BURN SURGE CAPACITY IN THE SOUTH

WHAT IS THE CAPACITY OF BURN CENTERS WITHIN THE AMERICAN BURN ASSOCIATION SOUTHERN REGION TO ABSORB SIGNIFICANT NUMBERS OF BURN INJURED PATIENTS DURING A MEDICAL DISASTER?

BY

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A doctoral project submitted to the faculty of the Medical University of South Carolina in partial fulfillment of the requirements for the degree Doctor of Health Administration In the College of Health Professions

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Medical disasters with significant numbers of burn injured patients create incredible challenge for disaster planners. North Carolina is served by two Burn Centers, with a similar ratio of resources (comparing staffed beds with the population). Burn Centers of the ABA Southern Region created a plan should there be a need for additional hospital burn beds (capacity) and burn care (capability) in response to a disaster.

All disasters are local. Nevertheless, regional support is critical in burn disaster planning. This work identified intrastate capacity and a stochastic model was developed using Monte Carlo simulation to quantify the regional capacity.

Results confirmed the scarcity of burn bed capacity with a key finding including identification of the threshold for needing interstate surge capacity. Findings include a more finite understanding of regional capacity, capability, and when a surge of patients may require the practice of altered standards of care.
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past commander for North Carolina DMAT 1. Furthermore, I had the distinct honor of serving with Dr. Alson when he was Chair for the North Carolina Disciplinary Committee, which was not an experience for the faint of heart.

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Data provided by UNC Hospitals was made available through the UNC Health Care Trauma Program and the UNC Hospitals Trauma Registry. All data related to the admissions, patient days, and occupancy rates were provided by the UNC Hospitals Trauma Registry. All data provided by the UNC Hospitals Trauma Registry remains the property of the UNC Hospitals Trauma Registry.

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I. INTRODUCTION

Scarce medical resources such as the capacity to manage trauma, burn, and pediatric patients are generally in limited supply each day in the American healthcare system. The Agency for Healthcare Research and Quality (AHRQ) United States Department of Health and Human Services (DHHS) 2004 report (Altered Standards of Care in Mass Casualty Events, 2004) made clear the need for allocation guidelines in a mass casualty. The need for these guidelines was based on significant limitations, identified in the report as scarce resources such as "ventilators, burn beds or surgical suites." The September 11, 2001 attack on America and the ensuing tragedy had the potential for overwhelming the medical disaster capacities for much of the American healthcare system. Catastrophic events, tragic as they may be, generally serve as a consensus reminder for the importance of preparedness. As with previous catastrophic events, the aftermath of the 9/11 attack was the impetus for improved surge capacity planning and medical disaster preparedness.

Burn care is generally provided in a Burn Center. Burn Centers are typically identified as locations where an array of services and clinical expertise exist to coordinate the management of a burn patient. These services include acute and
multiple surgical interventions as well as ongoing critical care life support in one of the most comprehensive and complex medical environments. As the patient moves from rescue to recovery, a Burn Center provides both short-term and long-term rehabilitation so the burn survivor can regain much of the quality of life previously enjoyed. Burn Centers are normally located in large major medical centers where other related expertise, diagnostics, and ancillary care are available. Probably the most important co-located service for the burn patient is a Trauma Center. Many burn patients also have a traumatic injury (such as blunt, concussive, or penetrating trauma from vehicle collisions, jumping from heights, or other extraordinary measures to escape structure fires, blast injuries, or other dangers). Burn Centers focus specifically on the burn injury but the burn surgeon who is managing the overall care of the patient must assure the burn patient is cleared of or actively managing the traumatic injury.

Burn injuries lead to long term sequelae if not managed correctly. However, the patient’s greatest immediate risk for mortality or morbidity when the patient has a combined burn traumatic injury is exsanguination. Burn injuries can be distracting, and providers can overlook the immediate risk posed by internal exsanguination, due to masking of the typical external signs and symptoms associated with hypovolemic shock. The burn surgeon, along with a highly skilled team, can maximize the survival potential for these patients.

Patients with critical burn injuries make multiple trips to the operating room for removing large areas of eschar, amputations, skin grafts, as well as other
extensive surgeries involving preservation of life and limb during the course of the injury management. With burn patients, the acute event is the burn injury. However, the long term impact can lead to a host of chronic health conditions which are far more prominent and more likely to be fatal when poorly managed. Rehabilitation includes restorative care for functionality of the burned extremity or managing the grafting and healing process to minimize contractures and improve flexibility, use, and appearance.

Comprehensive medical disaster planning and preparedness includes reasonable efforts to get the right patient to the right destination. When the patient cannot be transported to the best destination (such as a Burn Center) due to either the distance or the time involved in the transport, this should be addressed in the planning process. This strategy can include the development of buffers in the system to absorb and manage the critically injured patients. Improving care and capacity at a local and regional level to make the wait for access to limited resources is vital to comprehensive planning, especially for burn patients that cannot immediately be moved to a Burn Center. This strategy is successfully used in military medicine and has applicability in civilian medicine as well.

The business behavior of the American healthcare system is similar to those business principles found throughout a market-based economy. Those principles include the supply of services (generally stated in healthcare as staffed beds), and clinical expertise is directly related to the demand for those services. That supply is influenced or deterred by the ability to pay for the services provided.
are many altruistic examples of care and healthcare services provided in the American system, disaster response strategies used by socialized medical systems (such as the Israeli and European healthcare models) have limited application in the United States. As an example, solutions used by The Netherlands following the café fire in Volendam to assure that burn patients had their needs met by the best available resources, could not be employed in the United States. In The Netherlands incident, they closed the Burn Center for admissions, forcing the burn injured patients to surge into regional hospitals. Then, the Burn Center worked with those hospitals to assure those with the most significant yet survivable injuries were the ones assigned beds and transferred to the Burn Center. In the American model, hospitals compete for patients and efforts to control the flow of patients can be circumvented if some hospitals chose to use different triage considerations such as the patient’s ability to pay.

According to the American Burn Association (ABA), ("Burn Care Resource Directory," 2011) there are 1895 burn beds identified in the United States (US) for ("United States Population 2010," 2010) the total United States population of 308,745,538 residents (equaling one burn bed for every 176,023.7 residents of the United States). The definition of a “burn bed” varies from state to state. The most common definition and most comprehensive approach of defining a “burn unit” is found in the ABA Document; ("Resources for Optimal Care of the Injured Patient," 2006). This document includes requirements for what equipment, services and clinical expertise should be available in a “burn unit".
For North Carolina, according to ("Definitions: Burn Intensive Care Services," 1990) Section 3400, 10A-NCAC-14C.3401, “burn intensive care services” is defined in G.S. 131E-176(2b).

A burn intensive care unit means a designated area within a hospital dedicated to the provision of burn intensive care services for severely burned patients. A ‘severely burned patient’ means ‘a patient who has burns covering more than 20 percent of the body area or that has burns which require intensive treatment, such as, but not limited to: inhalation injuries, chemical and electrical burns, burns with complications, such as fractures, burns to the face, full thickness burns to the hands and feet, burns on patients whose pre-burned health was known to be poor, such as patients with diabetes or heart disease, and, burns on patients who are under 5 or over 60 years of age’.

For the purpose of this work, we assumed those who self-report “burn bed” data to the ABA are compliant with either the ABA definition of a burn unit or a similar state definition.

The ABA data is derived from a self-reporting system updated at least semi-annually. Furthermore, the reports do not differentiate burn beds from those that serve principally as “dual use,” meaning they may be dedicated to both burn care and trauma services or burn care and general pediatric intensive care beds. The numbers reported are typically known as “static” beds which generally function as a larger number than staffed beds. Static bed counts are reported as a function of licensed capacity, while staffed beds are a subset of the licensed capacity where the
numbers fluctuate based on two primary market forces: demand and staffing. Thus, actual capacity for patients with specific burn injuries is less than the 1895 stated.

According to the American Hospital Association ("AHA Hospital Statistics 2009 Annual Survey, 2011 Edition," 2011) there are 5,795 registered hospitals with 944,277 staffed beds. With 123 self-identified Burn Centers reporting 1,895 beds collectively, this yields a ratio of approximately 1 Burn Center for every 47 hospitals or 1 burn bed out of every 498 licensed beds.

Additionally, these 123 Burn Centers are operating close to capacity. Therefore, the ability to manage a surge for a significant number of burn patients in most communities across the nation is limited, using the current system that relies on the day to day capacity for burn beds.

North Carolina is no different. Of the 122 hospitals found within the state, only two contain designated Burn Centers. The two Burn Centers are located at the University of North Carolina (UNC) Hospitals and the Wake Forest University Baptist Health, having 36 and 24 beds, respectively, dedicated to burn care. These 60 beds are used to serve the population of North Carolina. According to the United States Census Bureau ("North Carolina Population 2010," 2010) there are 9,535,483 North Carolina residents (which equates to a ratio of one burn bed for every 158,924.7 residents in North Carolina).
**Problem Statement**

The purpose of this doctoral dissertation is to understand and quantify the capacity of Burn Centers within the American Burn Association Southern Region to absorb significant numbers of burn injured patients during a medical disaster.

**Background**

This work focused on several areas of concern, starting specifically with North Carolina. The overarching planning perspective for any medical disaster operation centers around the principle that all disasters are local and all disaster planning begins on the local level. Given the limited resources in North Carolina (as with other states), processes must also be in place to create intrastate surge capacity using Trauma Centers and regional hospitals for short duration placement of patients (24 to 72 hours) before they can be moved to Burn Centers. Furthermore, on a regional basis, identifying and quantifying the capacity of the region's Burn Centers is an essential function to developing a comprehensive solution.

For North Carolina and the region, I focused on the capacity to manage multiple patients with burn injuries, and identified processes either in place or that could be put into place to improve capacity. For the purpose of this research and to understand the availability of capacity, I started with examining and discussing capacity fluctuations at Burn Centers in general. Key resources for this paper include primary and secondary data used from southern Burn Centers including their capacity and willingness to accept interstate patient transfers.
This work also considered existing burn resources across the nation and
explored the impact such a surge of patients could produce on the existing
infrastructure. Finally, the work also reviewed and discussed the costs of having a
capacity to absorb the burn patients from a disaster that produce significant
numbers of patients with a burn injury.

Future planning and preparedness efforts demand a better understanding of
the limitations of the scarce critical care resources which currently exist. While
there are several scarce resources in any disaster, burn care is the focus of this
work. The terrorist attacks of 9/11 were a profound disaster in many ways.
Nevertheless, by reexamining planning ranges and limitations, preparedness can be
improved. Following the 9/11 attacks, a wealth of academic resources began to
emerge discussing the significant efforts undertaken to better understand the
disaster. Today, these papers allow us to better understand the capabilities and
limitations of the American healthcare system to react and respond to future
disasters such as the 9/11 attacks. Furthermore, those papers with specific focus
on the response to those with burn injuries offers a candid look into the limitations
that exist in the world of burn care.

In broad terms, this work offers those in the field of medical disaster
preparedness a unique perspective that draws upon several diverse bodies of
research not initially designed specifically for burn care, and creates a model for
managing future disasters that involve significant numbers of burn injuries.
Surge Capacity

When hospitals are overrun with patients, there is a need to be able to adapt space in the hospital for the purpose of treating the sick and injured. This can occur following a disaster or something more subtle (but just as taxing) such as a surge of patients with Influenza Like Illness (ILI). While this space is generally not used daily for seeing patients, and the staff called into help with the surge of patients may or may not be routinely employed as emergency department staff, all must work together to meet the needs of the surge of patients. Depending on the facility, the staffing available, and the quantity of patients, each hospital can quantify both its capacity and capability for managing patients. Historically, this has been stated as staffed beds (capacity) and surge capacity, with surge being associated with using contiguous spaces in a hospital such as a hallway or holding area for managing emergency department patients.

One of the first academic papers published after the 9/11 attacks which was intended to address and add clarity to a concept we had come to describe as “surge capacity” was (Hick et al., 2004). While the paper did not offer the clarity of his later works, this was the first of several works that began to help us understand there was more to “surge” than just the notion that surge was anything more than what we typically dealt with on a daily basis.

The next paper by Dr. Hick that began to give us better definitions and stratify surge capacity, came in 2009 (Hick, Barbera, & Kelen, 2009). This paper provided medical disaster planners with a more finite and specific set of general
definitions of how to stratify the different aspects of surge capacity. The (Hick et al., 2009) work described these distinct capacities as “Conventional, Contingency and Crisis capacity.”

**Conventional Capacity** – The spaces, staff and supplies used are consistent with daily practices within the institution. These spaces and practices are used during a major mass casualty incident that triggers activation of the facility emergency operations plan.

**Contingency Capacity** – The spaces, staff, and supplies used are not consistent with daily practices but maintain or have minimal impact on usual patient care practices. These spaces or practices may be used temporarily during a major mass casualty incident or on a more sustained basis during a disaster (when the demands of the incident exceed community resources.)

**Crisis Capacity** – Adaptive spaces, staff and supplies are not consistent with usual standards of care but provide sufficiency of care in the setting of a catastrophic disaster (i.e. Provide the best possible care to patients given the circumstances and resources available.)

(Hick et al., 2009)

A 2011 paper by Dr. Hick, Dr. Dan Hanfling, M.D., and Dr. Stephen Cantrill, M.D., built upon previous works to more clearly define roles and decision boundaries when surges or waves of patients present and overwhelm the capacity and capabilities of medical centers (Hick, Hanfling, & Cantrill, 2011). A somewhat similar paper by Dr. Hick and a host of colleagues including Rear Admiral Dr. Ann
Knebel, D.N.Sc. of the Uniformed Public Health Service and the Office of the Assistant Secretary for Preparedness and Response (ASPR), (Hick, Weinstock, et al., 2011) discussed the application for these surge capacity definitions in the medical disaster planning aspects for a nuclear detonation.

The (Hick et al., 2009) paper represented a significant improvement in how we stratify and identify capacity. The most likely scenarios include what Hick describes as conventional and contingency surge capacity (Hick et al., 2009). Conventional surge capacity includes the capabilities of traditional capacities involving the two designated Burn Centers. There are two aspects of contingency surge capacity. Intrastate activities include absorbing patients with less acute burn injuries at regional hospitals and those Trauma Centers not co-located with Burn Centers for 24-72 hours before moving them to a Burn Center. Interstate activities include transferring patients to Burn Centers in other states either contiguous to North Carolina or in the southeast region of the United States.

In the aftermath of 9/11, Congress authorized and funded the Bioterrorism Hospital Preparedness Program (BTHPP) grant through the United States Department of Health and Human Services (DHHS) Health Research Services Administration (HRSA). The HRSA issued critical benchmarks for the three year grant period 2003-04, 2004-05, and 2005-06 which included Critical Benchmark (CB) 2-9:

**Surge capacity-Trauma and Burn Care**
Enhance statewide trauma and burn care capacity to be able to respond to a mass casualty incident due to terrorism. This plan should ensure the capacity of providing the trauma care to at least 50 severely injured adult and pediatric patients per million of population.

**Sentinel indicator #2-9**

To provide the number of patients for whom the awardee is capable of providing trauma and burn care, as of August 31\(^{st}\), 2004

Regional plans may be proposed for upgrading equipment or facilities to accommodate mass surgical and burn casualties due to terrorist incident.

*(Altered Standards of Care in Mass Casualty Events, 2004)*

The intent for states to meet these benchmarks as a condition of grant participation was to address known scarce medical resources including Burn, Pediatric, and Trauma bed availability. In the first two years following the 9/11 attacks, there was an improved effort for hospital disaster planning (Niska & Burt, 2007) and related training activities (Niska & Burt, 2006). However, both reports clearly identified a substantial gap between the current reported situation and an ideal situation.

With four years of preparedness activity following creation of the BTHPP, (Adini et al., 2006) assessed and reported developments regarding hospital preparedness activities. Successes varied, and with growing recognition for changes at the federal level, a bill was introduced that proposed creating an office specifically focused on medical preparedness activities.
The 2006 passage of the Pandemic and All Hazards Preparedness Act (PAHPA) (which became Public Law [PL] 109-417) ("Pandemic and All Hazards Preparedness Act ", 2006) amended the United States Public Health Service Act. One aspect of this law included moving the BTHPP to the newly created United States Department of Health and Human Services (DHHS) Office for the Assistant Secretary for Preparedness and Response (ASPR). The BTHPP was revised to focus on an all hazards approach and this particular program was renamed the Hospital Preparedness Program (HPP). However, the benchmarks were revised in 2007 and preparedness for burn surge folded into the general surge capacity Critical Benchmarks (CB) (now referred to as measures) which is now in place through 2011-12.

**North Carolina Burn Surge Disaster Program: One State's Approach**

The North Carolina Burn Surge Disaster Program (NCBDP) was conceived in 2005 and based at the University of North Carolina at Chapel Hill (UNC). The NCBDP began in response to HRSA BTHPP CB 2-9, and serves as a model state preparedness program. (The NCBDP functions somewhat similar to initiatives in Florida and New Jersey.)

The NCBDP is a project funded by the North Carolina Office of Emergency Medical Services (NCOEMS) as a part of the Department of Health and Human Services (DHHS) Assistant Secretary for Preparedness and Response (ASPR) Hospital Preparedness Program (HPP). Based on the (*FY 2012 Online Performance Appendix, 2011*), the HPP measures compel the HPP awardee to fully develop surge
capacity for various aspects of hospitals, healthcare, and public health.

Measure 2.4.2.A-I. Improve surge capacity and enhance community and hospital preparedness for public health emergencies through (with measures A-I listing an array of strategies that were required for awardees to meet surge capacity needs.)

