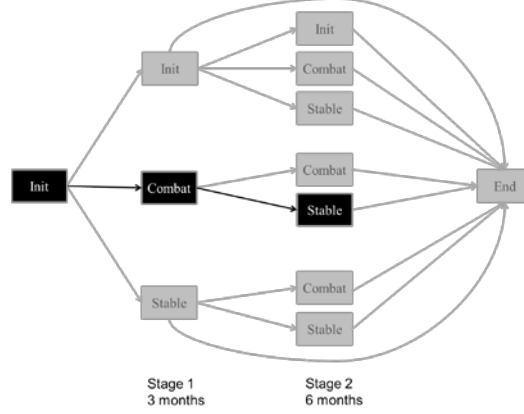


Figure 6. The scenario tree for a two-stage scenario. The highlighted path in the scenario tree represented in the set h is InitComStab and in the set $p(h)$ is InitCom.

C. GIVEN DATA

$rate_{p,op(h),i}$	95 percentile admission rate for a patient p with injury i in the current operation type for history h [person admitted/1,000 troops]
$time_{w,i}$	average time a patient with injury i will spend in ward w [hours]
$beds_w$	number of beds in a unit w (1 if configuring on beds, else # of beds in a ward) [beds/ward]
$hrs_per_day_w$	time in a day a bed in ward w can be in use [hours/day]
pax_needed_w	medical personnel needed per unit size of w (beds or ward) [person/ward]
med_pax_h	number of medical personnel assigned to the hospital in a given path h [person/hospital]
$troops_h$	number of army troops treatment provided to in a given path h [person]
$prob_h$	probability of a given path h [probability]
$need_{h,w}$	the number of beds we need for each ward and scenario [beds/ward]
	where $need_{h,w} = \frac{troops_h \cdot \sum_p \sum_i (rate_{p,op(h),i} \cdot time_{w,i})}{hrs_per_day_w}$, $\forall h, w$
$c_penalty_w$	penalty assessed for changing the configuration of w [utility]
$o_penalty_w$	penalty assessed for taking too much capability of w [utility]
$s_penalty_w$	penalty assessed for the slow reaction of providing assets of w [utility]

The data utilized for this study came from the Center for AMEDD Strategic Studies (CASS), a component of the Medical Capabilities Integration Center of the AMEDD. It primarily came from two published studies.

The first was a study by Wojcik, Davis, Humphrey, Stein, and Hassell in 2005, that developed a Disease and Non-Battle Injury Model utilizing recent peacekeeping (Bosnia and Kosovo) and combat operation's (Desert Storm and Desert Shield, OIF, and OEF) hospital admission data. They presented the 95 percentile admission rates for recent operation types of various soldier demographics. They concluded that the admission rates were different during the phases of a combat operation and between peacekeeping and combat operations. Their data analysis was on patient admission rates at role-3 MTF for various injuries and diseases of numerous demographics of patients in recent war-fighting operations (Wojcik, Stein, Humphrey, & Hassell, 2007).

The second was a continuation study by Wojcik, Stein, Humphrey, and Hassell in 2007 that further analyzed OIF/OEF data to identify the admission rates, length of stay, diagnosis, and disposition for various patient categories (i.e. U.S. Army, U.S. military, POW, contract employee, etc.). They identified the effect and planning factors for non-U.S. military patients on the Army medical system. They concluded that the use of just military patients in theater medical planning will result in an underestimation, and the addition of multinational and civilian population patients will result in a different medical requirement compared to the relatively healthy U.S. Army soldier.

Based on these studies and its associated data, CASS provided us with the 95 percentile daily admission rates per 1,000 deployed soldiers by phase of combat operation and injury type, $rate_{p,op(h),i}$. CASS derived the parameters from the Contingency Tracking System of the Defense Manpower Data Center and the Standard Inpatient Data Records from the Patient Administration Systems and Biostatistics Activity (Center for AMEDD Strategic Studies, 2012). CASS also provided us with expected treatment times in a medical treatment facility ward for various injury types, $time_{w,i}$. They developed this data based upon a survey and focus group of subject matter

experts that estimated times a wounded or disease patient would spend in each ward of a role-3 MTF.

The $hrs_per_day_w$, $beds_w$, and pax_needed_w parameters are dependent on and adjust the available unit sizes. The $hrs_per_day_w$ parameter provides the number of hours we can utilize a bed/suite in ward w per day. This specifically addresses continuous work rest cycles of surgeons in the operating room. The current MRI CSH Operating Room (2 OR tables) is doctrinally capable of sustained operations for 36 hours. The $beds_w$ parameter allows us to optimize over the individual bed or the number of suites. We can set the parameter equal to one to optimize by the individual bed or set the parameter equal to a number greater than one to represent a set number of beds per suite. For example, an ICU bed has 24 hours of utilization, so a single ICU ward has a total of 288 hours.

The med_pax_h , $troops_h$, and $prob_h$ parameters are situation dependent and determined by the combat operations and logistical capacity. A medical commander will have a form of expectation for the phased timeline of the operational mission $prob_h$, the number of planned units deploying $troops_h$, and can analyze the number of medical personnel they will take, med_pax_h .

The $need_{h,w}$ parameter tells us how many beds we need for each scenario and ward. The admission rate data for a patient ($rate_{p,op(h),i}$) is presented as a proportion of 1,000 U.S soldiers. We multiply this admission rate by the respective time the admitted patient would spend in a ward and add over the injury type and patient type, giving us the total expected bed time needed in a ward for all patients admitted. We then scale this by the thousands of soldiers supported and divide by the hours per day a bed in a ward is used. We do this for the current operation type of each history and over all wards.

The three penalty parameters are specific to the individual medical commander and represents where they may be more comfortable taking a small risk. We assess a penalty every time we adjust the size of a ward in the hospital, $c_penalty_w$. This penalty

models the cost of adding and removing capability from the field and can be associated with actual logistic costs for moving assets in and out of theater. We also assess a penalty to model the negative effects of having an over capacitated hospital, $o_penalty_w$. This penalty makes sure we don't cause a drain on movement and logistics with excess, and can also be associated with contract costs for CONUS replacements of medical providers deployed. The last penalty term, $s_penalty_w$ models the cost of not anticipating increases in demand. In the model, a commander always brings sufficient capability to serve the demand. However, if the capability is not available ahead of time, before the additional demand arrives, we assess a slow response penalty, $s_penalty_w$. We can utilize multi-criteria decision making analysis to relatively assess these penalties and sustain transitive properties for the medical command team (Kahraman, 2008). The penalty parameters must be greater than or equal to one.