(Altered Standards of Care in Mass Casualty Events, 2004)

The NCBDP represents a partnership that includes leaders from the state’s two Burn Centers, the North Carolina Jaycee Burn Center, located at the University of North Carolina Hospitals; and The Burn Center at Wake Forest Baptist Health (formerly known as Wake Forest University Baptist Medical Center). Both entities are American Burn Association (ABA) Verified Burn Centers. To become an ABA Verified Burn Center, an organization must be reviewed by a peer group who examines patient care standards from acute to rehabilitation as well as mutual aid and disaster planning. Once verified, the ABA rules require the Burn Center to be re-verified within three years to remain current.

A third partner in the program includes a representative for the East Carolina University (ECU) School of Medicine and the Pitt County Memorial Hospital (PCMH). As a major academic medical center, and a university hospital with 861 beds at the main campus ("Pitt County Memorial Hospital Nursing," 2011), the PCMH is one of the largest academic medical center in North Carolina. Due to the distance to a Burn Center, the outpatient burn care clinic at PCMH allows citizens of the region to have minor burns managed there while major burns are referred elsewhere (typically to UNC Hospitals) for their inpatient stay until
discharge to the service at PCMH for follow up.

North Carolina has a history of recent disasters involving significant numbers of burn injuries. While not at the magnitude of the 9/11 attacks, these disasters inspired an improved preparedness level that was not uniformly seen in other states at that time. As terrible as 9/11 was, it served as a stark reminder of both the capacities of the national disaster capabilities while exposing limitations in the system, specifically as they relate to planning and preparedness. 9/11 was an event that redefined the scope of “terrible” in the world of preparedness and planning for disaster.

The 9/11 attacks were followed by a new approach to medical disaster preparedness. For states like North Carolina with significant disaster experience, it was less difficult to make this transition than others, but for all states, 9/11 created a new threshold for the meaning of preparedness. The drive for improved medical preparedness was funded through the United States Department of Health and Human Services Health Resources and Services Administration (United States DHHS/HRSA) using a benchmarking system that was tied to funding. Referred to as critical benchmarks, one of the benchmarks (CB 2-9) specifically called for capacity creation for a surge of burn patients.

The North Carolina approach to addressing HRSA Critical Benchmark 2-9 regarding the management of burn surge included a review of the published national burn disaster standards, such as holding burn patients for up to 24 hours for secondary triage. However, the local experience quickly led to reconsidering
that approach. Furthermore, the EMS system and the trauma system in NC are both regulated by the North Carolina Office of Emergency Medical Services (NCOEMS) ("Statewide trauma system," 1993). Logically, it concluded that it was necessary to involve the trauma system, the EMS system, and community hospitals in the planning process. During early presentations regarding the development of this program, the common report from both EMS and local community hospitals was that they were quite uncomfortable with holding burn patients for any length of time beyond what was usual and customary for transferring the typical event of one or two burn patients to the regional Burn Center.

Based on the feedback received, it was determined that the key solution for burn disaster preparedness would include providing burn care specific training that extended well beyond the 45 minute to one hour topic typically included in the core trauma programs. Thus the efforts were made to focus specifically on a national day-long (eight hour) program developed by the ABA known as the Advanced Burn Life Support (ABLS) program. As of January 2011, the ABLS has been completed by more than 1300 physicians, nurses, and paramedics across North Carolina.

No matter how grand or simple the plan or the event, all solutions must include and be embraced by local personnel. One aspect of the NCBDP included researching historical accounts for disasters involving significant burn injuries in North Carolina. This information became a graphic reminder that North Carolina is no stranger to disasters with these types of patients, and demonstrated a frequency
that was similar to hurricanes, another disaster that most North Carolinians could easily relate to. This historical data was presented across the state at various regional trauma meetings and statewide conferences, and the information was published on the North Carolina Burn Surge Disaster website, (Kearns, 2011a) www.ncburndisaster.org.

Focus was placed on developmental and educational efforts at the local level, including the community hospital emergency department personnel and personnel with the local EMS Systems. This included a rewrite of statewide EMS Treatment protocols which were adopted by the North Carolina College of Emergency Physicians (NCCEP) (NCCEP, 2009). The NCCEP has statutory authority to develop and manage the reference document for all clinical care practice guidelines for prehospital providers. As of 2009, the new burn-specific EMS protocols were being used by all EMS agencies in the state. (A current revision effort is underway in North Carolina, and the NC Burn Disaster program has submitted an update to the committee overseeing the protocol revisions.)

A hospital based set of guidelines were created and published for community and regional hospitals to serve as basic guides for management of a burn patient until the patient can be transferred to a Burn Center. These guidelines are also published on the NCBDP website, (Kearns, 2011b) www.ncburndisaster.org/Downloads.html. This aspect of the work also included a decision tree for aiding community hospitals in determining what patients need to be moved to a Burn Center.
During the past two years, the NCCEP also implemented a destination triage and transport requirement for all NC EMS systems. This includes destinations for burn patients. In general, each EMS system must agree to transport their burn patients to Burn Centers or to a location where air transport or critical care transport services can move the burned patient to a Burn Center. In certain circumstances, the burn patient is initially transported to a Trauma Center before being moved to a Burn Center based either on distance or co-morbidities.
Figure 1. North Carolina Trauma Centers
One aspect of the NCBDP is reliance on intrastate resources. While the intent is to manage burn patients at Burn Centers, reliance on Trauma Centers to aid in the process by absorbing a portion of the surge of burn patients with lesser burn injury is both consistent with the literature and safe. The work of (Yurt et al., 2008) followed several years of developing their program in New York. They developed a system that assumed the four Burn Centers could accept 100 burn patients. Furthermore, they relied on 17 Level I Trauma Centers and another 13 major hospitals (30 total) to manage up to 10 patients each for 72-120 hours until they could be transferred to one of the four Burn Centers in the city.

While North Carolina has a similar population to the city of New York (9 million) the population is distributed over a significantly larger geographic area with far less density. Furthermore, there are far fewer Level I Trauma Centers in North Carolina (four outside UNC Hospitals and Wake Forest Baptist Health (WFUBH) where the two Burn Centers are also located). Additionally, there are six additional Level II or Level III Trauma Centers. These centers can serve as a buffer where burn patients can remain should there be a disaster of significant proportion. With Level I centers managing up to 10 patients, and Level II or Level III Trauma Centers managing 5-10 each, additional capacity within the state can be called upon should it be necessary. The 60 beds at the two Burn Centers in North Carolina were the first option for a disaster with area Trauma Centers being that intrastate buffer.

Nevertheless, as with the New York plan, this is an extemporizing measure
and secondary triage of burn patients to Burn Centers assures patients with burn injuries are managed at Burn Centers. If they cannot be managed with the intrastate resources, they are transferred to interstate Burn Centers.

The NCBDP is a program that is both scalable and has broad application for replication in other states. Components of it are now in use in other states. It also shares similarities with programs in Florida and New Jersey. Efforts in New York and Washington DC are also working closely with the NCBDP. The overt message for all disaster planners remains: all disasters are local, and all response operations begin with a local solution. Nevertheless, the key to success includes developing intrastate resources and identifying regional interstate resources as well.

**Regionalism**

Each geographical area of the United States is identified as a region for the purpose of working with federal partners in the aspect of disaster planning and response. North Carolina is located in what is known as Region IV (which includes North Carolina, South Carolina, Georgia, Tennessee, Mississippi, Alabama, and Kentucky) by the United States Department of Homeland Security (DHS) Federal Emergency Management Agency (FEMA) and the United States Department of Health and Human Services (DHHS) Assistant Secretary for Preparedness and Response (ASPR). FEMA is responsible for the overarching federal disaster preparedness and response activities including the development and coordination of the National Response Framework (NRF) *(National Response Framework, 2008)* for disaster response. The NRF has 15 critical support functions with Health and
Medical Services being identified as Emergency Support Function (ESF) 8.

**EMAC and R-IV UPC**

The Region IV states have a long tradition of interstate cooperation. Hurricane Hugo in 1989 and Hurricane Andrew in 1992 both reinforced the importance of interstate resource sharing through mutual aid. The governors of the southern states created the Southern Governors Association (SGA) mutual aid agreement that worked from state to state. Ratified in 1993, the document became known as the Southern Region Emergency Management Assistance Compact (SREMAC). SREMAC was the predecessor of the Emergency Management Assistance Compact (EMAC) ("Emergency Management Assistance Compact," 2011). In 1995, the SGA voted to open membership into SREMAC to any state or territory and the administration moved to the National Emergency Management Association (NEMA). The EMAC ("Emergency Management Assistance Compact," 2011) was ratified by Congress as Public Law [104-321] in 1996. These efforts grew in the years that followed. EMAC and the cooperative efforts were in full swing and operation during the devastating hurricane seasons in 2004 and 2005.

In the aftermath of the hurricanes, Region IV ESF-8 leaders at the state and federal level began to hold regular meetings for the specific purpose of planning for hurricanes. By 2008, this somewhat unofficial alliance became a more organized group known as the Unified Planning Coalition (UPC), and thus the Region IV, ESF8 UPC was created. North Carolina agreed to participate with Region IV ESF8 UPC Leadership in assisting regional states with their planning efforts where possible,
including the development of burn surge planning.

The Southern Burn Disaster Plan, the first of its type for regional Burn Centers in the United States, was presented conceptually in 2004 at the Southern Burn Conference (Barillo et al., 2006). Peer reviewed and academically published in 2006, the document serves as a guide for regional disaster operations with significant numbers of burn injuries today. While the program has significant limitations, it is a good start for the current planning efforts that are underway.

Although unrelated, with neither knowing the efforts of the other, these groups initially were on somewhat of a parallel path to address many of the same concerns regarding the regional management of a surge of patients with burn injuries. The critical point for a medical disaster plan includes the ability to re-distribute patients who have arrived at a hospital based on access and geographical proximity, not the endless capacity to meet the needs for all who arrive.

By leveraging roles with Region IV ESF8 UPC and the Southern Burn Disaster Plan, I was able to identify opportunities to link the two efforts. Additionally, regional efforts are critical for successfully creating a useful and operational solution for North Carolina, or any state for that matter.

**Requesting Disaster Assistance**

All disasters occur at the local level. Disaster activities such as planning, preparedness and response also occur at the local level. As events escalate, state and, when requested, federal response agencies provide assistance to the local agency responsible for managing the disaster.
State and federal efforts are important, but neither is more important than the local response. When a local disaster occurs, if the local response agency has needs that cannot be met with local resources, a request is made through the state emergency management agency for the needed resource. When the need is great and the disaster impact is dramatic, the state may request aid from the federal government. The request for federal assistance could include a presidential declaration of disaster, officially requested by the governor of the impacted state to the president. There are three general types of disaster declaration: Major Disaster Declaration, Emergency Declaration and Fire Management and Assistance Declaration.

Disaster medical resources function in the same manner. When a local event occurs, requests for needs that cannot be met locally are forwarded through the local emergency management agency to the state emergency management agency. If the needs cannot be met at the state level, those needs are forwarded to the federal representative. In each situation, both the state and federal response rely heavily on the organization responsible for the ESF-8 activities. For North Carolina, this organization is the North Carolina Office of Emergency Medical Services (NCOEMS) and at the federal level, the United States Department of Health and Human Services, Office of the Assistant Secretary for Preparedness and Response (US DHHS/ASPR).

When a local medical disaster occurs that produces significant numbers of burn injured patients, additional assistance requests may include ground based
critical care transport (CCT) or advanced life support (ALS) ambulances to aid in the transport and medical care during transit of the injured patients either from the scene or from one hospital to another. Air transportation may be more useful given the distance to be covered and the access to the patients' location. Transportation may include moving patients to a Burn Center or redistributing them from one Burn Center that initially dealt with the surge of patients to other large Burn Centers in the region.

In the immediate area of the disaster, the civilian medical helicopter is the most common form of air transportation, but it has volume limitations, generally restricted to one patient per helicopter. Furthermore, with only 17 medical civilian helicopters stationed in North Carolina (Figure 2) and given their daily utilization, it is highly unlikely that substantial numbers of helicopters are readily available for a disaster. Civilian medical helicopters are generally smaller than their military counterparts, with a more limited capacity. However, civilian helicopters have a rapid response to civilian events, while attaining the necessary approvals can significantly extend the time necessary for a military helicopter to assist with a civilian medical response.
Flight Program Locations in North Carolina

**UNC Hospitals**
Chapel Hill and Fayetteville

**Wake Forest University Baptist Health**
Lexington and Elkin

**Duke University Medical Center**
Durham x 2

**University Health Systems Eastern Carolina**
Greenville x 2 and Rocky Mount

**Carolinas Medical Center**
Charlotte and Catawba/Morganton (Rock Hill SC)

**Carolina Medical Center**
Fixed Wing, 2 King Air Turbo Prop and 2 Citation Jets

**Mission Medical Center**
Asheville and Franklin

**New Hanover Regional Hospital**
Wilmington

**WakeMed Health and Hospitals**
Raleigh

**Dare County EMS**
Manteo

**Out of State Locations**
Chattanooga Tn., Bristol Tn., Chesapeake Va., Conway SC

Figure 2 Locations of civilian medical helicopters stationed around the state.
Fixed wing air transport may include medical transportation relying on civilian aircraft but again, with only four stationed in North Carolina (all in Charlotte), resources are limited. Capacity is limited as well; civilian fixed wing air transport use small turboprop or jet airplanes with a capacity of one to four patients each. Requesting civilian resources can be facilitated either through a hospital-to-hospital request for assistance or by relying on the ESF-8 contact if a disaster declaration has occurred. The ESF-8 component is activated either anticipating a disaster declaration or the state has determined the scope or size of the disaster is such that the ESF-8 coordination should be active.

If there is a need for large fixed wing aircraft configured for transporting significant numbers of patients, then a request for state Air National Guard or the United States Department of Defense (DOD) for airlift support may be indicated. This request process must be made by the local emergency management agency (EMA) to the state EMA. State and federal assets must be requested through EMA (Federal Coordinating Center Guide, 2006).

Aircraft such as the C-130 and the C-17 are two examples of large fixed wing aircraft typically used for this purpose. Use of the C-130 is a simple means of moving large numbers from one location to another with limited on-board area for care of the patient. The C-17 is significantly larger and configured for medical missions. However, access to either is dependent on current and ongoing military missions, with C-130s being a more likely available resource. North Carolina Air National Guard (a component of state government) has C-130s in inventory and their uses for
medical evacuation are more readily available than tasking a military mission for an aircraft such as a C-17.

Based in Charlotte, the 145th Medical Squadron of the 145th Airlift Wing of the North Carolina Air National Guard can be mobilized as a component of state government upon authorization by the governor. While this is not a “first response” organization, in the hours and days following a major disaster with burn patients who may need to be moved to other states, this is one resource that could be used in that manner.
### Comparison Table for C 130 to C 17

<table>
<thead>
<tr>
<th>Comparison</th>
<th>C-130E Turbo Prop</th>
<th>C-17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wingspan</td>
<td>132 ft. 7 in.</td>
<td>169 ft. 10 in.</td>
</tr>
<tr>
<td>Length</td>
<td>97 ft. 6 in.</td>
<td>174 ft.</td>
</tr>
<tr>
<td>Height</td>
<td>38 ft. 10 in.</td>
<td>55 ft. 1 in.</td>
</tr>
<tr>
<td>Range</td>
<td>1,150 miles</td>
<td>Global</td>
</tr>
<tr>
<td>Load</td>
<td>74 Stretcher OR 64 Ambulatory patients or attendants (restricted care area)</td>
<td>36 Stretcher and 54 Ambulatory patients or attendants</td>
</tr>
<tr>
<td>Source:</td>
<td>USAF</td>
<td></td>
</tr>
</tbody>
</table>


*Figure 3 Comparison Table for military patient transport aircraft: C 130 to C 17*
North Carolina has a long standing and well established trauma system enacted by the North Carolina General Assembly as NCGS 131E-162, Statewide Trauma System Act of 1993 ("Statewide trauma system," 1993). EMS systems move patients based on their destination triage guidelines, either to a Trauma Center or a Burn Center with burn patients generally being moved directly to a Burn Center. When hospitals begin to see or anticipate a surge of patients, processes are in place behind the scenes to determine what capacity other centers have to assist with managing the volume of patients. Intrastate movement of patients involving the two Burn Centers and intrastate cooperation is spelled out in the transfer and mutual aid agreement that exists between UNC Hospitals and WFUBH.

Southern Burn Plan: Using Military Experiences in Civilian Burn Care

Interstate movement is facilitated by the Southern Burn Plan (Barillo et al., 2006). This document reflects the cooperative efforts of the representative burn directors from around the region. It is based on a premise that has been confirmed by recent military experiences in Iraq and Afghanistan. The critical components of burn care and the patients' needs are best met with excellent initial care, rendered as soon as possible after the injury occurs. On the battlefield, a Medic or Corpsman initiates care and secures transport either by ground or air to a forward medical station or a ship. There, care continues to assure the airway is managed, pain is controlled, fluid resuscitation begins, and the Soldier or Marine is cleared of their traumatic injuries. As soon as possible, the patient is again moved to a larger hospital, typically Landstuhl Regional Medical Center in Landstuhl, Germany, the
largest US military hospital operated outside of the United States. Nevertheless, burn patients only remain there long enough to arrange for or schedule a flight to Brooke Army Medical Center in San Antonio Texas, the location of the Burn Center for the United States Military.

While there are limitations to applying this strategy to the civilian world, it does serve as an important reminder that burn care should be provided in specialized Burn Centers. According to (Cancio et al., 2005) provided the patient receives excellent initial care, and is cleared of his or her traumatic injuries, they tend to have their best outcomes, even with being moved over great distances for several hours or days until they can reach a Burn Center. (Throughout the conflict, no Burn Centers were built in Iraq or Afghanistan).

The Southern Burn Plan leverages this approach for addressing a surge of patients that overwhelm resources at the initial Burn Center receiving patients. With this strategy in mind, patients with burn injuries can successfully be moved to other states for burn care, provided care is not available in the area closer to where they are located. Generally, the decision tree begins with the closest Burn Center, and follows lines of geographical distance, with variances favoring ABA Verified Burn Centers co-located with Verified Trauma Centers.
Burn Centers in the South

Ohio, Maryland and DC are not in the Southern Region but proximity may warrant their use ahead of Texas and Oklahoma. Nevertheless, their numbers are not included in the Simulations.

Texas and Oklahoma are included in the ABA Southern Region. Distance however, limits our access. Nevertheless, their numbers are included in the Simulations.

Figure 4 Burn Center Locations across the American Burn Association Southern Region, 2011.

- Self Identified Burn Center
- Self Identified Pediatric (only) Burn Center
- ABA Verified Burn Center
For a disaster to go well in terms of access to and utilization of needed interstate resources, it is essential to include local and state emergency management. This specifically includes the ESF-8 contact to aid with interstate coordination in terms of destinations and coordination of transportation resources. Barriers include payer source for the patients. Burn care is one of the most expensive specialty care programs, and it may be unrealistic to expect a receiving hospital to bear the burden of multiple uninsured patients who could accumulate a patient charge in excess of $1,000,000 per patient without a known payer source, according to the ABA NBR Annual Report ("Burn Center Referral Criteria," 2006).

In the context of a disaster declaration that has presidential approval, there is a FEMA policy for medical care and transportation reimbursement of the first 30 days of care as a payer of last resort according to (Emergency Medical Care and Medical Evacuations. Disaster Policy 9525.4, 2008). For this policy to apply, it must be a presidentially declared disaster. The process is managed by the local providers who must be eligible applicants (function of government or a private not for profit provider) and the payment is made based on the FEMA Infrastructure/Public Assistance process based on (FEMA 321 Public Assistance Policy Digest, 2008) in accordance with (FEMA 322 Public Assistance Guide 2007).

Another Federal response option allows FEMA in coordination with DHHS to activate the National Disaster Medical System (NDMS) using the Federal Coordinating Center (FCC) and the United States Department of Defense (DOD) Transportation Command (TRANSCOM) according to the NDMS FCC Guide (2006).
NDMS can be used for patient evacuation and moving patients to other appropriate hospitals. However, there is one significant limitation: not all Burn Centers are participants in NDMS. (NDMS activation includes payment guarantees that are slightly higher than Medicare but are not always timely in making payment for the services provided.)

There is yet another option. Under a disaster declaration, the United States Secretary for DHHS has limited authority to impose certain rules allowing a temporary expansion of Medicare, Medicaid, and Children’s’ Health Insurance Program (CHIP). According to the (Request for an 1135 Waiver, 2009) and known as an “1135 Waiver,” the DHHS Secretary may declare a public health emergency. This action is taken in accordance with Section 319 of the Public Health Service Act. An “1135 Waiver” is only requested during a presidentially declared disaster under the Stafford Act or the National Emergencies Act. The purpose of an “1135 Waiver” is to assure sufficient services are available to beneficiaries in time of a disaster. Examples for the use of the waiver (or modification) include:

- Conditions of participation or other certification requirements
- Program participation and similar requirements
- Preapproval requirements
- Requirements that physicians and other healthcare professionals be licensed in the State in which they are providing services, so long as they have equivalent licensing in another State (this waiver is for purposes of Medicare, Medicaid, and CHIP)
reimbursement only – state law governs whether a non-Federal provider is authorized to provide services in the state without state licensure)

- Emergency Medical Treatment and Labor Act (EMTALA) sanctions for direction or relocation or of an individual to receive a medical screening examination in an alternative location pursuant to an appropriate state emergency preparedness plan (or in the case of a public health emergency involving pandemic infectious disease, a state pandemic preparedness plan) or transfer of an individual who has not been stabilized if the transfer is necessitated by the circumstances of the declared emergency. A waiver of EMTALA requirements is effective only if actions under the waiver do not discriminate on the basis of a patient’s source of payment or ability to pay.

- Stark self-referral sanctions

- Performance deadlines and timetables may be adjusted (but not waived).

- Limitations on payment for healthcare items and services furnished to Medicare Advantage enrollees by non-network providers

The “1135 Waiver” is used only during a period of emergency and will either end after 60 days or when the emergency period ends, unless extended an additional 60 days. Nevertheless, it creates still another mechanism for assuring that those patients who need care receive that care and that providers have a means of recovering their associated costs.

All of the aforementioned payer strategies predicate upon a federal declaration of disaster. Unfortunately, for a disaster with significant number of burn
injuries, a federal declaration of disaster is unlikely. Unless the disaster produced significant numbers of patients with burn injuries is more widespread than a building or industrial explosion, airplane crash, etcetera, it is more likely be seen as a local disaster which typically does not rise to the threshold needed to be designated as a federally declared disaster.

Regardless of payer source or the size and scope of the disaster, all disaster planning and response efforts start at the local level. For North Carolina, as with most states, the first contact with the regional Trauma Center or a Burn Center is the local EMS agency. Thus it is vital that those local, regional and state EMS resources are (and have been) engaged from the onset. This is the case in North Carolina, since their transportation resources and medical expertise, as well as those they may call upon for mutual aid; serve as that first link into the NC healthcare system. The EMS, the Trauma Center, or the Burn Center may also serve as the first to notify the ESF-8 lead for NC (NCOEMS) of a burn disaster. This “heads up” aids the effort should additional intrastate or interstate resources be needed. Burn resources are limited in North Carolina as they are in most all states.

Development of a successful plan for burn disasters in any state or region demands that all stakeholders are involved, know the rules, leverage the available resources, and understand the capacities. While the focus of this paper is aimed at one particular state, the lessons learned are adaptable to meet needs in other states. The overarching focus of this work includes understanding regional resources and how they can be leveraged to address a local disaster.
Successful disaster planning includes trigger points in a plan to expand the response such as reaching a certain number of patients. Predetermined trigger points in a plan, serve as a reminder to command or responders to summons additional intrastate and interstate regional resources. Timely decision making and accurate assessment of the events as they are unfolding both contribute to successful disaster response. Having a plan that is scalable, with strategic triggers for moving into different phases of the plan, allows responders to focus on the immediate need and quickly recognize the need to escalate the response to manage the evolving needs. Some of the most colossal failures in disaster response occur when either local plans lack scalability or regional and federal plans do not interface well with the local response. Conversely, successful response to disaster begins with local responders who manage what they can and recognize the need for mutual aid and assistance, relying on state and federal partners when appropriate.
II. REVIEW OF THE LITERATURE

The literature reviewed for this work includes background and data regarding the general state of preparedness from the hospitals and healthcare system that represents the burn community. Additionally, the literature review includes analysis of events from the 9/11 attacks to more local disasters such as the Hamlet Fire, the Pope Air Force Base aircraft collision (Mozingo, Barillo, & Holcomb, 2005), the West Pharmaceutical dust explosion (Cairns, Stiffler, Price, Peck, & Meyer, 2005), the Savannah Dixie Cristal Sugar Factory explosion ("ED handles 30 burn patients after plant fire and explosion in Georgia," 2008), and the ConAgra Factory explosion.

Other areas reviewed in the literature include hospital and healthcare system preparedness, public health and governmental planning and preparedness, and the after-action report following the 9/11 attacks. Several significant plans and preparedness systems emerged following 9/11. Subsequent wars in Iraq and Afghanistan created valuable opportunities to explore optimal methods for burn care at the point of the injury and after evacuation to a hospital, and the type of specialty care available only in major medical centers. For American military personnel injured, this included initial care provided in field hospitals until they could be flown to the United States for surgical and long-term care. This review also
includes the methods of stabilization and evacuation of the burn patients.

Historical disasters with significant burn injuries are great predictors of patterns, capacities, and challenges. This remains so even with the substantial changes in technology through the years that has impacted both fire prevention and medical care for the burn patient. One of the more relevant works by (Vaghela, 2009) specifically focused on British medical disasters with significant numbers of burn injuries. Others identified trends and discussed factors related to historical medical disasters with significant burn injury generally in the United States, including (Barillo & Goode, 1996), (Barillo & Wolf, 2006) and (Saffle, 1993). One of the papers, (Barillo & Wolf, 2006), discussed several of the more prevalent trends including the decline in the number of events with substantial numbers of patients, which were attributed to improved building codes, and burn prevention.

A paper by Feller et al. was the first to catalogue Burn Centers around the United States and discuss their role in a disaster (Feller & Crane, 1971). Dr. Feller published another paper in 1980 discussing the improvement of burn care (Feller, Tholen, & Cornell, 1980). It is also interesting to note that the subsequent work by Dr. Feller (the 1980 paper) also reported there were 120 Burn Centers in the United States, a number that today is basically the same.

The literature review in this dissertation also covers the national ambulance contract that was established in the aftermath of Hurricane Katrina, a catastrophic Category 4/5 hurricane that struck the United States Gulf Coast in 2005. While not intended to address burn care needs, the contract is a valuable resource should
there be a need to evacuate and redistribute critically injured over a network of Burn Centers throughout the nation. Medical transportation is critical for burn disaster planning. For small numbers of burn injuries, it should be noted that more than 75% of the national population live within a two hour aero-medical transport of a Burn Center (Klein et al., 2009).

For longer transports or multiple transports, military medical experience has shown us proven ways of traveling with the necessary portable equipment (Barillo et al., 2008). Renz et al. provided a great insight into the logistics and successes of these large scale long distance transports for burn patients (Renz et al., 2008), and Hudson and Weichart discussed self-contained transport modules that would aid long range transport of patients (Hudson & Weichart, 2002). During a burn disaster, moving patients over several states by open configuration aircraft would work best provided there were ample access to interchangeable transport modules (a stretcher type device that has components such as a ventilator, cardiac monitor, blood pressure monitor, end-tidal carbon dioxide monitor, and saturation of oxygen monitors built into it and constructed in such a way that it can be easily moved with the patient and locked into a common rack system found in the body of most airplanes.)

The self-contained (patient) transport modules are vital for safe long-distance transports in the movement of injured Soldiers and Marines from Afghanistan and Iraq. Internationally, Tran and his Australian colleagues associated with CareFlight (formerly known as the National Roads and Motorists Association...
[NRMA] CareFlight) discussed air transportation and distribution of patients from a burn disaster in Bali, (Tran et al., 2003). (It should also be noted that a North Carolinian visiting Bali was injured in the Balinese explosion and flown to the North Carolina Jaycee Burn Center from Indonesia for care involving his burn injuries.)

Understanding the scope of the problem in terms of how scarce the burn resources are, begins with an analysis of the access to a Burn Center. One of the more recent publications, (Klein et al., 2009), examines the proximity of the United States population to a Verified Burn Center either by ground or by air within one and two hours respectively. Their data included the 128 Burn Centers that existed in 2008 (now 123 Burn Centers as of 2011) and focused on the Verified Burn Centers which comprise 25% of the Burn Centers in the Southern Region for the American Burn Association. Their findings concluded that the lowest proportion of the United States population with access to a Verified Burn Center was in the southern United States.

**Hospitals, Healthcare systems, and Governmental Planning and Preparedness**

The nation’s major hospital emergency departments are experiencing record volumes of patients (McCaig & Burt, 2004). The nation’s Burn Centers are also experiencing growth for the past four consecutive years after several decades of decline (Milenkovic, C.A, & Elixhauser, 2007). At the same time, the country is facing significant threats from terrorism (Arnold et al., 2003). Other threats include mass casualty medical disasters and pandemic flu (Devereaux et al., 2008). Just two years
before the 9/11 attacks, Kvetan published a work discussing the readiness of the United States critical care system, (V. Kvetan, 1999). If any single threat became a reality, it could dramatically overwhelm the nation’s healthcare system. Information learned from historical events and the presence of current threats and their potential to create situations similar to those we have learned from history strongly suggest a need to develop solutions to this looming crisis. One such solution includes creating and developing surge capacity into existing facilities and services.

Dr. Jeffery Hammond took a more general approach to mass casualty planning and how it interfaced with trauma care (Hammond, 2005). As the chief of trauma at a major medical center and a former Burn Center surgeon, Dr. Hammond also provided insight as to how burn programs interfaced with the nation’s Trauma Centers. Hammond accurately identifies that the term “disaster” varies depending on the perspective of the hospital or EMS agency impacted by the particular event. Hammond’s interchange of the terms “disaster” and “catastrophe” also reinforce the fact that these concepts are neither uniformly understood nor clearly defined.

A key focus of the Hammond paper includes the challenges faced by on scene commanders. This work reinforces a key point made by the Dr. Valad Kvetan (Vlad Kvetan, 2001) and the Cassuto and Tarnow (Cassuto & Tarnow, 2003) publications as well regarding the difficulties on scene managers face in these disasters. Their works also address and affirm a key hurdle: the difficulties involving destination decisions for victims to area hospitals during a mass casualty event. Local resources (which include on scene responders, transportation resources, and hospitals) are
quickly overwhelmed. Thus, coordination by the on-scene commanders and the need to establish immediate communications and maintain them is imperative.

The broader view of disaster preparedness for those involved in managing disasters with a medical component includes mass casualty planning, specifically surge capacity planning. The most recent surge capacity publication includes several HRSA grant funded initiatives. In 2003, the State of Utah Department of Health passed HRSA funding to a group represented by the Utah Medical Surge Planning Task Force. Their work focused on developing 1,250 surge capacity beds to include 125 additional burn and critical care beds. These efforts are detailed in Moser (Moser et al., 2005), and include a follow up work by many of the same group to include the core research group (Moser et al., 2006). Utah is generally a rural state with some frontier areas. However, to a far lesser extent, there are also some suburban and urban areas as well.

Another project focused on developing burn surge capacity in the New York City greater metropolitan area. The work of Yurt et al (Yurt et al., 2008) followed several years of developing their program in New York. Yet another project, (Vandenberg et al., 2009) offered a solution for the greater Los Angeles area.

Developing a rural program has its own set of challenges in the post-9/11 world, but everyday burn disasters continue, (Cairns et al., 2005). Furthermore, there are some commonalities between rural and suburban planning aims and those of their urban counterparts. [I have discussed the planning concepts and processes used for the New York plan on multiple occasions with one of the co-authors of (Yurt et al., 2008), Dr. Soloff of the New York City Department of Health, as well as
Nichole Leary, R.N., since both the New York and the North Carolina programs share some developmental similarities such as surge identification and plan activation].

The Agency for Healthcare Research and Quality hosted a conference regarding surge capacity (*Altered Standards of Care in Mass Casualty Events*, 2004), with a focus on an attack involving bioterrorism which resulted in a substantial influx of patients. Panelists involved in the AHRQ conference discussed the importance of developing networks across multiple community and regional boundaries to improve surge capacity. While the focus was general enough to address public health as well as mass casualties, there is clear applicability to a burn disaster event. This dissertation also discusses at length and focuses on the two-part work of Moser's 2005 and 2006 articles (Moser et al., 2005) and (Moser et al., 2006) as well as contrasting the need with the reality that the problem in rural America continues to be exacerbated by the closure of hospitals there.

Several significant academic works emerged regarding either the 9/11 attacks or the Station Nightclub Fire in Rhode Island in 2003. Both were substantial events producing many victims with extensive burn injuries, significantly stressing and surging the capacity of the impacted area healthcare systems. (Simon & Teperman, 2001) and (Cushman, Pachter, & Beaton, 2003) offered early assessments of the medical disaster lessons learned, including surgical capacity for two of the hospitals immediately impacted by the 9/11 disaster. (Feeney, Goldberg, Blumenthal, & Wallack, 2005) discussed the preparedness and response capabilities of the first receiving hospital from both the 1993 bombing of the World Trade Center (WTC) North Tower and the 2001 attack on the WTCs. St. Vincent's
Hospital, a Level I Trauma Center located near the WTC complex, saw a significant number of patients (844) related to the attack on the WTC. A second article published by (Kirschenbaum, Keene, O'Neill, Westfal, & Astiz, 2005) also discussed the St. Vincent’s response to the WTC attack. Both articles discussed the readiness efforts of the facility, which should certainly be applauded. However, there was not specific discussion regarding the triage and transfer of patients with burn specific injuries to a Burn Center (the closest being the William Randolph Hearst Burn Center, New York Presbyterian, Weill Cornell Medical Center). Furthermore, based on the review of the data, it appears burn patients field triaged to the William Randolph Hurst Burn Center were the only patients either directly transported there or transferred there.

It should also be noted that St. Vincent’s Hospital, a 758 bed Level I Trauma Center, closed and filed for bankruptcy April 14, 2010. The Board of Directors voted on April 6 to close the facility, employees were notified on April 7, and patients were no longer admitted after April 7 as the hospital spun down operations. A matter that is in dispute is what impact, if any, did the 9/11 attacks have on patient admissions in the months that followed, and on the financial health of the facility in the years that followed.

Dr. Harrington was the burn surgeon attending on duty the night of the Station Nightclub Fire in Rhode Island in 2003. In the United States, this was the first major burn disaster to strike after the 9/11 attacks. The successes of the Rhode Island Hospital and their challenges were detailed in (Harrington, Biffl, &
Cioffi, 2005). Dr. Harrington went on to report that 15 local hospitals initially received patients during the aftermath of the Station Nightclub Fire. Patients with burn injuries were later transferred either to the Rhode Island Hospital (RIH) or to Massachusetts General Hospital (MGH) with a majority of the burn survivors remaining at the RIH. The response to the disaster at RIH included managing the surge of patients through discharging patients and transferring patients to MGH and a recall of all staff to RIH. Their distribution of burn injured patients included seeing 64 patients, admitting 47. 33 out of the 47 had burns of less than 20% TBSA and 12 with burns of 21-40% TBSA. The balance (two) had greater than 40% TBSA. EMS community and regional hospitals greatly contributed to the outcomes of the patients by initiating care that was consistent with ABA criteria for the initial management of a burn patient. Key conclusions as a result of their work included the need to develop regional burn surge preparedness, national guidelines for care and transfer, and additional protocol development for burn care outside of a Burn Center.