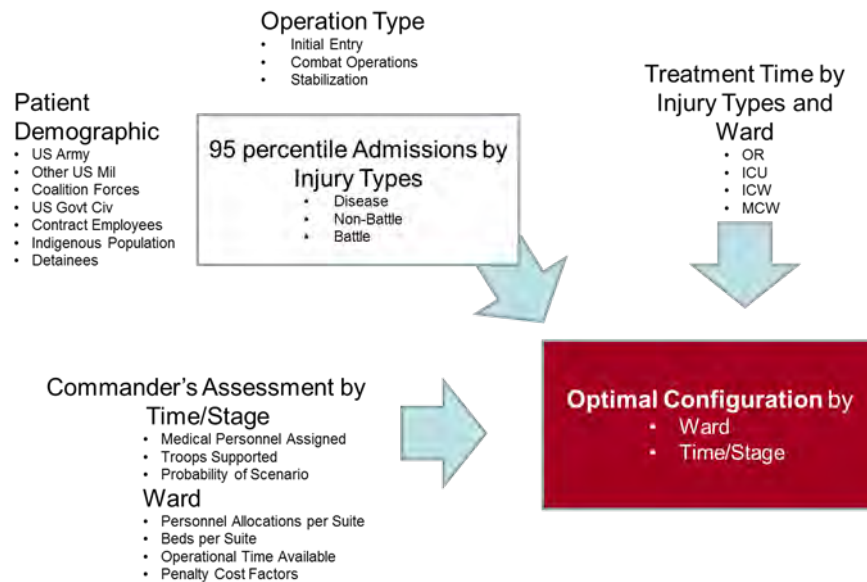


Figure 7. We feed parameters into the model from data analyzed by CASS and the scenario assessments by an individual commander utilizing the model.

D. DECISION VARIABLES

$Y_{h,w}$	the number of beds we take for each ward and scenario [beds]
$SLOW_{h,w}$	accounts for the slow response when we take too few beds [beds]
$CHANGE_{h,w}$	how much bed adjustments are made to the hospital [beds]
$OVER_{h,w}$	accounts for taking too many beds [beds]

The $Y_{h,w}$ integer variable tells us the optimal number of beds to deploy for each scenario and ward, to make sure we optimize on executable sizes. We also use positive variables to account for the change, overage, and slow response that occur at each stage.

E. FORMULATION

$$\min \sum_w Y_{init,w} \cdot c_penalty_w + \left(\sum_h prob_h \cdot \sum_w (CHANGE_{h,w} \cdot c_penalty_w + SLOW_{h,w} \cdot s_penalty_w + OVER_{h,w} \cdot o_penalty_w) \right) \quad (1)$$

s.t.

$$med_pax_h \geq \sum_w \frac{pax_needed_w}{beds_w} \cdot Y_{h,w} \quad , \quad \forall h \quad (2)$$

$$need_{h,w} \leq Y_{h,w} \quad , \quad \forall h, w \quad (3)$$

$$need_{h,w} - Y_{p(h),w} \leq SLOW_{h,w} \quad , \quad \forall h \neq 'Init', w \quad (4)$$

$$Y_{h,w} - need_{h,w} \leq OVER_{h,w} \quad , \quad \forall h, w \quad (5)$$

$$Y_{p(h),w} - Y_{h,w} \leq CHANGE_{h,w} \quad , \quad \forall h \neq 'Init', w \quad (6)$$

$$Y_{h,w} - Y_{p(h),w} \leq CHANGE_{h,w} \quad , \quad \forall h \neq 'Init', w \quad (7)$$

F. OBJECTIVE FUNCTION DISCUSSION

The objective function (1) sums over all wards two groups of terms. The $Y_{init,w}$ variable in the first term allows us to record the optimally smallest number of beds to initially deploy with. We weigh it with the initial cost to take the medical force, $cPenalty_w$.

The second term in the objective function adds a proportionate penalty based on two things: the total changes in beds required and the probability of the future mission set. Each path from the start node to the end node has an associated probability of

occurrence. For each path, we weigh the probability of the path by a penalty for the changes that need to occur.

G. CONSTRAINT DISCUSSION

Equation (2) ensures that we do not utilize more than the number of personnel we assign to a role-3 MTF, while making sure we have enough personnel to maintain and care for the number of beds we take in each ward for all scenarios. Constraint (3) ensures we take at least what we need in each ward. Constraint (4) accounts for the difference in what we had on-hand in the previous stage and the amount we need in the current stage; our slow reaction to need. Constraint (5) accounts for the amount we have more than what we need, and constraints (6) and (7) make the amount of change in absolute value.

H. MODEL ASSUMPTIONS

This model has some critical assumptions. For one, we assume that the current medical personnel assignment per ward is optimal. We utilized the current ratio of personnel to suite/bed as the optimal configuration. This is a conservative estimate since there is built in redundancy into the personnel structure during non-critical timeframes.

Secondly, we assume that the current evacuation assets will also evolve and undergo a configuration change to equivalently support all evacuation requirements previously rendered. If we break the larger CSH into smaller components, this will result in longer evacuation lines, a larger dispersion of medical assets, and more required evacuation stops. A CSH can always fall back on ground evacuation assets; however that is not the ideal situation. Air evacuation assets must be capable of at least equivalent evacuation support as previously rendered.

We also assume that the hospital size has a positive correlation to mobility, flexibility, and adaptability. Based on the literature review and historical case studies, this appears to be a safe and correct assumption.

Finally, we assume that the data from previous engagements are comparable to the future rates. We have not had a near-peer opposition force in recent history with our current medical technologies.

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IV. ANALYSIS

The purpose of this analysis is to demonstrate the planning and analysis potential of this model and it does not represent any current operational plan. We intentionally simplified the scenarios in this section to simplify the explanation while sustaining the purpose of demonstration. The base case analysis is a medical treatment facility supporting a task force of 4-5 brigade combat teams (BCT).

We formulate our model in the Generalized Algebraic Modeling System (GAMS) and solve it utilizing the integer linear program Cplex 12 (GAMS, 2012). The solution found by Cplex minimizes the number of beds initially deployed while considering the optimal configurations of potential future missions. The model takes less than one second to solve for all the scenarios we analyzed, but the solver time is relative to the cardinality of the sets used. Our largest model analyzed consisted of about 200 continuous variables, 50 integer variables, and 250 constraints.

We utilized a two-stage optimization, although the model is capable of multiple stages to identify the optimal hospital size. The analysis has five parts.

We start our analysis with an optimization of the hospital based on the current suite configurations already existent in the CSH. We do this across all types of operations to see if and when the current suite configuration has slack or bounds the optimization. For this portion of the analysis, we make sure we always have more than we may need by using a large $sPenalty_w$.

In the second part of the analysis, we look at the optimal role-3 MTF unconstrained by the size of the current suites over the different types of operations and by the phases of combat operations. For this portion of the analysis we seek a lower bound for the potential optimal hospital size, so we keep all penalties equal.