Retrospective evaluations of the 9/11 response in both Washington D.C. by Dr. James (Jim) Jeng at Washington Hospital Center, MedStar Health and Dr. Roger Yurt, in New York at New York Presbyterian Hospital, Cornell Health were discussed in (Jeng et al., 2006) and (Yurt et al., 2006). While it is generally thought that the major Burn Centers in Washington D.C. and New York City provided incredible care under difficult circumstances, the introspective view was insightful. Furthermore, the frank discussion in their respective papers served as a reminder to medical disaster planners and Burn Center leadership that a short term surge of
burn patients was far less taxing on a Burn Center than trying to manage a long term surge of patients.

An article by Yurt et al (Yurt et al., 2005) discussed the burn patients received or distributed to other Burn Centers after the 9/11 attacks. With 40 staffed beds and additional capacity at the hospital to absorb a surge of patients, the data indicates this facility was positioned to receive and manage a significant number of the actual burn patients. The (Yurt et al., 2005) work also discusses the involvement of a Disaster Medical Assistance Team (DMAT) and Burn Specialty Teams (BST) using the National Disaster Medical System (NDMS) to bring in additional burn care resources as occurred at New York Presbyterian following the WTC attacks.

(Sheridan et al., 2005) discuss the concept and development of the BST program in the NDMS. One of the co-authors, Dr. Briggs, was a principle proponent of the development of the BST program. Until 2009, there were four BSTs across the nation, each attached to an existing DMAT in their area. Conceptually speaking, the BST was a deployable solution for disasters where the need for additional surge capacity might exist, such as that which occurred following the 9/11 attacks.

In late 2009, the BST program was dissolved as a standalone program with team members and assets being folded into existing DMATs. Requests for burn specialty resources today are routed through DMATs that have burn resources.

**Burn Surge Capabilities**

In the years the followed the 9/11 attack, representatives for the American
Burn Association produced a framework regarding disaster management as it related to burn care, to include establishing basic definitions to include a “Mass Burn Casualty Disaster” and create guidelines for Burn Centers (Gamelli et al., 2005). The work also discusses the interface with the federal civilian disaster program, NDMS, and the Military Support to Civil Authorities. A significant component of this work includes a triage decision table created by Dr. Jeffery Saffle, who used data from the ABA National Burn Repository of data to compare and contrast patient outcomes and their ages with respect to the size of their burn. This triage decision table is the basis for consideration known as “benefit to resource ration based on patient age and total burn size.” This work is a good basis for developing burn care components of disaster plans locally, statewide and nationally. This chart also serves as a means to allocate resources when patient volumes exceed capacities and capabilities.

(Milenkovic et al., 2007) published a statistical analysis for hospital admissions involving burn care reviewing data for the past 10 years. Their findings of note include a 44% decrease in burn admissions from 1994-2000. They also noted a 22% increase in burn admissions from 2000-2004. The trending change in admissions came at a time that either followed or were accompanied by closures and a reduction in capacity at Burn Centers across the nation.

One significant limitation regarding the data in the Milenkovic paper is the number of patient days. Ideally, to understand the change in Burn Center capacities, the key unknowns to be measured include patient days, admissions, and
staffed burn beds. Once you have that information you can trend the data on an annual basis to better have a true understanding of burn capacity for the day-to-day events. If the Average Length of Stay (ALOS) for burn care has diminished for the day-to-day events (even with an increase in admissions), there may be sufficient market forces in place to provide a stable number of available burn beds for day-to-day operations.

One particular striking aspect of the Milenkovic paper focused on burn admission by region. The southern region of the United States (defined by the US Census Bureau as consisting of Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Kentucky, Tennessee, Alabama, Mississippi, Louisiana, Texas, Oklahoma, and Arkansas) has the highest incident of burn event and related admissions to a Burn Center (15.6 admissions per 100,000) when compared to other regions of the United States. The northeast region (with a ratio of 6.6 admissions per 100,000) had the lowest rate of admission when compared to the population. It should also be noted that the area identified as the "southern region" in the ABA NBR Annual Report ("National Burn Repository, Report of Data from 2001-2010. ", 2011) includes Delaware, Maryland, the District of Columbia, Texas, and Oklahoma, while the southern region of the ABA did not include these states or the District of Columbia prior to January 1, 2011.

The daily capacity for burn care in the United States is limited, and the trend had shown a decline for the past 10 years until stabilizing this year with a slight
increase in the overall number of beds. According to (Gamelli et al., 2005) there were 1897 burn beds nationwide, operated by the 132 Burn Centers across the nation. However, by 2008, according to the American Burn Association *Burn Care Facilities* (2008) lists 128 Burn Centers, with 1833 total beds. The current iteration of this document, The ABA Burn Care Resource Directory, ("Burn Care Resource Directory," 2011) now lists 123 Burn Centers with 1895 beds.

Another means of measuring Burn Center capacity is to review the data regarding the number of Verified Burn Centers and their number of reported burn beds. ("Burn Care Resource Directory," 2011) listed 61 Verified Burn Centers with 1026 burn beds nationwide. (This report omitted a Verified Burn Center in Australia which has also completed the ABA verification process). The American Burn Association offers a verification process for Burn Centers. This process is an adaptation from the American College of Surgeons (ACS) Trauma Center designation and was first developed when the ABA was a part of the ACS. It is accurate to say that some hospitals offer trauma care or have a state designation but lack the ACS designation as a Trauma Center. The same can be said for burn care, as more than 50% of those hospitals who self-report that they operate a Burn Center actually lack ABA verification designation.

Two papers with similar findings and published within a two year period include (Pacella et al., 2006) (Pacella, Harkins, Butz, Kuzon, & Taheri, 2005) where they concluded patients with burn injuries seen in high volume hospitals generally had better outcomes, shorter stays, and fewer complications. While these efforts
looked at several aspects of burn care in the state of Michigan, the trends noted there are important questions to consider in other states as well. One recent analysis regarding the differentiation between the Verified Burn Centers and those who lack verification (Palmieri, London, O'Mara, & Greenhalgh, 2008) found that while the work validated the importance of the verification process, there were no overwhelming conclusions that could be directly related to patient outcomes. In general there remains a shortage of burn beds for surge capacity during a disaster, regardless of verification status. More specifically, the Burn Centers that do operate based on the guidelines of the verification standards are generally the larger, comprehensive centers, which receive more patients with a higher acuity. Regardless, the verification process indicates a clear path to a best practice approach, which should be the goal (if not a requirement) for all Burn Centers. Ultimately, given the scarcity of burn beds, having capacity that includes Burn Centers that either do not or have chosen not to meet the standards found in the verification process may be the best that can be achieved at this point.

Planning for Disaster

(Cancio et al., 2005) discusses both national and international support for burn care related to military operations, primarily those in Iraq. This work is particularly important to discuss and understand patient movements following a burn injury. Burns are unlike some of the more critical medical situations such as multi-system trauma and heart attacks. Burn patients have their best outcomes when their airway is properly managed, their pain controlled, fluid resuscitation is
appropriate in terms of flow rates and fluid type, and the patient is monitored for ongoing adequate distal circulation. This premise allows for patients to be managed regionally outside of a Burn Center for several hours and transported to Burn Centers throughout the region. A Soldier or Marine with a major burn injury initially occurring and managed in Iraq and Afghanistan may wait several hours before being flown to other hospitals in Europe or the United States for additional care. (Chung et al., 2006) published another view that is similar to the previously discussed work, which resulted in similar findings.

One of the first academic papers to be published regarding burn care in the aftermath of the 9/11 attack involving the New York management of burn injuries was by (Simon & Teperman, 2001). Their paper was an initial recap that did not discuss shortcomings of the response. Dr. Simon's discussion of burn patients included the initial patients who were evacuated to the one Burn Center on Manhattan Island, the New York Presbyterian Cornell Medical Center.

Following 9/11, the most significant burn event in the past 10 years occurred in 2003 at a nightclub near Providence, Rhode Island, known as the Station Nightclub Fire. Details related to the medical response were included in two similar papers; the first by Dr. Harrington (Harrington et al., 2005), and the second by Dr. Eric Mahoney (Mahoney et al., 2005). The fire resulted in 215 victims being injured and needing treatment either there in Providence or neighboring medical facilities. Another 96 died at the scene with four additional deaths in the days that followed the disaster. Dr. Harrington's paper was focused more on the burn care
aspects of the response, while Dr. Mahoney's paper focused more on the Trauma Center and trauma system, both papers clearly detail what was obviously an incredible effort to have produced such a successful outcome. Nevertheless, there are also lessons to learn that must also include a review of this event with a critical analysis.

Nevertheless, the notion that a substantial majority of the patients for each of these events could be managed at one or several nearby facilities suggests a position that is contrary to the general consensus of burn plans and published military experiences from both Afghanistan and Iraq. The U.S. Military experience in Afghanistan and Iraq included no effort to convert existing medical facilities into Burn Centers. Instead, local facilities in those countries were used to stabilize these patients and triage them generally to the United States, where they were typically treated at the Burn Center located at Brooke Army Medical Center.

Jordan et al, from the Washington Hospital Burn Center in Washington D.C., published a follow-up paper in 2005 regarding their response to the 9/11 attack on the Pentagon and the subsequent burn injured patients from that attack (Jordan, Hollowed, Turner, Wang, & Jeng, 2005). Their paper focused on the response of the Burn Center at Washington Hospital Center, as well as the capabilities and capacities for that facility. Their work stated that the capacity of the Burn Center was nine patients with severe or critical burn injuries. The Burn Center at Washington Hospital Center has 17 licensed beds and is one of the 53 Verified Burn Centers in the United States. For a Burn Center of this stature to recognize and
conclude their best, had limitations during this disaster due to its size and scope is an important introspective view that few will ever conclude. This realization is an excellent reminder for other facilities that it is in the patients' best interests to distribute these patients to other area and regional Burn Centers when that Burn Center is over capacity.

The report generated by the Board of Trustees and the Organization for the Delivery of Burn care for the American Burn Association detailed a basic ABA Disaster Plan Framework (Gamelli et al., 2005). The paper was a candid evaluation of the capabilities and (more specifically) the limitations of the burn community from a national view.

While much of the qualitative information that is in this work is both logical and reasonable, there are several points made that are difficult to affirm other academic publications, or that is inconsistent with current practice. Two such examples include the ABA Primary Triage Policy and ABA Secondary Triage Policy. With the ABA Primary Triage Policy, the point is made that "burn patients should be triaged to a Burn Center within 24 hours of an incident." Holmes discussed the challenges faced throughout the country by Burn Centers, particularly those related to disaster preparation. (Holmes, 2008)

The development, operation and deployment of the Burn Specialty Teams (BST) was discussed in a paper by, (Sheridan et al., 2005). The BST came into prominence following the 9/11 attacks. A BST could be used to aid in the triage and decision making for transfer of these patients to other facilities. Dr. Sheridan's
paper specifically discusses extending capacity in such a fashion that dramatically exceeds the typical capacity of the local Burn Center. It is difficult to logically understand, even using a BST, how substantially exceeding the equipment, staffing, and physical plant capabilities may yield the best outcome for the burn patients produced by the disaster without significant preplanned logistical support.

**Potential Catastrophic Events**

During my literature review several models were identified that should be noted. Internationally, (Albores & Shaw, 2008) used discrete event simulation to examine the ranges of major events in England. Three additional domestic papers were identified that used modeling for the purpose of examining potential patient numbers following a given event. These papers include (Coleman et al., 2009), which discussed the dimensions of a medical response to a nuclear event; and the work of (Dallas & Bell, 2007) and (Bell & Dallas, 2007), which included a predictive model to measure the impact of a nuclear detonation involving several major cities. Given the thermal wave generated by a nuclear detonation, tens of thousands of the survivors would have some degree of burn injury.

The medical disaster management for something so catastrophic would certainly include the use of adaptive spaces for the volume of injured that would overwhelm the local medical resources. This was seen and discussed from various points of view in papers regarding Hurricane Katrina including (A. L. Eastman, K. Rinnert, I. R. Nemeth, R. L. Fowler, & J. P. Minei, 2007; A. L. Eastman, K. J. Rinnert, I. R. Nemeth, R. L. Fowler, & J. P. Minei, 2007). The numbers of patients who could be
produced by a nuclear weapon detonation or improvised nuclear device (IND) are well beyond the scope of this work. Nevertheless, the magnitude of a disaster such as this would produce substantial numbers of casualties.

**International**

In Kobe, Japan, Takahashi et al (Takahashi, Ishii, Kawashima, & Nakao, 2007) mathematically explored and quantified Hospital Treatment Capacity (HTC) by exploring what supplies and equipment were on hand and contrasting that with the arrival of patients during day to day activities. Posner et al (Posner, Admi, & Menashe, 2003) discussed a strategy for expanding a burn unit in Israel tenfold for managing a surge of patients. Both of these concepts are unique but should be considered in future planning efforts.

Much of the North Carolina Burn Surge Disaster Program, I developed while working at the University of North Carolina. The activation trigger includes a 6:5:6 strategy. This is a concept that suggests that if there are more than six burn patients from a mass casualty event, each with a 2\textsuperscript{nd} or 3\textsuperscript{rd} degree burn covering more than 5\% of the body, then the regional hospital or Trauma Center may have to manage one or several patients for up to six hours while transportation and admission to Burn Centers can be arranged.

As components of this program were developed, representatives from the various regional hospitals and Trauma Centers in North Carolina (ones that are not Burn Centers) objected to plan development principles which included those same facilities holding significant numbers of patients for any significant length of time. A
survey involving emergency department physicians and nursing staff at these facilities indicate a real concern with having to manage these patients for any extended period of time (beyond 90 minutes). The compromise position that was developed between the Burn Centers and those hospitals in the Trauma Center community included a plan involving the 6:5:6 concept. One standard procedure of the NC Burn Surge Disaster Program includes developing routine orders (also known as care plans) to manage a patient for up to six hours while triage and transport can be arranged to a Burn Center for management of care and admission.

The ABA Secondary Triage Policy includes transferring patients to Verified Burn Centers. Following this policy in the United States southeast is generally a difficult goal to attain. There are seven Verified Burn Centers in the region (which includes Mississippi, Alabama, Tennessee, Kentucky, Georgia, Florida, South Carolina, Virginia, and North Carolina.) These Verified Burn Centers include the Wake Forest University Baptist Health; the North Carolina Jaycee Burn Center at UNC Hospitals in North Carolina; the Joseph A. Still Burn Center in Augusta, Georgia; Shands Medical Center at the University of Florida; Jackson Medical Center at the University of Miami; and the Tampa Regional Medical Center. The newest Verified Burn Center in the ABA South Region is the Virginia Commonwealth University Evans-Haynes Burn Center in Richmond.

The ABA Secondary Triage Policy recommends Verified Burn Centers for the first choice, given the lack of verified burn beds in the ABA South Region; it is difficult to rely solely on verified burn beds. Furthermore, according to "Burn Care"
Facilities (2009), there are 967 verified burn beds in the United States. Consequently, there are significant limitations for medical responders to access an ample supply of burn beds regardless of verification status.

In review of the response to the 9/11 attacks, a paper discussed the critical nature of disaster planning and execution, and reinforced the vital link between planning and plan execution, (Cancio, 2008). Cancio specifically focused on the recent released paper by Yurt et al. who were developing the disaster plan for New York City (Yurt et al., 2008). Cancio’s conclusion could be summarized as “relentless training with support from both individuals and institutions leads to success.” Administration and physician buy-in is critical to success with disaster medicine. An earlier paper by O’Neill challenged surgeons to get more involved in understanding their role in disaster planning and response, the incident command system, and the basics of disaster operations (O’Neill, 2005).

Training and education is a cornerstone to the response capabilities of an agency. These include core training programs such as Advanced Burn Life Support (ABLS); locally produced programs such as discussed by Wetta-Hall et.al., at the University of Kansas (Wetta-Hall, Jost, Jost, Praheswari, & Berg-Copas, 2007); or, for those training abroad, Emergency Management of Severe Burn (EMSB). Stone and Pape (Stone & Pape, 1999) discuss the importance and implementation of EMSB (a program similar in nature to ABLS) and it is discussed here to note the similarities related to response and care for burn disasters in Europe, Australia and New Zealand.
Response to Disaster

On a national level, response to disasters includes organizations such as the National Disaster Medical System (NDMS) and their rapid response teams, also known as Disaster Medical Assistance Teams (DMAT). (NDMS originated in DHHS, was moved to DHS/FEMA and with the passage of PAHPA, much of NDMS was assigned to ASPR of the DHHS.) Response to the WTC disaster included activation of all 28 teams. There are several state models that have evolved into national models for response. Through the Emergency Management Assistance Compact (EMAC), the state resources and assets have also been involved in interstate response to disasters. Other approaches aimed at the types of programs that are not fully engaged include the Academic Medical Centers (AMC). Sklar et al. reported the efforts at the University of New Mexico and discussed their response experiences (Sklar, Richards, Shah, & Roth, 2007). This work could serve as a means of encouraging those AMCs not currently involved in either a federal or a state initiative to develop disaster response capabilities.

A January 1, 2001 burn disaster in Volendam, in the Netherlands involved both academic medical centers in the Amsterdam area (approximately 20 kilometers away) as well as a Burn Center and 18 other hospitals across three countries. The Volendam café fire with 245 burn injured victims was the basis for (van Harten et al., 2006) and (van Harten, Welling, Perez, Patka, & Kreis, 2005) which included the interface with AMCs as well as involving other medical services from across the country.
Outside the Burn Centers and the hospital systems, the framework for all disaster operations is led by the various state emergency management agencies. The specific plan is generally known as the State Emergency Operations Plan (EOP) (State of North Carolina Emergency Operations Plan, 2009). Each state EOP operates under the guidelines of what historically was known as the Federal Response Plan, (FRP) which was renamed the National Response Plan (NRP) shortly before Hurricane Katrina. At that point, the NRP included eight support functions, with ESF-8 being assigned to Health and Medical (Couig, Martinelli, & Lavin, 2005). With the considerable federal shortcomings noted in the Hurricane Katrina response, the FRP was dramatically changed once again with the most recent version, known as the National Response Framework (NRF) (National Response Framework, 2008). This document was released for comment in 2007 and implemented effective March 22, 2008. Within the NRF, there are 15 Emergency Support Functions (ESF). ESF-8 (Federal Response Framework. Emergency Support Function 8, 2008) is responsible for the Health and Medical Services Annex.

The principle concept of operations is to "conduct a risk analysis, evaluate and determine the capability required to meet the mission objective and provide required public health and medical support medical assistance to State, tribal, and local medical and public health services" (Knebel & Phillips, 2009). Also, according to Dr. Knebel, the national strategy for ESF-8 includes activating staff and providing liaisons to either regional offices or state agencies where appropriate (Knebel & Phillips, 2009).
The focus of the Concept of Operations (con-ops) at the state level is generally similar. In a mass casualty event, ESF-8 lead personnel can play key roles in coordinating these activities. This would include disasters with significant burn patients and where resources may be used from several jurisdictions or involving multiple intrastate or interstate hospitals. Success in responding to a disaster is incumbent upon leaders from the healthcare community at all levels to include the local hospitals and local EMS providers and to allow them to interface regularly outside the heat of a disaster.

**Burn Centers and their Preparedness for a Large Scale Disaster**

More than 20 years before the 9/11 attack, Wachtel et al. discussed both the scarcity of burn care and the need for regional and national disaster planning (Wachtel, Cowan, & Reardon, 1989). While it appears the work gained little traction, it certainly discussed many of the concerns seen today in planning for a disaster which involves a sudden surge of patients with burn injury.

Two years after the 9/11 attacks, Warden and Heimbach offered a position stating that burn care provided in a regional manner may be an optimal model (Warden & Heimbach, 2003). Given the pricing and financial pressures, most markets cannot support multiple Burn Centers. In addition, there are significant barriers to interstate care (such as insurance and Medicaid coverage), even if it is the most reasonable approach. Guagliardo et al discussed the interstate barriers and opportunities at length (Guagliardo et al., 2008).

Dr. David Barillo discussed the need for and current challenges associated
with tracking national availability for bed resources (Barillo et al., 2005). Dr. Barillo also discusses the operations within Burn Centers in preparation for and during a disaster response (Barillo, 2006). Dr. Barillo and the leadership of the ABA Southern Region developed and published a southeast region burn plan in 2006. While flow diagrams and themes of the paper clearly reflect a framework for a plan, the document does not conform to what we recognize today as a National Incident Management System (NIMS) compliant plan.

The president of the ABA in 2005, Dr. Marion Jordan of the Washington Hospital (DC area) Burn Center, published a general overview of the American Burn Association Disaster Readiness Plan which shares some similar traits to the work of (Barillo et al., 2006) regarding the southeast region burn plan (Jordan, Mozingo, Gibran, Barillo, & Purdue, 2005). Dr. Jordan's paper, similar to Dr. Barillo's paper regarding the southern region, is more of a philosophical position paper with guides for decisions and process guidelines. Neither are actual NIMS compliant plans or written in a way to serve as an annex to a plan but both serve as a good starting position for understanding the intent of Burn Center preparedness in the United States.

Burn disaster planning is not unique to the United States. A study of the Turkish healthcare system by Dr. Mehmet Haberal of the Baskent University Medical Faculty in Ankara, Turkey, focused on triaging patients with survivable burn injuries (Haberal, 2006). While not as clear as the paper by Hick et al (Hick et al., 2009) regarding surge capacity, or as detailed as the paper by Saffle et al (Saffle,
Gibran, & Jordan, 2005), it gave researchers another view of burn disaster planning and preparedness. The perspective offered by Dr. Haberal shared many of the same concepts seen in the American academic works such as the scarcity of resources and importance of triage. The basic concepts including resource management and triage were common in other European and American papers as well. The papers discussed, all included problems with managing the surge of patients, all discussed basic approaches to addressing this problem, and all recognized shortcomings in the respective healthcare systems when confronted with a burn disaster.

Access to quality burn care is limited in Turkey. This point was discussed in a paper by Dr. Altug Kut, also of the Baskent University in Ankara, Turkey and colleagues (Kut, Moray, & Haberal, 2005), as well as the paper previously mentioned by Dr. Haberal's (Haberal, 2006). Nevertheless, their work and subsequent findings included guidelines which were created and used in the Turkish healthcare system and were intended to assure those patients who would benefit the most received the most sophisticated care available. Furthermore, these guidelines also offered steps to take to care for others with burn injuries that may not have immediate access to the same level of care. While this approach is consistent with what we refer to as triage in the United States, given the limited availability in Turkey, their focus is truly on those with the more significant, yet survivable injuries.

McGregor (McGregor, 2004) offered a similar strategy, based on historical burn disasters in the United Kingdom. Other international disasters with significant
numbers of burn injuries included the 2002 Bali Bombing as discussed by Kennedy et al (Kennedy, Haertsch, & Maitz, 2005); and several bombings in Tel Aviv, Israel during April, 2006, as discussed in the paper by, (Raiter et al., 2008). Activities in Israel are of particular interest to United States researchers given the constant terror threat in that country and their use of western-style medicine. Both the United States and Israel have substantial ongoing efforts to improve burn care and disaster response with the Israeli efforts being discussed in the paper by Meshulam-Derazon et al (Meshulam-Derazon, Nachumovsky, Ad-El, Sulkes, & Hauben, 2006).

The statistical information and trends previously discussed by Milenkovic et al (Milenkovic et al., 2007) also offer a concrete reason why some Burn Centers are struggling to meet today’s needs. The data suggests that without a dedicated staff member for the planning function, there is a lack of time or effort necessary to actively participate in the planning and preparedness processes.

A 2011 Fact Sheet from the American Burn Association ("Burn Incidence and Treatment in the United States: 2011 Fact Sheet," 2011) provides a good basis for general data regarding burn care across the United States. Other documents from the ABA included in this review of available literature include Resources for Optimal Care of the Injured Patient ("Resources for Optimal Care of the Injured Patient," 2006). Dr. David Barillo, M.D. and Dr. Steven Wolf, M.D. identify and discuss commonalities regarding most of the significant burn disasters for the past 100 years (Barillo & Wolf, 2006). Dr. Barillo also has a work written with Dr.
Robert Goode which discusses the demographics of fire victims which was useful in developing the model for this work (Barillo & Goode, 1996).

Dr. Vlad Kvetan, M.D. provided one of the early academic works following the attack on the World Trade Center and offered valuable insight from a large academic medical center that was in New York, but not in the immediate catchment area for the first transports (V Kvetan, 2001). Significant academic publications have been offered to either support or defend the initial triage and distribution of patients. Nevertheless, Dr. Kvetan's work offered a reminder to the disaster community that while substantial resources were activated and available, there were a disproportionate number of patients distributed throughout the New York healthcare system (Vlad Kvetan, 2001).

Hudson and Weichart, both members of the United States Army Nurse Corps of the White House Medical Unit, discussed the high rise building terrorist attacks at Oklahoma City (1995) and New York City (2001) (Hudson & Weichart, 2002). Their work focused on transportation of the injured to the appropriate facilities. They discussed the importance of using available transportation capabilities, while making sure patient distribution is made to the appropriate facilities. Their review of military experiences using an off the shelf product (Life Support for Trauma and Transport [LSTAT]) to assure each patient is transported using monitoring equipment was a great example for the civilian application. With large-scale mass casualties, one of the best solutions is to take the military approach, with immediate and aggressive stabilization close to the site of the disaster followed by
distribution of the patients in a way that maximizes resources and improves patient outcomes.

Dr. C. L. Leslie and her colleagues at the Baystate Medical Center in Springfield, Massachusetts reported their experiences at a Level I Trauma Center not co-located with a Verified Burn Center and their involvement regarding an industrial explosion with several severely burned patients (Leslie, Cushman, McDonald, Joshi, & Maynard, 2001). The explosion occurred at a foundry in the New England area in 1999. This paper supports the position that Trauma Centers, even without co-located Burn Centers, can serve as a point of treatment and absorption for the initial surge of burn patients following a significant event. The role of Trauma Centers as a buffer to aid in the management for a surge of patients with burn injury is generally seen as essential in burn surge disaster planning.

Since the 9/11 attacks, there was an unprecedented buildup of preparedness in the healthcare community, with an emphasis on surge capacity. However, general burn care, and specifically burn surge capacity, remains scarce. One proposed solution includes a strategy focusing on the Level I Trauma Centers. These efforts were discussed in Yurt et al (Yurt et al., 2008) and Vandenberg et al (Vandenberg et al., 2009). It is important to note these efforts, in general, are more theoretical and yet to be fully tested by an actual large-scale event. The Leslie (Leslie et al., 2001) and Sagraves papers (Sagraves et al., 2007) describe real world solutions which confirm several of the underlying principles proposed in the paper by Yurt et al (Yurt et al., 2008).
Socialized medicine, as found in most of the European countries, allows for slightly different strategies in the management of burn injuries. (Welling et al., 2005), (Welling et al., 2006), and (Welling et al., 2006) describe their management of a significant number of burn injured patients (245) following a nightclub fire in Volendam in the Netherlands on the evening of December 31, 2000. Their immediate action was to close the Burn Center to all new admissions and route all burn patients to other hospitals until a better understanding of the quantity of patients and degree of their injuries can be determined. This allowed them to surge their staff, discharge patients, and triage patients at the other hospitals to assure that those who could most benefit by care provided at a Burn Center were allotted one of the Burn Center beds. Given the competitive nature of the American healthcare system, it would be difficult to replicate this approach in the US. However, there are useful strategies here relating to managing large numbers of patients, such as the value of rapport with the community hospitals that patients generally visit first before being moved onto the Burn Center.

**When the Surge of Burn Patients exceed capacity of the NC Burn Centers**

When there are a surge of patients with burn injuries, and the surge outnumbers the capabilities of both NC Burn Centers, there are two other less conventional approaches to manage the surge of burn patients. One involves managing some burn patients with minimal or less serious burn injury in intrastate Trauma Centers. The other strategy involves moving patients to Burn Centers in other states.
Relying on the trauma and burn care relationship is a successful strategy in the states where a more mature relationship exists between the centers and progressive efforts have been undertaken to develop these capacities. Most of the Burn Centers in the Southern Region are co-located on a campus with a designated Trauma Center. Most burn surgeons are also board certified trauma surgeons. While there are many more Trauma Centers than Burn Centers in each state, trauma surgeons know where the most appropriate Burn Center is in relationship to their Trauma Center. Regardless of location, the two service lines are complementary. Leveraging this relationship is critical in managing the surge of burn patients prior to their arrival at Burn Centers.

Providing burn care in Trauma Centers that are not co-located with Burn Centers is not consistent with the standard of care for the burn patient if the care extends beyond stabilization. Thus, utilization of the Trauma Centers for surge capacity would be considered Crisis Surge Capacity and outside the scope of this paper.

Nevertheless, it would be reasonable for the North Carolina Burn Surge Disaster Program to adapt the strategy discussed by Dr. Yurt in (Yurt et al., 2008) which included a modified version of the table first published by Dr. Jeffrey Saffle, M.D. in a paper (Saffle et al., 2005). This strategy could allow North Carolina to include the use of Trauma Center beds in their system in order to manage patients for extended brief burn critical period (24 up to 72 hours with the target period being up to 24 hours). Dr. Saffle and colleagues created this table as a decision
guide using historical data from the NBR, contrasting and comparing two variables (age of the patient and the Total Body Surface Area [TBSA]), and stratifying the chart to predict outcomes based on a survival rate of greater than or equal to 90 per cent.

Dr. Saffle’s work was a comprehensive retrospective look at what was once seen as a simple mathematical calculation created by Professor Serge Baux approximately 50 years ago, which included the sum of the patient’s age and the TBSA to predict mortality for the burn injured patient (Osler, Glance, & Hosmer, 2010). Similar to the Baux score, this academic work reflected outcomes based on the most recent data from the NBR at that time. For disaster programs, guides and tables such as Dr. Saffle’s work are vital to aiding decision-makers during disasters.

The five levels Dr. Saffle’s work identified were:

“Outpatient, survival and good outcome expected without requiring initial admission; High benefit/resource, survival and good outcome expected (survival >=90%) with limited/short term initial admission and resource allocation (length of stay, <=14 days, one to two surgical procedures); Medium benefit-resource, survival and good outcome likely (survival, >50%) with aggressive care and comprehensive resource allocation, including initial admission (>=14 days), resuscitation, multiple surgeries; Low benefit-resource, survival and good outcome <50%, even with long-term, aggressive treatment and resource allocation; Expectant, survival <10% even with unlimited, aggressive treatment.” (Saffle et al., 2005)

While there are other variables that could significantly influence outcomes
(including co-morbidities such as lung cancer, poorly controlled diabetes, and chronic obstructive pulmonary disease), the table created by Dr. Saffle and his colleagues work focused on the two most important predictors to outcomes, TBSA and the patient's age. The published work included a disclaimer clearly reminding the clinician that the chart is not intended for daily use for individual burn patients, but could serve as a guide when patients outnumber resources during a medical disaster.

Dr. Saffle's table was later adapted by Dr. Yurt in his paper regarding the New York City Burn Disaster Plan (Yurt et al., 2008). The table used in Dr. Yurt's paper served as a key guide to stratify what patients would most benefit by immediate transport to a Burn Center and what patients could, during a surge of patients with burn injuries, be managed for a finite period of time at regional hospitals and Trauma Centers not co-located with Burn Centers. Burn Centers were identified as Tier 1 hospitals (High Benefit), Trauma Centers as Tier 2 (Medium Benefit), Regional Hospitals as Tier 3 (Low Benefit), and all other facilities as Tier 4, with Expectant and Outpatient classified patients being triaged to Tier 4 hospitals. This approach can serve as a means of initially triaging patients who require Medium and Low levels of resources to hospitals other than Burn Centers for 24-72 hours, leaving the Burn Centers to deal with the patients requiring high resource levels.

This process as designed by Dr. Roger Yurt, M.D. and his New York City colleagues (Yurt et al., 2008) can be adapted to North Carolina. Using Trauma
Centers to serve as a buffer for patients with Medium and Low resource needs can aid the Burn Centers in staying focused on those patients with the greatest needs. This process allows for the management of Outpatients and Expectant patients without pulling resources from the Burn Centers.

For this process to work, we must assume that a safe and effective means of medically transporting these patients was available and did not alter the process described herein. Nevertheless, this component poses a significant potential limitation and was discussed accordingly in the limitations section.

When the Surge of Burn Patients exceeds conventional and contingency capacity of NC Burn Centers and NC Trauma Centers

Burn Centers working together within the ABA Southern Region participate in a plan to absorb patients needing critical burn care. Managing surge capacity for North Carolina also included secondary triage of patients with burn injuries to other Burn Centers in the region. Much of the guidelines for secondary triage (within 24 hours to another Burn Center, preferably a Verified Burn Center) and interstate utilization of resources is found in the paper published by the Organization for the Delivery of Burn Care Committee for the ABA Trustees (Gamelli et al., 2005). While the potential exists for available capacity from Burn Centers in the region, the primary gap in the information is the bed availability in these Burn Centers and what is the probability these beds could be available if needed.

According to Gamelli et al., each percent of TBSA generally equates to the
number of days the patient spends in the burn intensive care unit (ICU) (Gamelli et al., 2005). Major medical centers throughout the region (as well as across the nation, where Burn Centers are typically located) routinely accept transfers every day and these centers have minimal excess capacity. Furthermore, given the extended stay of the critically injured burn patient, it is imperative to know the capacity for these centers to accept additional critically injured burn patients in the event of a major disaster. Since these centers participate in the Southern Burn Plan, it can be assumed these centers will accept interstate transfer patients in a disaster. Currently, it is unknown to what extent the region can accept and manage a surge of patients, on an interstate basis.

**Triage and the Burn Patient**

Patients with burn injuries are most commonly first seen at a local hospital before being transferred to a Burn Center. Historically, practitioners relied on the Edlich Burn Score, the Zawacki Score, or the Baux Score (most often the latter) to evaluate burn injured patients for the extent of injury and potential survivability (Krob, D'Amico, & Ross, 1991). Mathematically, the Baux Score was the easiest to use, basically adding the patient's age to their Total Body Surface Area (TBSA) for $2^{nd}/3^{rd}$ degree burns to yield a mortality percentage.