Then, we investigate optimal hospital sizes that occur with exaggerated injury rates. We utilize the combat phases of recent operations to conduct sensitivity analysis on whether our optimal initial hospital is capable of supporting injury rates three times those seen in OIF. We also look at the optimal role-3 MTF over the full spectrum of

operations. We utilize both combat and peacekeeping operations admissions data and compare the optimal hospital sizes through the scenario stages.

Next, we analyze the effect a commander’s imposed risk penalty has on the optimal size of the hospital. We base the risk on the commander’s decided priority between sustaining a small contingency, minimizing the changes required, and ensuring a quick response to the required need. We reflect the commander’s priority by changing the penalties in the model.

Finally, we investigate if the optimal hospital size supports the Army’s strategic plans. We utilize a potential hospital size based on our previous optimization and analyze its sustainability within a cycle of deployments otherwise known as the Army’s force generation (ARFORGEN) cycle.

A. OPTIMIZING USING THE CURRENT SUITE CONFIGURATION

Currently, a 248-bed CSH is comprised of 3 OR suites, 10 ICW suites, and four ICU suites. The MCW suites are augmentation assets added to the CSH as required. We do not count the surgical tables in the aggregated CSH size. The enumerated beds per ward are in Table 2:

Ward	Wards per CSH	Beds per Ward	248-bed Aggregate
OR	3	2	Not counted
ICU	4	12	48
ICW	10	20	200
MCW	0	40	0

Table 2. The breakdown of the 248-bed CSH by the number of wards in the CSH, and the number of beds in each ward. The 248-bed aggregate count consists of the ICU and ICW beds (after Center for AMEDD Strategic Studies, 2012).

1. Results

Based on our model and the operations studied, the 248-bed CSH was larger than required for the last 20 years of Army operations. The model produced optimal hospital configurations for recent operations when we utilize the current CSH suite size, as shown in Table 3.

	Total	OR	ICU	ICW	MCW
Bosnia	72	1	1	1	1
Kosovo	92	1	1	2	1
OIF	92	1	1	2	1
OEF	124	1	2	3	1
Current 44-bed	44	1	2	1	As Needed
Current 84-bed	84	1	2	3	As Needed
Current 164-bed	164	2	2	7	As Needed
Current 248-bed	248	3	4	10	As Needed

Table 3. The model results for a hospital supporting 20,000 soldiers utilizing the various conflict admission data. The 248-bed CSH has more bed capacity than the optimal hospital in all operations studied (after Center for AMEDD Strategic Studies, 2012).

2. Analysis

Based on our model results, the current 248-bed CSH has more bed capacity than the optimal hospital configurations for all operations studied. The 164-bed CSH had sufficient bed capacity for all operations, with slack to provide a cushion for variance in larger admissions rates in unknown environments. This cushion however comes at the expense of unnecessary personnel deployed, excess equipment and logistics costs, and reduced mobility of the hospital. The 84-bed company had sufficient bed capacity and most closely matched the optimal hospital configuration of all operations (Figure 8). The 44-bed early entry element did not meet the optimal initial configuration for all operations.

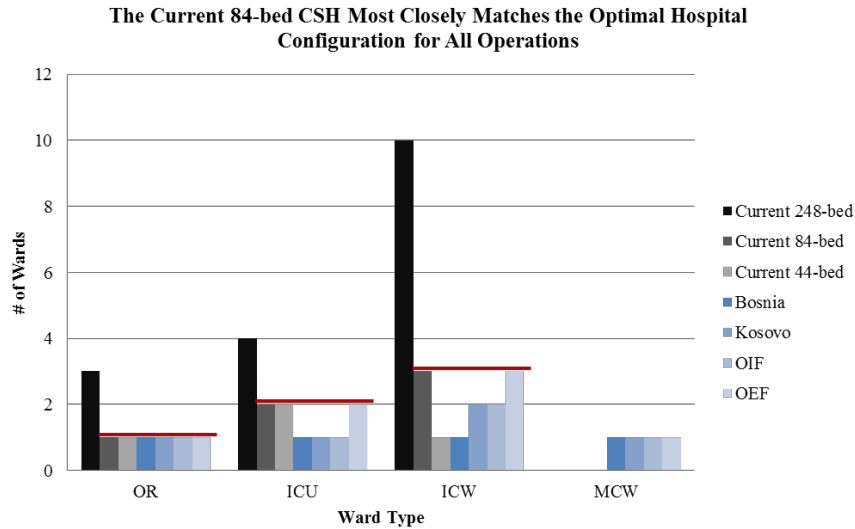


Figure 8. The 248-bed CSH had excess bed capacity for all operations analyzed. The 44-bed CSH lacks bed capacity for all operations analyzed. The red lines show that the 84-bed has enough bed capacity for all operations (after Center for AMEDD Strategic Studies, 2012).

Using current suite sizes in the reorganization of role-3 MTFs, minimizes the cost of adjusting operations, while at the same time, moves in the direction of an agile and appropriate force structure. Based on this model, an 84-bed medical treatment facility has sufficient bed capacity to support the expected 95 percentile admissions rate of 20,000 soldiers in future similar operations. In terms of personnel and equipment, we could potentially split the 248-bed CSH into two 84-bed facilities with the resources to have additional augmentation ICU, ICW, and MCW teams. The smaller hospitals could operate autonomously or we can build a larger facility by combining 84-bed hospitals or adding augmentation wards to an 84-bed hospital.

The 248-bed hospital has excess that hinders its mobility to provide proximal care. Doctrinally, the role-3 MTF needs to have control to adjust a flexible hospital task organization that can conform to the operation. A smaller hospital will inherently have more mobility to provide the most proximal care.

B. HALF-SIZED SUITES FOR HOSPITALS

Although we optimized the hospitals, there is still excess bed capacity because the suites are integer constrained. Reducing the size of the suite is one step to increasing the flexibility of the role-3 MTF configuration and increasing the control afforded to commanders.

1. Using Half the Current Suite Size

If we break the current suite configurations in half so that the ICU has six beds, the ICW has ten beds, and the MCW has 20 beds, we can reduce the excess capability sustained. The most difficult and unreasonable suite to reduce in size is the OR suite, because too many personnel positions and equipment allocations provide overlap in sustaining two OR tables as one suite. For this analysis, we maintain the OR suite with two operating tables.