However, with dramatic advances in medicine during the past 20 years, that calculation is no longer as insightful. Today, hospitals generally use the criteria from the American Burn Association ("Burn Center Referral Criteria," 2006) which follows guidelines issued by the Committee on Trauma of the American College of
Surgeons. Saffle et al urges great caution when using the Age/TBSA Survival Grid without considering other factors such as co-morbidities (Saffle et al., 2005). Thombs et al conducted an extensive review of 31,338 patients in the NBR from 1995-2005, and concluded that preexisting medical conditions that included HIV/AIDS, metastatic cancer, liver disease, and renal disease have particularly poor prognoses (Thombs, Singh, Halonen, Diallo, & Milner, 2007). In a 2010 article by Dr. Turner Osler, M.D et al, they suggested a modification of the Baux Score with an accommodation for respiratory injury. Using a regression analysis with an adjustment for respiratory injury, they have created a rather logical and simple tool for real-time use by the typical emergency medicine practitioner (physician, nurse or paramedic) (Osler et al., 2010).

The Yurt (Yurt et al., 2008) adaptation of the Saffle (Saffle et al., 2005) Age/TBSA Survival Grid was the first published work to take the survival grid information and translate it to initial triage destinations. The next logical step is to adapt the information from the Thombs (Thombs et al., 2007) findings and improve the application of triage decision-making by including the co-morbidities identified in the Thombs (Thombs et al., 2007) work. That effort could logically improve the focus of how the survival guide is used while maximizing the triage process.

**Research Summary and Gap**

Following the 9/11 attacks, there was a renewed focus on disaster planning. Published efforts to reflect on the lessons learned and the planning revisions have been identified and summarized in this dissertation. Limited federal guidance
provided some basis for the work of others, but that guidance had a limited lifespan, and efforts to address the need for burn surge capacity was limited. Cornell University's Dr. Roger Yurt, M.D., director for the William Randolph Hurst Burn Center in New York City, and Ms. Victoria Vandenberg R.N., an independent contractor for the Los Angeles County Emergency Medical Services Agency, describe unique efforts in two major cities that received substantial grant funding to develop their programs (Yurt et al., 2008) (Vandenberg et al., 2009). The collective works of Dr. Yurt and Ms. Vandenberg addressed managing patients in the metropolitan area, but lacked an effort to move patients outside of this area.

When Dr. David Barilla published the Southern Regional Burn Plan paper, it represented the first regional effort to develop a multi-state plan burn surge disaster plan (Barillo et al., 2006). Nevertheless, that effort did not extend beyond an overview of the distance to be traveled and a decision tree for whom to call and at what point that call should be made. Furthermore, instead of trigger points for patient movements, it gave rather ambiguous directions for either keeping all of the patients at the local Burn Center while bringing in staff and personnel to manage the disaster, or moving patients to other regional Burn Centers. Currently, there is nothing in the literature that indicates an effort to model capacities of Burn Centers in a general region, or to determine what types of capacities actually exist in the region.

One key produce of this dissertation includes developing a predictive model for what resources could be available in the Burn Centers across the region.
Although the paper by Dr. Kanter and Moran (Kanter & Moran, 2007) did use Monte Carlo simulation, their focus was capacity for pediatric beds in New York City. Nevertheless, their paper did provide insights that were valuable for how I proceeded with this dissertation.

Hwang et al published a review of 2,660 academic papers (with 46 of them meeting inclusion criteria), for the purpose of identifying common elements in the definition for "crowding in the emergency department" (Hwang et al., 2011). As this dissertation evolved, I looked to the discipline of emergency medicine for identifying a method or methods regarding how patients can be triaged and managed in the most efficient manner available.

A common and well-rehearsed process could be essential for managing a surge of burn patients. Thus, if emergency medicine had coalesced around a given set of standard definitions, there could be some useful adaptation for my work as well. However, Hwang et al identified 71 unique crowding measures with most of those measures having good correlation with validated criteria. Given the number of unique crowding measures (71), the findings suggest that at this point, the discipline is still searching for a uniform standard that could be modeled and replicated across the country. Nevertheless, Hwang et al did conclude there were two overarching principles being used as the most promising tools for measuring flow and non-flow (also known as crowding): time intervals and patient counts. While no specific model was identified for replication from this paper, their broad conclusion to include a focus on time intervals and patient counts are important to
quantifying capacity for the burn injured patient as well.

Klein discussed the geographical distribution of Burn Centers in relationship to population centers across the state, in terms of both ground and air transport (Klein et al., 2009). In this analysis, he included destinations that were Verified Burn Centers. However, the paper by Dr. Klein focused on the individual burn patient and lacked an explanation of how this geographical distribution of Burn Centers could interact during a disaster, also based on those same measured distances and those same transportation resources.

A total of 384 articles were reviewed based on an extensive literature review with key words including “burn, trauma, emergency medicine, disaster, catastrophe, Monte Carlo, and ESF-8”. Following the review, 132 were identified for inclusion in this work. So much as the 9/11 attacks and Hurricane Katrina have redefined how we approach disaster planning, many of those works were included in this dissertation.
III. METHODS

The Setting

This dissertation was completed to satisfy one of the requirements for the Doctoral degree for Health Administration through the College of Healthcare Professions at the Medical University of South Carolina. The focus of the work included a descriptive analysis and simulation to better understand the available capacity of intrastate Burn Centers, Trauma Centers, and interstate Burn Centers to manage a surge of patients with burn injuries. Data was reviewed from secondary sources, including material from the American Burn Association (ABA) National Burn Repository (NBR), the UNC Hospitals Trauma Registry and a document found on the ABA website; (“National Burn Repository, Report of Data from 2001-2010.,” 2011).

An Institutional Review Board (IRB) approval for the project was received from the Medical University of South Carolina for use in this work. The IRB notice, Pro00012763 was determined to be “confirmed not human subject research.”

Study Design and Overview:

Dr. John Hick first suggested the most succinct descriptive categories for surge capacity currently being used in disaster medicine. One aspect of Dr. Hick’s 2009 paper included defined and stratified surge capacity with three specific
categories of capacity: conventional, contingency, and crisis (Hick et al., 2009).

For the purpose of this work, an adaptation of the phrase “conventional capacity” was defined as that which can be absorbed and managed at the two North Carolina Burn Centers—the North Carolina Jaycee Burn Center at UNC Hospitals (NCJBC) and The Burn Center at Wake Forest Baptist Health (WFBH)—relying on the Burn Centers’ available capacity. The conventional capacity is defined as the static bed count self-reported to the ABA minus the current census of burn patients. The static bed count includes those beds that are licensed as appropriate by a state or federal agency and staffed on a regular basis. The conventional capacity also includes an additional 50% of the self-reported static bed count to the ABA based on the ABA standards for Verified Burn Centers (Gamelli et al., 2005). (Given the more recent publications of Dr. Hick and the refined definitions for surge capacity, this additional 50% suggested in 2005 by the ABA falls within what is considered conventional surge capacity.) A descriptive analysis was provided including both the stated and ABA (Gamelli et al., 2005) defined surge capacity for the two Burn Centers.

**Contingency surge capacity** included interstate capacity. Interstate contingency capacity included a Monte Carlo simulation method to estimate surge capacity for Burn Centers in the ABA Southern Region.

**Crisis surge capacity** was not evaluated for the purpose of this work. Crisis surge capacity also includes altered standards of care which are beyond the scope of this work. One aspect of this work includes identifying that point where we have
maximized the use of conventional and contingency surge capacity, and the number of patients is greater than can be met with conventional and contingency surge capacity. When we cannot meet those needs with either conventional or contingency surge capacity, we move into crisis surge capacity. One key contribution that this work will offer to the body of available knowledge in disaster medicine is a better understanding of where that line is drawn. While response strategies and activities related to crisis surge capacity are outside the scope of this work, it is essential for planners to identify the point where we cross into crisis surge capacity. There are no current published works that answer this question.

The problem statement (which in this case is my question to be answered through this research) for this work is: "What is the capacity of Burn Centers within the American Burn Association Southern Region to absorb significant numbers of burn injured patients during a medical disaster?" This is of great importance since it serves to quantify the availability of regional Burn Centers to support the medical disaster response efforts in a major disaster in North Carolina. However, in order for the problem statement to be relevant, we must first identify and verify the intrastate capacity. Historical events have occurred that produced volumes of burn injuries which overwhelmed intrastate Burn Centers and required patients to rely on interstate Burn Center resources.

In order to answer the question posed by the problem statement, several steps must be taken to arrive at the capacity available both in terms of intrastate capacity and interstate capacity on a regional level. More specifically, these steps
include what has been described as conventional capacity involving the two Burn Centers on an intrastate level. On a regional level, the capacity is contingent on acceptance of interstate transfers, bed availability, and transportation resources (and as such, this is also considered to be contingency surge capacity).

For the data used in this dissertation, conventional capacity is determined using actual data from the Trauma Registry for the University of North Carolina Hospitals, which manages the data for the North Carolina Jaycee Burn Center (NCJBC). This data and the resulting distribution curve are determined by examining daily census numbers and comparing them to the static capacity for the Burn Center. Taking this set of data and developing a distributive curve using a Monte Carlo simulation, I relied on the assumption that drivers for admissions and patient acuity were similar for all of the Burn Centers in the ABA Southern Region. With the data in an Excel spreadsheet, and using an adjunct program by Palisade ("@Risk Professional," 2011), I was able to complete my simulations.

*Monte Carlo simulation is a computerized mathematical technique that allows people to account for risk in quantitative analysis and decision making.*

*Monte Carlo simulation furnishes the decision-maker with a range of possible outcomes and the probabilities they will occur for any choice of action. It shows the extreme possibilities—the outcomes of going for broke and for the most conservative decision—along with all possible consequences for middle-of-the-road decisions.*
The technique was first used by scientists working on the atom bomb; it was named for Monte Carlo, the Monaco resort town renowned for its casinos. Since its introduction in World War II, Monte Carlo simulation has been used to model a variety of physical and conceptual systems, (@Risk Professional, 2011).

Interstate contingency capacity is a product of a Monte Carlo simulation for the ABA Southern Region Burn Centers, with the models relying on admission data for each day for each Burn Center, as well as daily census data for each of the Burn Centers.

**Step 1**

For the North Carolina Jaycee Burn Center (NCJBC), we have empirical data regarding the patient days, admissions, average length of stay, and daily occupancy. From this data, we know the range, mean, median, and standard deviation of daily occupancy. The data was recorded in a mathematical spreadsheet using Microsoft Excel 2010. I used the software by Palisade (@Risk Professional, 2011) in conjunction with the spreadsheet to perform a Monte Carlo simulation with these entries for the 730 days of January 1, 2009-December 31, 2010.

According to a recently published paper by Dr. James Holmes IV, M.D. and other researchers involved in burn care in North Carolina, from 2000-2007 the Verified Burn Centers (NCJBC and WFBH) admitted 57% of the patients with burn injuries (Holmes et al., 2011). Dr. Jeffery Carter, M.D., a co-author in the Holmes work, presented the actual data table during an oral presentation of a paper at the Southern Regional Burn Conference (Carter, Neff, & Holmes, 2010). Relying on the
data from the NCJBC, the Holmes paper, and the Carter presentation, my first step was to mathematically adjust the 2000-07 data to where we are now for average daily census, and the subsequent capacity for each Burn Center. I started with the 2000-07 data, and updated it with the 2009-10 data from the NCJBC. From there, I used an algebraic equation and the factors from the Holmes paper, which reported the two Burn Centers together, represented 57% of the admissions for burn injury in North Carolina. Assuming the length of stay for each admission was approximately the same, I was able to determine the average daily census for each hospital. Furthermore, by subtracting self-reported staffed beds for each center, I was able to record the number of available beds per facility.

**Step 2**

The sum of the available capacity of the two Burn Centers (also stated in mean and range) plus theoretical surge capacity (50% of self-reported staffed beds, mathematically expressed in the following equations as 0.5) as identified in the paper by the ABA Organization for the Delivery of Burn Care Committee on behalf of the ABA Trustees (Gamelli et al., 2005), yielded the total conventional surge capacity for North Carolina. As an example, if the number of staffed beds was 50, and the average daily census was 40, leaving a balance of 10 for available capacity, the mathematical equation for conventional surge capacity would be: 10 + (0.5 * 50) = 35.)

UNC Hospitals self-reported 36 burn beds to the ABA. Thus, the conventional capacity is 36 minus the mean daily census with the range being
mathematically expressed by mean plus or minus the range divided by two. As an example, if the mean is 28 and the range is 20-36 then the mathematical expression is \( 28 \pm (36-20)/2 \) or \( 28 \pm 8 \). This is determined in the model where the mean is expressed using the symbol \( \bar{x} \). The range (represented by \( r \)) is divided by two and expressed as \( \pm r \). Mathematically, the equation is: \( (\bar{x} \pm r) + (0.5 \times 36) = \) conventional capacity for UNC Hospitals. The number of self-reported burn beds for WFBH is 24. Mathematically, the equation is \( (\bar{x} \pm r) + (0.5 \times 24) = \) conventional surge capacity for WFBH. The sum of the two figures gives us the total conventional surge capacity for North Carolina.

**Step 3**

Contingency surge capacity is based on bed space located at interstate Burn Centers within the ABA Southern Region. Data for this step was obtained from the National Burn Repository of the American Burn Association. From this data, we know the number of Burn Centers, their range, mean, and standard deviation of daily occupancy for 2006-2008. However, this data was blinded to us since it could be used in a competitive nature. Thus, we have data that was represented to me as approximately 40% of the centers and 60% of the admissions for the Southern Burn Centers. Nevertheless, we do know the staffed beds for each Burn Center and I was able to match data to the two largest Burn Centers in the region just based on their respective known sizes and how disproportionately larger their known staffed beds and capacities are compared to the rest of the region. For each of the remaining facilities, applying the average daily census distribution curve to each of
the remaining facilities creates a distribution I can use for each of the Burn Centers.

**Step 4**

The data was analyzed to identify the frequency and percentage distribution curve for the available capacity for the North Carolina Jaycee Burn Center (NCJBC). This was calibrated by using the mean and standard deviation of each Burn Center's actual daily vacancy rate (capacity – census) during 2009-2010. The frequency distribution for the NCJBC was derived by reviewing and recording the data for admissions by day for each of the 730 days for the two-year period 2009-2010. Capacity minus the average daily census equals available beds. The distribution curve (a normal distribution) was derived from the data for daily availability of beds using the average and mean, and the @Risk modeling software.

**Step 5**

I used the NBR data for the ABA Southern Region Burn Centers to include census and admissions. The availability was created by comparing the number of staffed beds with the average patient days for the two largest Burn Centers in the south. Since we need bed availability for this work, I subtracted the average number of daily beds in use (census) from the number of the staffed beds for a given facility to produce an average number of available beds per Burn Center in the south.

For the purpose of modeling, I assumed the shape of the frequency distribution curve for admissions and census to approximately the same for all ABA Southern Region Burn Centers as that of the NCJBC. This assumption is based on
the fact that the predictability of burn injury is similar given the seasonal contributing factors: heating sources and home heating related accidents during the late fall, winter, and early spring; and outdoor activities as seasonal temperatures allow.

**Step 6**

Relying on the frequency distribution from the NCJBC and historical events for input, we ran Monte Carlo simulations using the Microsoft Excel spreadsheet and an adjunct program by Palisade called @Risk Version 5.7. I tested the model with data from three intrastate historical events: the 1991 Imperial Foods/"Hamlet" industrial fire; the 1994 "Green Ramp Disaster"; and the 2003 West Pharmaceuticals Industrial Plant dust explosion. For these three events, I identified Hamlet as simulation 2 (S2), the “Green Ramp Disaster” as simulation 3 (S3), and West Pharmaceutical as simulation 1 (S1). In each of these situations, I used actual patient numbers with burn injuries and assumed all patients with burn injuries should be treated either in Burn Centers or in the system as described in Step 2. S1 had 38 burn-injured patients, S2 had 54 burn injured patients, and S3 had 130 burn injured patients. Rerunning the model using data from previous disasters yielded the probabilistic results for what capacity could be available to address a surge of burn patients from a North Carolina disaster that could exceed the capacity of intrastate resources.

Using Monte Carlo Simulation, I compared the patient needs of each of the simulations identified in Step 7 and Step 8, to the capacity of meeting the needs of
the patients, assuming the patients would first present to the NCJBC. If the NCJBC could not meet the needs, then the patients would be moved to the WFBH, and then on to interstate Burn Centers first in contiguous states and ultimately the entire region.

**Step 7**

In addition to real intrastate events, I reran the Monte Carlo simulation using two historical events from other geographical areas where the potential exists for a similar event occurring in North Carolina. These were the 2003 Rhode Island (Station) Nightclub Fire based on the patient numbers reported in the paper; (Harrington et al., 2005), which I identified as simulation 4 (S4). For Simulation 5 (S5), I used the New Year's Eve café fire in Volendam, the Netherlands and the patient numbers as reported in the paper by (Welling et al., 2005). While a worst case scenario for each given event, I assumed each of the patients with burn injuries needed care in a Burn Center. It is unlikely that all patients from each of these events require care in a Burn Center but for the sake of using actual numbers from actual events, this takes a worst case scenario approach to a given and known event.

**Step 8**

One additional theoretical event, which yields a known quantity of burn patients were also analyzed relying on the Monte Carlo simulation model to identify the potential range of contingency capacity. This step was the sensitivity
analysis for the Monte Carlo model. By definition, when contingency capacity is exceeded and care is provided in a manner referred to as “altered standards of care,” the situation has moved into crisis capacity. Again, I relied on the frequency distribution and from the results, discussed the probability of the meeting the patient needs. I also identified and discussed the point where we have exceeded the conventional capacity and contingency capacity of the state and the region.

This theoretical event was 500 patients, identified as Simulation 6 (S6).