Utilizing the half-sized suites as the variable size, the model results in the following configurations:

	Total w/current CSH suite constraint	Total w/suites half of current size	Difference Of Totals	OR	ICU	ICW	MCW
Bosnia	72	46	26	1	1	2	1
Kosovo	92	56	36	1	1	3	1
OIF	92	56	36	1	1	3	1
OEF	124	108	16	1	3	5	2
Current 84-bed	84	84		1	4	6	As Needed
Current 164-bed	164	164		2	4	14	As Needed
Current 248-bed	248	248		3	8	20	As Needed

Table 4. The optimal aggregate hospital size for various conflicts with smaller suites. Smaller suites reduce the total hospital size while maintaining care for the 95 percentile admission rate. The smaller suites reduce the excess bed capacity that results when we constrain the suites to integer values (after Center for AMEDD Strategic Studies, 2012).

When we utilize a smaller suite size as the basis, we can get closer to the optimal hospital. The difference in aggregate bed capacity indicates the potential savings that occurs when we utilize a smaller suite (see Table 4). A smaller suite supported by a

commander deploying an optimal hospital size, has the potential for 16-36 less required beds; this results in less medical practitioners deployed per medical treatment facility used. The second and third order cost factors of having excess medical practitioners deployed like replacement contractors in CONUS, retention, and logistics support are compounding.

Based on this optimization, we propose a 124-bed CSH that is comprised of the 84-bed CSH and two 20-bed MCWs as the upper bound for the role-3 MTF size. In addition, we propose making the ICU, ICW, and MCW half of its current suite size to further reduce excess assets deployed. Doctrinally splitting the unit and suites improves health services by providing the medical commander more flexibility and control in the medical employment of smaller units.

2. Minimal Hospital Sizes

Currently our Army has a brigade centric force structure; therefore we will limit our model parameters to support the BCT environment. Operationally, we deploy about 3–5 BCTs in a Task Force, equaling somewhere between 9,000 to 20,000 soldiers. For this portion of the analysis, we utilize data from both Operation Iraqi Freedom and Operation Enduring Freedom. We based the optimal initial deployed hospital on the sequential transition from initial entry operations to combat operations to stability operations.

While we would never downsize our hospital suites to individual beds, the following analysis explores the optimization by individual beds to look at the lower bound of the aggregate optimal hospital size. This is highly dependent on our assumption that we can equip and break down key personnel optimally by bed.

The following results reflect the optimal number of initially deployed beds when we change the number of troops supported:

The Optimal Hospital Size Based on the Number of Troops Supported

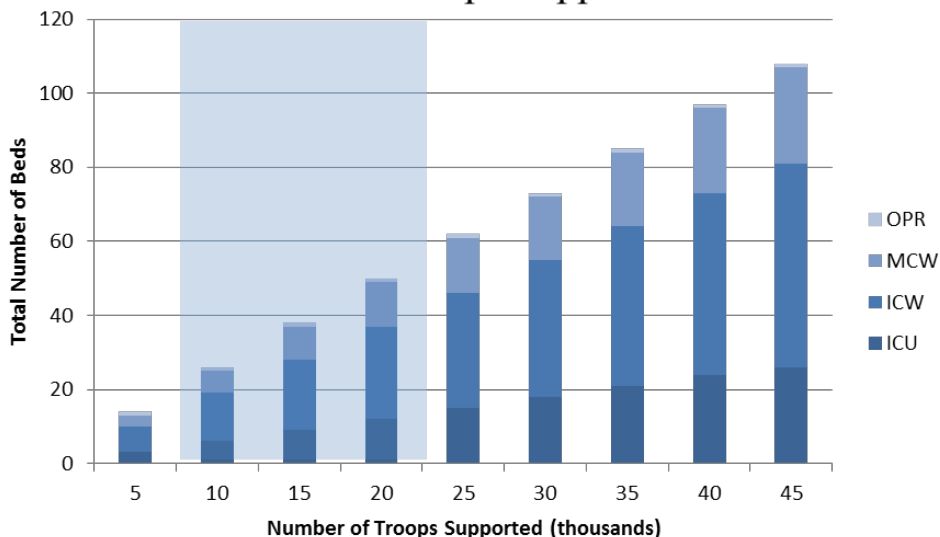


Figure 9. If we assume that a role-3 MTF will support the brigade centric Army that organizes into a 3-5 BCT task force, then the role-3 MTF will need to support between 9,000 to 20,000 soldiers. This results in an aggregate hospital capacity of approximately 44-beds. Our current 248-bed CSH can support far more than how the Army will operationally employ them (after Center for AMEDD Strategic Studies, 2012).

The results in Figure 9 show, not surprisingly, a relatively linear increase since we are linearly increasing the number of troops supported. This example is important in communicating the discrepancy of the role-3 MTF we need and the role-3 MTF we currently have. If the next contingency has similar admission rates and treatment times as those encountered during OIF and OEF, then in order to support a BCT force structure we would optimally deploy a treatment facility between 25-49 beds. This size relates relatively well to the 44-bed element of the current CSH. The current configuration of a 248-bed CSH has the capability to support far more soldiers than we would operationally use it for.

In the previous section, the 44-bed early entry element did not have enough bed capacity to support all operations, but when we remove the integer constraint of suite sizes an aggregate 44-bed hospital is ideal. This makes it a good lower bound for the optimal hospital size.

C. SCENARIOS OF LARGER CASUALTIES

When considering smaller medical units, the scenario of most concern is a contingency that results in a larger number of casualties. We utilized our model to look at the optimal hospital size when we increase select injury types in combat operations.

1. Results

If we double the battle injury admission rate, the role-3 MTF needs a 70-bed hospital, similar in size to the MASH. If we triple the battle injury admission rate, the role-3 MTF should be at least 90-beds. The current CSH capacity exceeds the required capacity ranges for all increased injury scenarios studied (see Figure 10).

2. Analysis

We expect future weapons to cause even more and increased violent injuries, at the same time we expect medical advances that will sustain an evacuated patient for longer periods and with a better probability of survival. The key to supporting the increase in injuries is the capability to augment and/or combine our role-3 MTF capabilities when required in later operational stages. The optimization model supports a smaller role-3 MTF that has the capability to combine and add augmentation teams to construct an optimal hospital for unknown future scenarios.