Step 9

Patients from a given real or theoretical disaster are represented by X. Thus for the Hamlet Fire, which had 54 patients, the input parameter X equaled 54. Relying on the frequency distribution of available beds for the NCJBC (represented by Y1), the model randomly selected the number of beds available as identified in Step 5. If X < Y1 then all patients can be managed with the conventional surge capacity of the NCJBC represented as Y1. (WFBH is represented as Y2 and subsequent Burn Center resources by state are represented by Y3, Y4, Y5 ...)

Mathematically, the simulation takes on this appearance: if X < Y1, then stop. If X > Y1 but < Y1 + Y2 then stop. If X > Y1 + Y2 but < Y1 + Y2 + Y3 then stop, etcetera.

Step 10

If X > Y1 then, using the frequency distribution for the next closest Burn Center (in this case, WFBH) determines the number of available beds, mathematically represented as Y2. If X < (Y1 + Y2) then all patients can be managed
in the conventional surge capacity of the two Burn Centers and no further action needs to be taken.

**Step 11**

If \( X > (Y_1 + Y_2) \) then this step should be repeated until \( X < (Y...) \) relying on available beds in Regional Burn Centers measuring the closest and most appropriate transfer locations from the disaster staging area. Once intrastate resources were consumed, I relied on interstate resources by state since the request for assistance in a disaster declaration would be made from one state to another. Thus, \( Y_3 \) represented part or all Burn Centers in Virginia, \( Y_4 \) represented part or all Burn Centers in Georgia and \( Y_5 \) represented part or all Burn Centers in Tennessee. The final attempt to fulfill the request for bed space was represented by \( Y_6 \) which reflects use of some or all of the available remaining burn beds in the ABA Southern Region.

**Step 12**

For this step, I used the data from the NCJBC and the ABA NBR for the Regional Burn centers and repeated this process for 10,000 iterations, relying on the software (@Risk Professional, 2011) add-in for Microsoft Excel. This was the first run for the Monte Carlo simulation.

**Step 13**

I repeated Steps 9-12 using the patient numbers from the six input simulations (S1-S6) and recorded the results in a chart of the six simulation sets. I
also indicated, in recording this set of data, if the surge capacity used was conventional, contingency, or crisis surge capacity.

**Assumptions**

The 2011 ABA Burn Care Resource Directory ("Burn Care Resource Directory," 2011) identifies the number of self-reported burn beds in use in North Carolina and ABA Southern Region, and the United States. These data represent the population of staffed burn beds for each Burn Center. The Resource Directory which includes these data is updated periodically.

I have the daily admissions and census (thus the availability) for the NCJBC for all 730 days from January 1, 2009 to December 31, 2010. This was the only complete data available to me for this work but established the basis for percentage of availability and a distribution curve. The Burn Centers of the ABA Southern Region share similar trends that impact patient demand and utilization such as outdoor activities, fire hazards, and other similar risks. Thus, I assumed the distribution curve for the NCJBC could be used for all Burn Centers in the ABA Southern Region. I also assumed the potential bed availability ratio that I mathematically was able to determine from the NBR data for the two largest Burn Centers was applicable to the rest of the Burn Centers in the ABA Southern Region.

It is a long held fact that for general patient populations, larger and busier hospitals are generally able to operate closer to actual staffed capacity. Logic would suggest using the known data which is only available for the two largest Burn Centers as the basis for assuming the same percentage of utilization could slightly
understate the actual availability. Nevertheless, for this model taking a somewhat conservative approach will assure the conclusions will not overstate the potential availability.

**Surge Capacity according to the ABA**

Additional capacity at the NC Burn Centers is identified by comparing the number of burn beds in the 2011 ABA Burn Care Resource Directory ("Burn Care Resource Directory," 2011) with the mathematically reported surge capacity (an additional 50% of stated capacity for Verified Burn Centers) according to the ABA Organization for the Delivery of Burn Care (Gamelli et al., 2005). Thus, surge capacity at the Burn Centers, in the conventional sense, includes those beds that are routinely available, as well as utilizing beds typically assigned to other service lines such as general surgery. (Nevertheless, these patients are admitted to the care of the burn service, and their care is managed by burn surgeons as they would any burn patient admitted to their service.) For the purpose of this work, it is assumed that the beds as self-reported are routinely available for burn patients. It is also assumed that self-identified Burn Centers included in the ABA Burn Care Resource Directory can manage an additional surge of 50% above stated staffed capacity.

**Patient Volumes from Historical Disasters, Sources and Assumptions**

It is assumed that patients identified in each of the academic works cited had a burn injury serious enough to require care in a Burn Center. While this is a “worst case scenario” approach it allowed me to specifically use real events, with real numbers of patients for the purpose of patient inputs into the model; (X1-X6).
IV. RESULTS

Conventional Capacity in the North Carolina Burn Centers

In 2011, 12 of the 123 North Carolina hospitals are Verified Trauma Centers. Of the 12 Trauma Centers, two are co-located with Verified Burn Centers. We looked at the self-reported bed capacities for the two Burn Centers; the North Carolina Jaycee Burn Center (NCJBC) with 36 beds and the Wake Forest University Baptist Health Burn Center (WFUBH) with 24 beds. Data from the NCJBC provides an average of 919 admissions per year for the NCJBC for calendar year 2009 and 2010. Based on a ratio from the Holmes et al. paper, (for every 1 admission at the NCJBC there is 0.548422 admissions at WFUBH).

For the NCJBC in 2009 and 2010;
Daily Staffed Beds: 36
Average Daily Census: 32.3836
Average Daily Available Beds: 3.6164
Standard Deviation: 5.8756
Average Daily Admissions: 2.5178
Standard Deviation: 1.71

Relying on the data from the NCJBC, and assuming length of stay and admissions trended similar to those of the NCJBC, and using the ratio 0.548422, I was able to arrive at:
For the WFUBH;
Daily Staffed Beds: 24 (Self-reported to the ABA)
Average Daily Census $32.3836 \times 0.548422 = 17.7599$
Average Daily Available Beds: 6.2401
Average Daily Admissions: $2.5178 \times 0.548422 = 1.3808$
Adding the average daily available beds for the two Burn Centers yields an average available daily capacity for North Carolina of: 9.8565 beds.

**Burn Center Conventional Surge Capacity**

According to the article by (Gamelli et al., 2005) the mathematical sum for surge capacity is an additional 50% of the self-reported capacity, or $((0.50 \times (36+24)) = 30$. Adding the average available capacity to the Conventional Surge Capacity yields 39.8565 burn beds in North Carolina on a daily basis. The "surge capacity" definition for the American Burn Association has not been revised to reflect what is being more widely used to stratify surge capacity. Nevertheless, for the purpose of this work, I used that original 2005 assumption of 50% of staffed beds and have clarified how I defined and stratified conventional, contingency and crisis surge capacities.

**North Carolina Trauma Center Contingency/Crisis Surge Capacity**

While it is generally accepted to be within the standard of care to initially manage burn patients in Trauma Centers not co-located with a Burn Center, these patients are generally held there only to the extent necessary to secure an available
bed at one of the Burn Centers and arrange for appropriate transportation.

To buffer the surge of burn patients on an intrastate basis, it is presumed that each Trauma Center that is not co-located with a Burn Center could manage up to 10 burn patients for up to 24 hours. This aspect of the plan includes relying on an adaptation of the (Yurt et al., 2008) criteria for Tier 1-4 Burn Disaster Resource Hospital (BDRH) (which in North Carolina is a Verified Trauma Center Level I, II, or III that is not co-located with a Burn Center). By multiplying the number of Level I Trauma Centers by a designated static capacity of 10 patients with Tier II/III injuries, we yield an additional capacity of 40 for the Level I Trauma Centers not co-located with a Verified Burn Center. \((6 - 2) \times 10\) = 40. (Holmes et al., 2011) found that 43% of patients meeting criteria for Burn Center referral were never seen in a Burn Center despite the fact that the non-Burn Centers where these patients were admitted were located a median of 68 miles from a Verified Burn Center.

The (Holmes et al., 2011) results concluded that patients with burn injury had not received optimal care in non-Burn Centers. Nevertheless, the findings did indicate a willingness to manage burn patients outside a Burn Center during normal operating periods. It should also be noted that the (Yurt et al., 2008) paper discussed holding burn injured patients in Trauma Centers for more than 24 hours (and up to 72-120 hours), which is approximately the same as current battlefield experiences as reported by (Cancio et al., 2005). Nevertheless, extending a burn injured patient’s stay to what is a traditional admission (more than 24 hours) is generally not consistent with the standard of care for the critically injured burn
patient. Furthermore, the military experience has some limitation prohibiting broad application here since the typical Soldier or Marine is a young and healthy individual, which is not always the case with typical civilians who experience a burn injury.

The papers by Hick et al both in 2009 (Hick et al., 2009) and 2011 (Hick, Weinstock, et al., 2011) clearly indicate that patients being cared for in a manner that is outside the bounds of standard of care is considered to be Crisis Surge Capacity (and beyond the scope of this work). Thus, reliance on Trauma Centers for a window of up to 24 hours will serve only as a holding area until the patients can be moved to their closest most appropriate destinations, Burn Centers in the US Southeast. Furthermore, this buffer will allow for Burn Centers to discharge or transfer those patients that could be managed elsewhere during this 24 hour period.

For North Carolina, there are three Level I Trauma Centers not co-located with a Burn Center and four additional Level II or Level III Trauma Centers. Relying on an adaptation of the Yurt et al. (2008) criteria for Tier 1-4 BDRH and multiplying the number of Level II and III Trauma Centers by an agreed-to capacity of 10 patients with Tier II/III injuries for Level I Trauma Centers, a temporary capacity of \(4 \times 10 = 40\) is available. Additionally, 5-10 patients with Tier II/III injuries for Level II and Level III Trauma Centers will provide additional temporary capacity of \(6 \times (5-10) = 45 \pm 15\). Relying on Trauma Centers in the first 24 hours can assure an additional buffer of capacity immediately following the incident. Mathematically,
this yields an additional \((4 \times 10 = 40) + (6 \times (5-10)) = 45 \pm 15\) beds for up to 24 hours. By adding the collective additional capacity of the Trauma Centers/BDRH, this yields an additional buffer of capacity of 85 \pm 15 as a holding location for up to 24 hours until the patients can be redistributed to Burn Centers.

**Interstate Resources Relying on the Southern Burn Centers**

In 2011, the Burn Centers within the Southern Region included four in Virginia, two in Tennessee, two in Kentucky, three in Alabama, two in Georgia, four in Florida, and one in South Carolina, with the Burn Center in South Carolina and one of the Burn Centers in Alabama available only for pediatric patients. Farther west, but still in the Southern Region, include Burn Centers located in Mississippi, Louisiana, Texas, Oklahoma and Arkansas. The Burn Center in Mississippi is a satellite facility for the Joseph M. Still Burn Center in Augusta, Georgia. This facility is less than two years old and is the only Burn Center in Mississippi. Of the three Burn Centers in Louisiana, two of them are north of the New Orleans area and survived the reshaping of the healthcare community brought on by the Hurricane Katrina in 2005, which flooded and closed multiple hospitals. No Burn Center has reopened in the City of New Orleans. A center has opened west of New Orleans in Lafayette, Louisiana, and as mentioned, the two centers that are a part of Louisiana State University Medical Centers (Baton Rouge and Shreveport) remain open.

In Arkansas there is one Burn Center. Furthermore, while Arkansas Children’s Hospital only admits pediatric patients to other areas of the hospital and is so named a “Children’s Hospital,” the only adult patients treated at this hospital
are those with burn injuries. Bed Counts for these facilities are identified in Table 11. Geographically, these facilities are displayed in Figure 4. There are two Burn Centers in Oklahoma and four Burn Centers in Texas, three of which are ABA verified. They are included in Table 11.

**Interstate Burn Center Resources**

It is uncommon to rely on burn bed capacity of other states for patients injured in North Carolina. Therefore, identified capacity in the region is a considered a contingency surge capacity. Furthermore, it was essential to rely on the Monte Carlo modeling to provide us with the probability for available capacity, since it is not assumed these centers would abruptly displace all current patients to make available their beds for patients injured in another state.

The average occupancy is 83.5% for the two busiest Burn Centers in the ABA Southern Region. This is approximately the same as identified in Step 1 for the NCJBC and a slightly more conservative count for availability at WFBH also as identified in Step 1.

**Modeling results with input data from Historical and Theoretical Events**

The following ten simulations include patient data from five real events and five theoretical patient volume inputs. The ten simulations were aimed at understanding the capacity and limitations of the Burn Centers for the Southern Region.

Relying on the frequency distribution derived from the North Carolina
Trauma Registry and the American Burn Association National Burn Repository, and using the six input simulations (S1-S6), we ran the Monte Carlo simulations using the Excel software add-in package of ("@Risk Professional," 2011). The results are graphed in Tables 1-6 on the following pages.

**Distribution Curve**

The distribution curve for the 730 days of patient data from the NCJBC is a normal distribution. Visually, the data appeared to be distributed normally, but a sensitivity analysis was performed to confirm this initial impression. Based on the findings from the sensitivity analysis, a normal distribution was selected in the distribution input definition for the @Risk software to run the Monte Carlo simulations. This distribution curve was consistently used for all of the Monte Carlo simulations (S1-S6).

**Average Daily Census, Utilization and Subsequent Bed Availability**

For the Burn Centers, relying on the ABA NBR data, the average daily census was developed by comparing the total patient days for the three most recent complete years of data (2006-08) to the current staffed beds multiplied by 365. This ratio, gave me the average daily census for the region's two largest/busiest Burn Centers. Since the facilities were blinded to us by the ABA, I could only identify the two largest Burn Centers simply because the number of patient days for each facility was larger than the balance of those from the region.

Furthermore, the busiest Burn Center (in terms of patient days) had an average daily census that was larger than the total staffed beds for any other Burn
Center. The second busiest (in terms of patient days) was significantly smaller than the largest, but significantly larger than the rest in the region. Thus, I could develop an Occupancy/Availability ratio for those two Burn Centers. Relying on the average daily census for these two centers, the average daily census for the NCJBC for 2009-10 and the approximate average daily census for the Burn Center at WFBH based on the ratio described in Step 1, the average daily census was determined to be 83.5%. It is assumed this is similar to that of other Burn Centers in the South. Accordingly, the vacancy rate of 16.5% is an assumption used for all Burn Centers in determining availability of beds for a disaster.
Figure 5 Screen capture of the 6 Simulations (X) and the 6 hospital inputs (Y).

Y1 NCJBC, North Carolina Jaycee Burn Center at UNC Hospitals

Y2 WFUBH, Wake Forest University Baptist Health

Y3 Virginia, All four Burn Centers in Virginia

Y4 Tennessee, Both Burn Centers in Tennessee

Y5 Georgia. Both Burn Centers in Georgia

Y6 All of the remaining Burn Centers in the ABA Southern Region
38 Patients, Historical Event

Simulation 1: 2003 West Pharmaceutical Industrial Plant dust = 38 patients. Patient numbers are based on the article by Dr. Cairns et al; (Cairns et al., 2005). This dust explosion shared similar characteristics with subsequent industrial dust explosions such as the one at the Savannah, Georgia at the Dixie Crystal Sugar Plant in 2007; ("ED handles 30 burn patients after plant fire and explosion in Georgia," 2008). For this disaster, Burn Centers in North Carolina, relying on conventional surge capacities of the two Burn Centers and their hospital infrastructure, could reliably manage the patients from this event (Table 1).
Table 1, Simulation 1: 2003 West Pharmaceutical Industrial Plant dust explosion

The probability of accommodating all patients in Burn Centers based on the hierarchal described in Methods, Step 9. Mean is 1.12 and the SD is 0.356 with 10,000 iterations performed using @Risk and Monte Carlo Simulation.

The vertical axis represents the likelihood of meeting the need posed by the patients in Simulation 1 based on the inputs of Y1-Y6. Y1 and Y2 are intrastate hospitals, and were measured first with the North Carolina Jaycee Burn Center, then the Burn Center at Wake Forest Baptist Health and are represented on the horizontal axis by blue bars. If intrastate resources are unable to meet the need, then interstate resources would be called upon one state at a time. Each state (and the Burn Center resources therein) is represented by a red bar. Available beds relying on the remaining ABA Southern Region Burn Centers are collectively represented by a green bar.
**54 Patients, Historical Event**

**Simulation 2**: 1991 Imperial Foods/Hamlet Industrial Fire = 54 patients.

Patient numbers are based on the report by investigator Jack Yates for a report by the United States Fire Administration (Yates, 1991). The circumstances of the Imperial Foods Fire include a fire source and multiple employees involved in processing food at typical cooking temperatures. While it is unlikely that fire exits are locked today in the industrial setting, egregious fire code violations continue to occasionally occur throughout the country. For a burn disaster such as this, Burn Centers in North Carolina, relying on conventional surge capacities of the two Burn Centers and their hospital infrastructure, it is unlikely they could reliably manage the patients from this event (Table 2). However, relying on resources from Virginia combined with intrastate resources places the solution at 99%.
Table 2, Simulation 2: 1991 Imperial Foods/Hamlet industrial fire

The probability of accommodating all patients in Burn Centers based on the hierarchal described in Methods, Step 9. Mean is 1.95 and the SD is 0.226 with 10,000 iterations performed using @Risk and Monte Carlo Simulation.