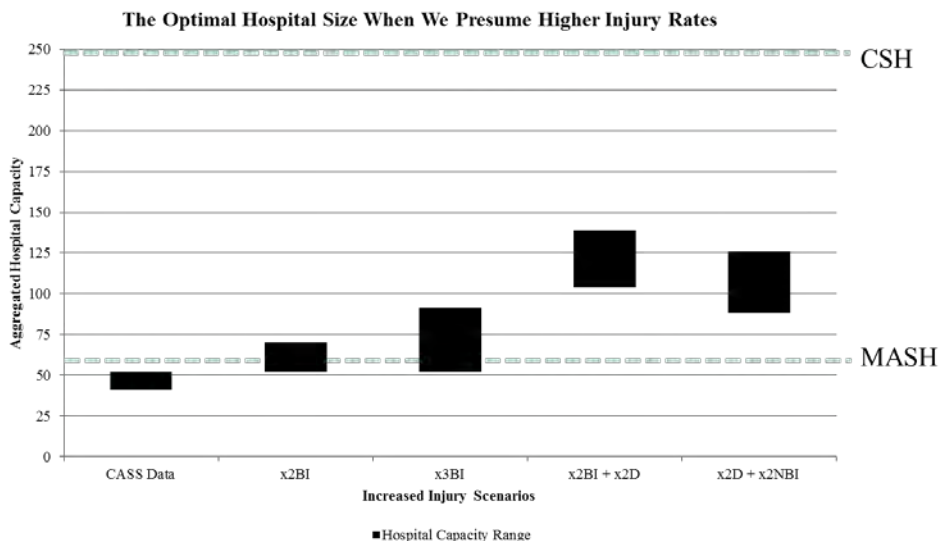


Figure 10. The black bars represent the range of hospital sizes needed through phases in combat scenarios with increased battle injury (BI), disease (D), and non-battle injury (NBI) admission rates. The dotted blue lines represent the bed capacity of recent role-3 MTF units. If future operations result in three times the battle injuries admission rates (x3 BI) in recent conflict, a 60-bed facility like the MASH will require augmentation to support 20,000 soldiers. The CSH has more capacity than optimally needed to support three times the battle injury rates (after Center for AMEDD Strategic Studies, 2012).

D. OPTIMIZING OVER A FULL SPECTRUM OPERATION SCENARIO

The Army also deploys in support of Operations Other than War (OOTW). OOTW missions are very sensitive to overcapacity of a medical treatment facility, because of the continuous mission creep potential (Davis et al, 1996). Historically, we deploy elements smaller than our current 248-bed CSH (see Table 5).

Operation	Location	U.S. Military Deployed	# Echelon-III Beds	Source
Joint Task Force Andrew ('92)	Florida	22,800*	20	GAO 1993b / Carroll 1996
Provide Relief/Restore Hope ('92/'93)	Somalia	17,000	42	Stewart 1994
Provide Promise ('92-'96)	Croatia	38,000**	60	Wentz 1999
Uphold/Restore Democracy ('94/'95)	Haiti	20,000	52	Deal 1997
Implementation Force (IFOR) ('96)	Bosnia	20,000	60	Kozarvn 1997/ERMC 2003
Stabalization Force (SFOR) ('97+)	Bosnia	8,500	24-to-16	ERMC 2003***
Task Force Hawk ('98)	Albania	5,500	18	Moloff 2001

*Hospital served both military personnel and civilians affected by the hurricane
 **The U.S. hospital primarily served United Nation forces; only about 2000 of the 38,000 troops were U.S.
 ***European Regional Medical Command

Table 5. Historical examples of hospitalization support provided for small-scale contingencies in the 1990s (from Cooper, 2005). Our 248-bed CSH is far larger than we needed to support OOTW missions in 1990s.

The following analysis utilizes 95 percentile admission rates from OIF, OEF, Bosnia, and Kosovo, to look at a robust optimal configuration. We conduct the analysis utilizing a hypothetical situation for demonstrational purposes.

1. Results

If we expect the probability and troop strength parameters depicted in Figure 11, then our model identifies the optimal hospital size at each stage of the expected scenario. Our model for this specific scenario shows a 40-bed difference between a robust hospital that is optimized by individual beds versus a robust hospital optimized by the current CSH -suite size. In general, a hospital optimized on the current CSH suite size deploys excess capacity at all stages.

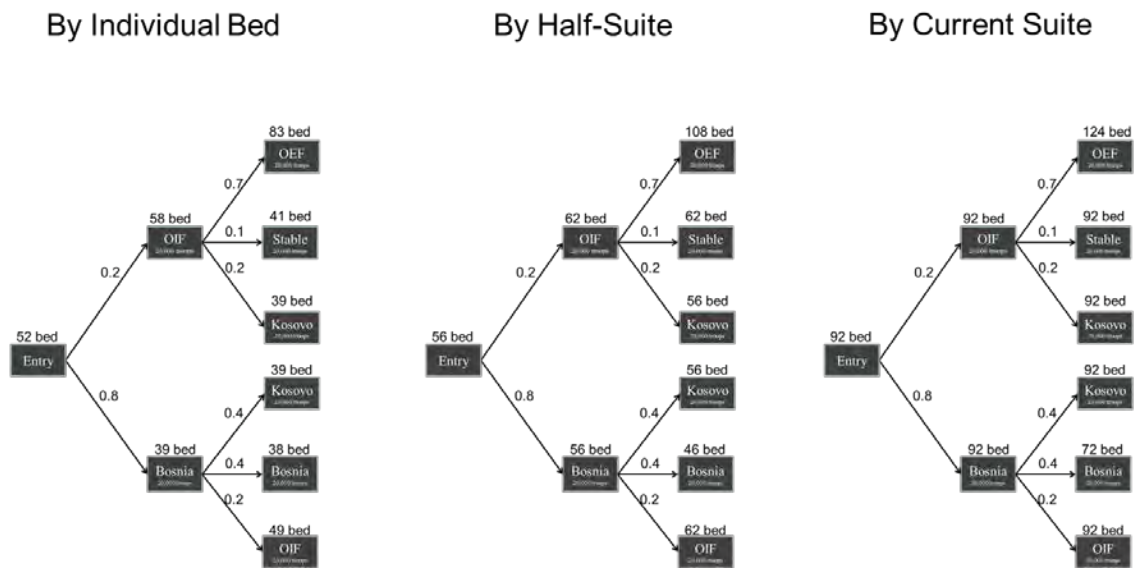


Figure 11. Utilizing the same situation parameters on a full spectrum of operations, the optimal hospital for this specific scenario is less than 92-beds and more than 52-beds. There is a 40 bed difference between the current optimal CSH deployment and the ideal optimal CSH deployment. The current suite configuration does not provide enough flexibility for a commander to conform role-3 MTF care to the required operation (after Center for AMEDD Strategic Studies, 2012).

2. Analysis

Utilizing this model, we can analyze a number of scenarios and operation types that are plausible for the future situation. In full spectrum operations, we deploy the medical facility to support combat operations and stability operations. We do not designate or configure a hospital for a specific operation type, but rather expect them to have the capability to conduct all operation types. Smaller suite sizes will allow commanders to better tailor their unit to the required changes of the battle space.

The current larger suite sizes make the hospital less flexible to scenario stages. The half-suite optimization provides a potential configuration that improves the rigidity of the current CSH.

E. COMMANDER'S RISK ASSESMENT EFFECTS ON CONFIGURATION

The model also incorporates a penalty parameter to allow a commander to impose priorities within the model. A high $oPenalty_w$ would be assessed when a commander needs to reduce the footprint of his assets; potentially used in scenarios where we don't want to portray an escalation of force or during a drawdown. Utilizing a high $sPenalty_w$ occurs in scenarios where a commander needs to plan for the worst case; potentially we can use it in scenarios where the timeline for transition to the next stage of operation is unknown or during a planned operational surge. A high $cPenalty_w$ will support scenarios where we have less flexibility in adding or removing units from the operational theater; for example when logistics costs for insertion is high or when deployment cycles are established and changing them causes a domino effect for other deploying units.

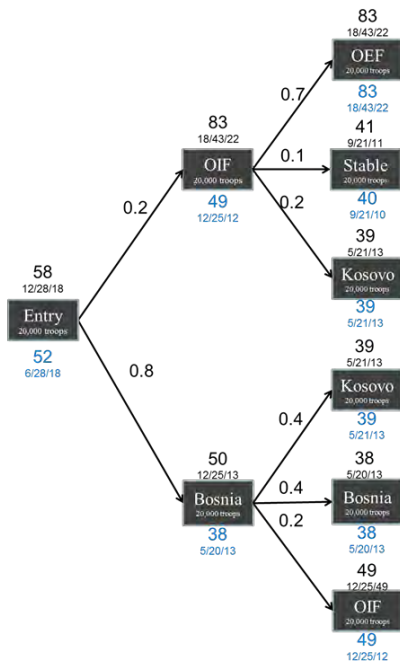
1. Results

When we utilize a high $oPenalty_w$, the optimal initial hospital is within mid-range and smaller than when we utilize a high $sPenalty_w$. When we utilize a high $cPenalty_w$ we reduce the fluctuation of optimal hospitals throughout the scenario stages. In all risk assessments, the optimal initial hospital deployed is not the largest hospital required throughout the scenario (see Table 6).

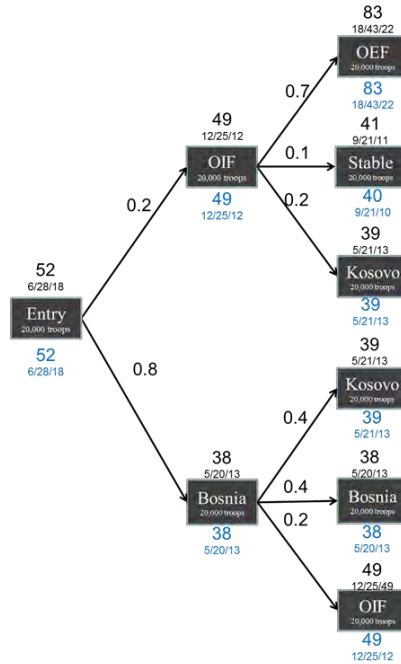
Commander's Risk Scenarios									
Penalty	A. Reduce the Footprint: Take What We Need			B. Reduce the Slow Reaction of Medical Forces: Have More Than We Need			C. Rigid Force: Don't Allow the Medical Force to Easily Change		
	Over	Slow	Chng	Over	Slow	Chng	Over	Slow	Chng
	100	1	1	1	100	1	1	1	1
Init	52			58			52		
Range	38-83			38-83			52-83		

Table 6. A snapshot look at the extremes of a commander's imposed risk penalty assessments. When we need to reduce the footprint of our hospital in OOTW missions our initial optimal is smaller than when we ensure we have more than we need. When we make the force more rigid and limit the changes across scenario stages, the range of optimal hospitals decreases; we take more capacity than required (after Center for AMEDD Strategic Studies, 2012).

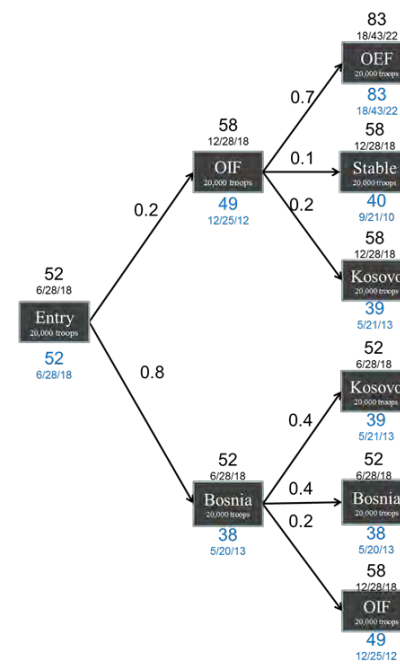
High Slow Response Penalty



High Over Capacity Penalty



High Change Penalty



Total Optimal Beds Taken
ICU/ICW/MCW

Total Beds Needed
ICU/ICW/MCW

Figure 12. The optimal configuration of the hospital for penalty scenarios at each stage is in black. The hospital capacity needed for a given stage of a scenario is in blue. We show the optimal hospital configuration down to the individual wards to explain some non-intuitive results. (after Center for AMEDD Strategic Studies, 2012) .

a. High Slow Response Penalty

A high $sPenalty_w$ would push our hospitals to take more than needed. Intuitively, we expect an 83-bed initial hospital, the largest hospital over all stages in the slow response penalty scenario. However, the optimal initial hospital is 58-beds (see Figure 12). The 58-bed initial hospital is the optimal hospital size that satisfies the current need and the need in the immediate upcoming stage 1 for each ward. Although an 83-bed hospital is the optimal capacity we would take in stage 1, it is not the required need for stage 1. The 58-bed hospital satisfies the maximum beds needed for each ward in the current and next stage.

b. High Overcapacity Penalty

For a high overcapacity penalty, the optimal initial hospital is 52-beds (see Figure 12). The high overcapacity penalty keeps the hospital as close as possible to the required need at each stage.

c. High Change Penalty

When we assess a high change penalty, the range of the optimal hospitals decreases (see Figure 12). Just like in the slow response penalty scenario, the need of each ward is driving the optimal configuration. For example, in the path from Bosnia to OIF of the high change penalty scenario, Bosnia needs 38-beds, and optimally will have 52-beds. If we transition to OIF, we need 49-beds, which is less than the 52-beds that we notionally deployed. However, the optimal hospital for OIF increases to 58-beds. This occurs because we constrain the optimal configuration to be at least the need for each individual ward.

Intuitively you may expect that since the high slow response penalty pushes us to take more than needed, that the most excess would occur with that penalty. However, the high change scenario had the largest discrepancy between the optimal hospital and need at each stage for the penalties analyzed. When we try to minimize the changes in force size by assessing a high penalty for change, we create excess in each stage (see Table 7).

	High Slow Response Penalty	High Change Penalty	High Over Capacity Penalty
Difference = Optimal Beds Taken – Beds Needed			
Init	6	0	0
InitBosnia	12	14	0
InitOIF	34	9	0
InitOIFOEF	0	0	0
InitOIFStab	1	18	1
InitOIFKosovo	0	19	0
InitBosniaKosovo	0	13	0
InitBosniaBosnia	0	14	0
InitBosniaOIF	0	9	0
Total Difference	53	96	1

Table 7. For each stage in the penalty scenarios, we look at the difference between the optimal beds taken and beds needed utilizing the data from Figure 12. When we minimize our flexibility, by assessing a high penalty for change, we plan for excess capacity (after Center for AMEDD Strategic Studies, 2012).

2. Analysis

An Army medical treatment facility’s mission in OOTW is to support the military troops deployed in support of the security operation. It does not typically have a primary mission of medical support to the indigenous population unless an emergency situation arises. Having excess capability leads to a misunderstanding of medical mission and results in mission creep. It becomes important to get the capacity correct and changing the requirement is less critical. On the other hand, combat operations typically make changing the requirement and having a slow reaction to the requirement undesirable.

The penalty parameters allow a commander to model the desired intent. A high slow response penalty appears to cause less excess than caused by a high change penalty.

In this example, the high slow response penalty hospital that was able to adjust its capacity one time stage prior to the need, resulted in half the excess beds that the less flexible high change penalty hospital produced.

F. SMALL AND FLEXIBLE ROLE-3 MTFs BETTER SUPPORT THE ARMY'S STRATEGIC MOVE TOWARD REGIONALLY ALIGNED FORCES

In 2012, the Army announced its intent to regionally align its forces to geographic regions (Lopez, 2012). Currently there are six unified commands with a geographic region; AFRICOM, EUCOM, CENTCOM, PACOM, NORTHCOM, and SOUTHCOM. I Corps will align with PACOM, III Corps with CENTCOM, and XVIII Airborne Corps will remain a global response force (Tan, 2012). General Odierno said that this effort will organize units for “specific mission sets and regional conditions” and that the “units will gain invaluable expertise and cultural awareness, and be prepared to meet the regional requirements more rapidly and effectively than ever before” (as cited in Lopez, 2012).

However, one of the major potential problems for this endeavour is the integration of combat support and combat service support units like military police, signal, and medical that are traditionally theater assets that support larger units (Griffin, 2012). Currently, many support brigades do not have enough units to support separate regionally aligned deployment cycles and therefore would need to sustain a total force deployment cycle; forfeiting the benefit of geographic alignment (Griffin, 2012).

Smaller units allow more potential deployment cycle combinations. For example, with the current ten active duty CSHs, if we regionally align at least one role-3 MTF with each geographic command, we can not sustain a 1:2 deployment ratio (deployed 12 months : train and reset 24 months) without breaking the geographic alignment. If at any time we require two deployed CSHs in a theater, then the regional alignment of CSHs is disrupted for the duration of the contingency. The command has to be willing to accept a shorter deployment ratio (see Figure 13) and regionally assign CSHs to a few select geographic commands. With the current active duty CSHs it would not make sense for role-3 MTF assets to be geographically aligned.

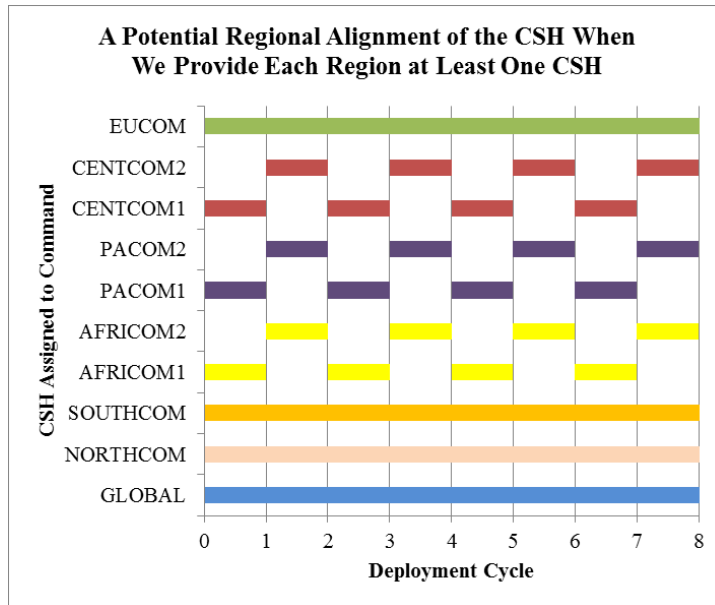


Figure 13. The vertical axis represents the regional assignment of the ten active duty CSHs. The colored blocks represent the potential deployment of a CSH in each geographic region, with a global force asset that can support quick deployment or fill in as needed. If we regionally align at least one role-3 MTF asset to each geographic command and sustain one Global Reaction Force, we can potentially maintain a 1:1 deployment ratio for AFRICOM, PACOM, and CENTCOM. There are not enough CSHs to support a sustained regional alignment without accepting a shorter deployment ratio and prioritizing geographic commands (after Center for AMEDD Strategic Studies, 2012).

Utilizing the optimization bounds for our role-3 MTF discussed in the previous paragraphs of this thesis, if we create four 60-bed facilities out of the personnel and equipment of the 248-bed facility, we can potentially have 40 role-3 MTFs to sustain a regionally aligned force. The forty hospitals, would allow us to maintain a 1:2 deployment ratio and plausibly maintain regional alignment.

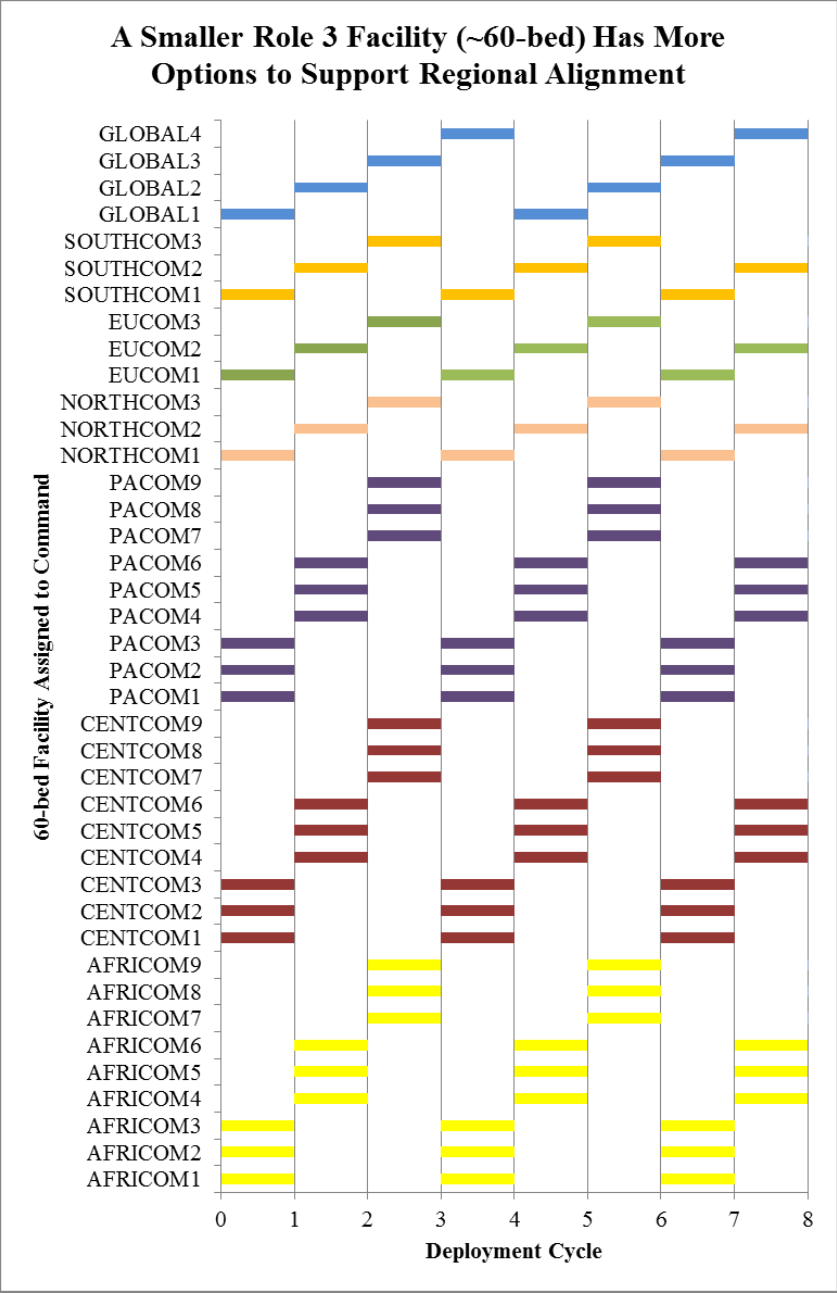


Figure 14. The vertical axis represents the regional assignment of 40 role-3 MTFs created by breaking the current CSH into four 60-bed hospitals. The colored blocks represent the potential deployment of a CSH in each geographic region, with a global force asset that can support quick deployment or fill in as needed. Utilizing smaller hospitals and wards allows a plausible regional alignment of role-3 MTF assets. Doctrinally making smaller hospitals in a regionally aligned force will allow us to sustain a 1:2 deployment ratio and 240 sustainable beds per three priority regions (after Center for AMEDD Strategic Studies, 2012).

V. CONCLUSION AND RECOMMENDATIONS

A. SUMMARY

As a reference point of combat operation requirements, during Operation Iraqi Freedom, we deployed six hospitals to initially support combat operations; one MASH and five CSHs. According to Nessen (2005), the 212th MASH single-handedly performed all level 3 hospital care for initial entry offensive operations into Iraq for the first 17 days. The 212th was soon after redeployed, and the 21st and 28th CSHs conducted split based operations and assumed all level 3 care within Iraq borders. Parts of the 10th CSH disassembled itself to augment the 21st and 28th CSH in order to sustain continuous split based operations. The 86th and 47th CSH provided hospitalization in Kuwait (Nessen, 2005). In 2003, we had nearly 70,000 U.S. soldiers in Iraq (Belasco, 2009). Essentially, we successfully supported the 70,000 soldiers with a single 60-bed 100% mobile hospital to conduct initial entry offensive operations and four small reorganized CSHs upon the start of the ground war (Nessen, 2005).

The Army continuously utilizes its CSH in split based operations and requires a role-3 MTF asset that is 100% mobile. Part of a robust solution to hospital sizing will be the ability to support both major combat operations and small scale contingency operations. Optimization of recent contingency operations supports doctrinally making the role-3 MTF that is within the lower bound of 44-beds and upper bound of 124-beds with smaller suite sizes to reduce excess and aid in flexible configurations. This hospital only works if we can combine the robust hospitals to form larger facilities and if augmentation assets are available to build the facility to the optimal size.

The analysis suggests that the current 248-bed hospital is too large for the expected need. The current 248-bed hospital also utilizes suites that are too large to allow the flexibility and control required by commanders. Smaller units will aid in improving the mobility and proximity of role-3 MTF care and allow these assets to better conform to the operational combat plan.

The model allows efficient analysis of a multitude of potential courses of action and provides a commander a quantitative starting point for proactive analysis of hospital utilization. The model can analyze stages as time periods or by phases of operation. Employment of this model can support proactive medical mission planning especially in phased deployment and redeployment, operational surges, and plausible medical course of action development.

B. FUTURE WORK RECOMMENDATIONS

1. Incorporating and Analyzing the Evacuation Support Platform

This model is dependent on and assumes that the evacuation platform can support the change in employment of role-3 MTF hospitalization. If we employ a smaller hospital, the evacuation timeline has less flexibility for missing a pick up. In Iraq, the evacuation policy was at least every three days from the combat support hospital. If the evacuation platform had a delay, the CSH had the operational overage to sustain. When we reduce the availability of hospital beds, adhering to the evacuation timeline becomes more critical. An investigation of whether the AMEDD can support a smaller CSH with its current medical evacuation platforms would be a valuable area of future study.

2. Conduct a Cost Analysis of a Smaller Role-3 MTF

Cost is a key driver to change in the military. Further research in the total cost analysis of transitioning and sustaining smaller role-3 MTFs is required for the AMEDD to consider a transition to a smaller hospital.

3. PROFIS Integration

The AMEDD utilizes a Professional Filler System in order to support both the deployable medical requirements and the medical requirements in CONUS. One major shortfall of the role-3 MTF is the requirement to integrate PROFIS strangers from around the nation into a synchronous unit. A valuable area of future study is a manpower model that investigates PROFIS assignments to smaller regionally aligned role-3 MTFs without draining the CONUS medical facilities upon a unit deployment.

4. Additional Data Analysis of Historical Role-3 MTF Admissions

This model was limited to OIF, OEF, Kosovo, and Bosnia data. Additional data analysis to obtain 95 percentile admissions rates for past operations would be extremely useful to include Desert Storm/Shield, humanitarian missions, and natural disaster missions. Also, further details in key operational phases like drawdown, Battle of Fallujah, or the surge in 2007 would provide useful insight into future medical planning.

5. Stochastic and Robust Analysis

This study utilized 95 percentile admission rates rather than the stochastic arrivals and queues in a hospital. A simulation with stochastic parameters can provide additional insight into a robust role-3 MTF solution. In addition, we can add validity to the robust role-3 MTF solution with sensitivity analysis on how the transition probabilities from one stage to another changes the optimal hospital solution.

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