The vertical axis represents the likelihood of meeting the need posed by the patients in Simulation 2 based on the inputs of Y1-Y6. Y1 and Y2 are intrastate hospitals, and were measured first with the North Carolina Jaycee Burn Center, then the Burn Center at Wake Forest Baptist Health and are represented on the horizontal axis by blue bars. If intrastate resources are unable to meet the need, then interstate resources would be called upon one state at a time. Each state (and the Burn Center resources therein) is represented by a red bar. Available beds relying on the remaining ABA Southern Region Burn Centers are collectively represented by a green bar.
130 Patients, Historical Event

Simulation 3: 1994 “Green Ramp Disaster” at Pope Air Force Base = 130 patients. Patient numbers are based on the article by Dr. Mozingo et al; (Mozingo et al., 2005). This disaster involved more than 100 soldiers boarding a flight for a practice jump from Pope Air Force Base (today known as Pope Army Air Field) and a crash landing of another fighter aircraft. Today, Fort Bragg has more soldiers assigned there than any other Army base around the world, and their training to include airborne paratrooper training is continuous. The components that contributed to the disaster discussed here remain omnipresent today. The US Armed Forces strive to provide a safe training environment. Nevertheless, the potential remains for another disaster that could share some or many similarities to the Green Ramp event. For an incident such as this, Burn Centers in North Carolina, relying on conventional surge capacities of the two Burn Centers and their hospital infrastructure, could not manage the patients from this event (Table 2,).

For the purpose of this work, all of these patients are assumed to have burn injuries serious enough to be managed at a Burn Center. As such, the probability of these patients being managed relying on: the two Burn Centers in North Carolina, and all available Burn Center beds in Virginia is 5%. By including all of the resources in Georgia, the probability becomes 49%. With all of the resources from Tennessee added to those previously mentioned, the probably becomes 97%.
Table 3, Simulation 3: 1994 “Green Ramp Disaster” at Pope Air Force Base near Fort Bragg

The probability of accommodating all patients in Burn Centers based on the hierarchal described in Methods, Step 9. Mean is 3.50 and the SD is 0.574 with 10,000 iterations performed using @Risk and Monte Carlo Simulation.

The vertical axis represents the likelihood of meeting the need posed by the patients in Simulation 3 based on the inputs of Y1-Y6. Y1 and Y2 are intrastate hospitals, and were measured first with the North Carolina Jaycee Burn Center, then the Burn Center at Wake Forest Baptist Health and are represented on the horizontal axis by blue bars. If intrastate resources are unable to meet the need, then interstate resources would be called upon one state at a time. Each state (and the Burn Center resources therein) is represented by a red bar. Available beds relying on the remaining ABA Southern Region Burn Centers are collectively represented by a green bar.
**215 Patients, Historical Event**

**Simulation 4:** 2003 Rhode Island (Station) Nightclub = 215 patients.

Patient numbers are based on the article by Dr. Harrington et al; (Harrington et al., 2005). The elements found in this disaster have occurred and will continue to occur. The situation involved a flash fire during a large gathering at a night club, with significant alcohol consumption and limited exits. Burn disasters such as this have occurred in various states and could occur in North Carolina.

For a disaster such as this to occur in North Carolina, intrastate Burn Centers, relying on conventional surge capacities of the two Burn Centers and their hospital infrastructure, could not manage the patients from this event (Table 4). As such, the probability of these patients being managed relying on: the two Burn Centers in North Carolina, all available Burn Center beds in Virginia, Georgia and Tennessee, is 80% with a 100% probably being reached if all available Burn Center resources are made available.
Table 4. Simulation 4: 2003 Rhode Island (Station) Nightclub Fire

The probability of accommodating all patients in Burn Centers based on the hierarchal described in Methods, Step 10. Mean is 5.21 and the SD is 0.408 with 10,000 iterations performed using @Risk and Monte Carlo Simulation.

The vertical axis represents the likelihood of meeting the need posed by the patients in Simulation 4 based on the inputs of Y1-Y6. Y1 and Y2 are intrastate hospitals, and were measured first with the North Carolina Jaycee Burn Center, then the Burn Center at Wake Forest Baptist Health and are represented on the horizontal axis by blue bars. If intrastate resources are unable to meet the need, then interstate resources would be called upon one state at a time. Each state (and the Burn Center resources therein) is represented by a red bar. Available beds relying on the remaining ABA Southern Region Burn Centers are collectively represented by a green bar.
245 Patients, Historical Event

Simulation 5: 2001 New Year's Eve Café Fire Volendam, Netherlands = 245 patients. Patient numbers are based on the article by Dr. Welling et al; (Welling et al., 2005). Burn Centers in North Carolina, relying on conventional surge capacities of the two Burn Centers and their hospital infrastructure, could not manage the patients from this event (Table 5).

For a disaster such as this to occur in North Carolina, intrastate Burn Centers, relying on conventional surge capacities of the two Burn Centers and their hospital infrastructure, could not manage the patients from this event (Table 5). As such, the probability of these patients being managed relying on: the two Burn Centers in North Carolina, all available Burn Center beds in Virginia, Georgia and Tennessee, is 22% with a 100% probably being reached if all available Burn Center resources are made available.
Table 5. Simulation 5: the café fire on New Year's Eve in Volendam, the Netherlands

The probability of accommodating all patients in Burn Centers based on the hierarchal described in Methods, Step 10. Mean is 5.78 and the SD is 0.417 with 10,000 iterations performed using @Risk and Monte Carlo Simulation.

The vertical axis represents the likelihood of meeting the need posed by the patients in Simulation 5 based on the inputs of Y1-Y6. Y1 and Y2 are intrastate hospitals, and were measured first with the North Carolina Jaycee Burn Center, then the Burn Center at Wake Forest Baptist Health and are represented on the horizontal axis by blue bars. If intrastate resources are unable to meet the need, then interstate resources would be called upon one state at a time. Each state (and the Burn Center resources therein) is represented by a red bar. Available beds relying on the remaining ABA Southern Region Burn Centers are collectively represented by a green bar.
**500 Patients, Theoretical Input**

**Simulation 6:** Theoretical input = 500 patients. Burn Centers in North Carolina, relying on conventional surge capacities of the two Burn Centers and their hospital infrastructure, could not manage the patients from this event (Table 6).

For the purpose of this work, all of these patients are assumed to have burn injuries serious enough to be managed at a Burn Center. As such, the probability of these patients being managed relying on: most if not all of the Burn Centers across the Southern Region. Of the 10,000 possible scenarios, none were identified that could be managed relying on all available burn bed resources of the Southern Region.

Early into the event, 500 patients with burn injuries will overwhelm intrastate and interstate Burn Centers and burn resources. Depending on the rate of arrivals for patients with burn injuries, and transportation resources, it would be unlikely that all patients would be cared for under what is considered the standard of care for the burn injured patient.

Even under ideal circumstances in terms of transportation assets to redistribute the patients, a means of triage and initial treatment, 500 patients with burn injuries would overwhelm regional resources. This event would pose a serious challenge for the American healthcare system. A Crisis Surge Capacity model would be required as a temporary buffer until ongoing efforts of distribution, redistribution and patient transfers could get the patients with the greatest needs to the most appropriate and available facilities.
Table 6. Simulation 6: 500 patient theoretical event

The probability of accommodating all patients in Burn Centers based on the hierarchal described in Methods, Step 11. With 10,000 iterations performed using @Risk and Monte Carlo Simulation, no potential scenario could be addressed with all of the resources of the region.

The vertical axis represents the likelihood of meeting the need posed by the patients in Simulation 6 based on the inputs of Y1-Y6. Y1 and Y2 are intrastate hospitals, and were measured first with the North Carolina Jaycee Burn Center, then the Burn Center at Wake Forest Baptist Health and are represented on the horizontal axis by blue bars. If intrastate resources are unable to meet the need, then interstate resources would be called upon one state at a time. Each state (and the Burn Center resources therein) is represented by a red bar. Available beds relying on the remaining ABA Southern Region Burn Centers are collectively represented by a green bar.
V. DISCUSSION

When we encounter atypical events in life, we perform best and are most comfortable dealing with them using a preplanned process. This is also how we are most comfortable dealing with an unexpected disaster.

If we are a small hospital and a typically busy day has us seeing 10 patients at the same time in a 10 bed emergency department, then 25 presenting for treatment within the same hour will stress the system. Yet we will continue to see patients in the same 10-bed area while creatively creeping into nearby spaces (such as a holding area for daytime surgery or the adjacent hallway of the emergency department) so long as the area is safe and allows us to pull staff, supplies, and equipment from other areas. Caring for patients with this staff, this equipment and in this space does not change the standard of care and patients generally are managed (in terms of the course of treatment) as they would be managed if there were fewer patients. The solution to this disaster response is institutionally based.

We may refer to that event where 25 presented for care at our 10 bed facility as a disaster. Due to the nature of the injuries, acuity of the patient, or the anticipation of additional arriving patients from the same event, we may move patients into space that is typically not used for patient care. This space may
include such areas as conference rooms or other nontraditional patient care areas of the facility. We may also utilize staff that infrequently sees patients in the course of their daily activities such as administrators or executive yet level medically credentialed professionals. This is seen as contingency surge capacity since it generally does not abandon what is considered the standard of care for the given patient needs.

However, when the patient numbers grow exponentially or the acuity or the long term needs of the patients are such that other facilities and resources are called upon, it is essential for medical disaster planners to understand where the triggers are to take us into other tiers of our disaster plans. Planners and employees must know where these trigger points are as we move from that “busy day” surge of patients which may trigger one chain of events to a surge of patients from a passenger train derailment which may trigger the same set of activities as well as some additional activities. Each section of our disaster plan must include guides for key decisions such as requesting significant resources for transporting patients away from our hospital to other hospitals, setting up temporary medical facilities to aid in managing the surge, and notification to neighboring hospitals to anticipate the transfer of these patients.

While I have not focused extensively on the financial implications of burn disasters, when the number of patients with a burn injury approach 500, my series of models confirms the current systems cannot address the needs regionally. Most likely, whatever the event that caused 500 patients with a burn injury to need
medical care would be part of a much larger disaster which triggered the response of state and federal medical resources and assets. These resources have limited capability to manage the burn injured patient. However, their response and presence will aid in containing the self-evacuation.

This dissertation includes models that reflect actual and theoretical patient numbers and challenges the existing resources for burn care to manage a variety of patient volumes. The aim is to consider what impact a surge of patients would have on the North Carolina Burn Centers and what happens when those resources are exceeded. Most specifically however, by utilizing Regional Burn Center resources, the model provides a critical insight as to what can and cannot readily be absorbed in the immediate region following a significant burn disaster.

Relying on actual patient occupancy and capacity counts and the daily census from the North Carolina Jaycee Burn Center (NCJBC) provided me with a point to estimate utilization and fluctuations in occupancy and capacity for the other Burn Centers in the ABA Southern Region. Admissions at most Burn Centers are relatively small. Since the numbers are small, this can lead to trending difficulties when using samples. Using two years of the actual daily census and admission numbers of the NCJBC (one of the nation’s largest and busiest Burn Centers) removes concern for the problems that can arise from small sample sizes. Another advantage to having the entire two years of daily entries, these data can provide actual seasonal variations, weekday and weekend differences, and other periods of traditionally high and low occupancy. These data were critical in
developing a distribution curve and performing a sensitivity analysis to assure I was on the correct path.

The series of simulations used in this dissertation assumes all facilities are operating at full capacity and their ability to function is not compromised. These simulations also assume all transportation routes remain intact. While no evacuation model was included, that must be considered as an area vital for future consideration.

During previous disasters such as the 9/11 attack, civilian air transport was, in general, grounded. Furthermore, highway travel was also impacted significantly. As such, reliance on ground based ambulances to move large numbers of patients in and out of areas where an impact of this nature had occurred was problematic during the aftermath of the 9/11 attack and could be the same in future disasters depending on the cause of the disaster. While I included data from large military air transport assets, their use depends on their access. During times of war, their availability is almost nonexistent.

Also, during previous disasters, some hospitals have been damaged and unable to perform their role. Earthquakes such as the Northridge Earthquake in 1994 created widespread disruption in the healthcare system in the greater Los Angeles area and resources historically reliable were no longer available.

The next major disaster could share similar transportation hindrances and difficulties in another similar event. Data from historical disasters have also shown a surge of patients arrive in substantial yet uneven numbers to those hospitals in
the region. Those hospitals farther away receive significantly fewer patients as noted in (Auf der Heide, 2006), leaving a few facilities in the immediate area overrun with patients well beyond the capacity and capability to manage the influx.

Other challenges would be faced if one or more of the hospitals in the immediate area were damaged and not available during a burn disaster. Several of the more concerning threats we face today in disaster planning includes response to an Improvised Nuclear Device (IND). Various aspects and components of the threat created by a thermal wave from a nuclear detonation, response to a nuclear detonation, standards of care and impact on infrastructure aspects are discussed in several academic papers including; (Coleman et al., 2009) (Bell & Dallas, 2007) (Hick, Weinstock, et al., 2011) and (Baez, Sztajnkrycer, Giraldez, & Compres, 2006). Each discuss medical disaster implications and concerns that would surround the accidental or purposeful detonation of a nuclear device and the potential for loss of healthcare infrastructure during such an event. In addition to the surge of patients such an event would create, it would further overwhelm a healthcare system that is currently challenged to meet the daily demand.

A limitation with this dissertation is that I have focused on the type of disasters that have already occurred, can be measured, and can be easily understood. Furthermore, I used relatively small patient volumes that still stressed and exceeded the system capacity. Potential events such as the nuclear weapon detonation previously discussed could be far more catastrophic and could yield tens of thousands or hundreds of thousands of burn patients, far more than
explored in this work. There are several academic publications, which rely on models to quantify the magnitude of threat and estimate the morbidity and mortality in the aftermath of such an event. If we struggle with managing a surge of 20-40 patients with burn injuries while maintaining the standard of care for the burn injured patient, our current healthcare system is no match for an event producing exponentially higher numbers of burn patients.

As the inputs for the model grew, the system began to break down. That break point for the region was between 250 and 500 patients. My first runs included inputs of higher patient counts but those inputs were basically an academic exercise to reinforce the limitation of current capacity and omitted from the final publication.

The most recent non-terror related disaster with significant burn injuries, the Volendam, Netherlands café fire, reinforced the importance of triage as a means of limiting access to Burn Centers for patients with minor burn injuries, (Welling et al., 2008). Another aspect was the limited but essential value of telemedicine that also supported efforts to keep patients with minor burns out of the Burn Center so that those with the greatest needs, and had survivable injuries, were assigned the burn beds as discussed in the paper by, (Benner, Schachinger, & Nerlich, 2004).

Although not explored in this model, another threat to the ability to manage burn patients is the closure of Burn Centers that has taken place in the past 10 years. While the number and trend of closures have somewhat subsided, the closures were typically due to economics or an inability to keep sufficient medical
staff to operate a Burn Center. In addition to nursing shortages, there continues to be a decline in the number of burn surgeons being trained even with the numbers of Burn Center beds no longer in decline but leveling out according to (Ortiz-Pujols et al., 2011). For those Centers that remain open, the challenge also includes the volume of patients that can be seen as they arrive. This trend parallels that seen nationally in other types of medical facilities, as hospitals and trauma beds have also closed during the past 10 years; (Harrison & Ferguson, 2011).

Hospitals in general have excess beds, just by the nature of the business. The count occurs at one time during the day (a static count so to speak), but the ongoing admission and discharge status is far more dynamic. In 2009, the nation’s 20 largest hospitals had an annual average daily census of 71.5% according to ("Leading Hospitals by Average Daily Census," 2010).

The American healthcare system is market based and as such, while some have closed, others have grown. Regardless, key aspects of the best managed hospitals include efficiently and effectively managing patients from the time they arrive through discharge (also known as throughput times.) Understanding throughput is more than good business, it is essential to understanding capacity and limitations during a disaster. Bayram, et al. explored and quantified throughput times to better understand capacity during a mass casualty event; (Bayram, Zuabi, & Subbarao, 2011). Furthermore, there are limitations to managing a disaster given the steps patients follow when they arrive at any hospital seeking care. This was also noted and discussed in (Hirshberg et al., 2005) where they used a computer
simulation model to test the casualty load for a Trauma Center following a bombing.

While the academic papers that discussed simulations and throughputs are important, for the scope of this work, I focused more on the general numbers, statistical capacities and distribution. I did not take into account the time of processing patients from triage to admission. While this is a real concern, the first goal of this work is to simply understand, under ideal circumstances, what quantity of patients with serious burn injuries, could be managed in Burn Centers.

Dr. Hick's 2004 paper first alluded to the notion that there is more to "surge" capacity than just differentiating between typical daily capacity and "surge" capacity, (Hick et al., 2004). However, the 2009 paper by Dr. Hick and his colleagues was far more definitive in stratifying surge capacity and linking what type of surge was being managed in a way that was outside the bounds of the standards of care (Hick et al., 2009). Stratification of surge capacity is critical as we make judgments as to who should be treated and where they should be treated when the numbers of patients with similar injuries overwhelm the typical services being provided.

One aim of this work is to identify the trigger point that allows disaster planners to stratify contingency surge capacity from crisis surge capacity. We can conclusively say that most historical disasters can be managed at Burn Centers relying on the existing medical transportation system of ground based and aeromedical ambulances to move patients to other Burn Centers. This scenario
assumes the disaster is primarily a burn disaster (such as a fire or explosion) and that the healthcare infrastructure remains intact and is not collaterally damaged.

We can also conclusively say that most of the theoretical patient numbers used for 500 or more patients would overwhelm the Regional Burn Centers beyond the point of conventional or contingency surge capacities. Nevertheless, the advantage of using theoretical patient volumes allows us to identify and quantify the contingency capacity both on an intrastate and interstate basis. By identifying the point where we exceed contingency surge capacity for the system, we have determined the break point. (Hick et al., 2009) identified this as the "crisis surge capacity".

By knowing the break points that take us into crisis surge capacity, plans can be made to develop mass medical care resources and policies can be vetted with ethics committees well before the disaster. The aftermath of Hurricane Katrina included a district attorney who sought indictment of a physician and nurses for what was suggested to be euthanasia. While the grand jury refused to indict them, this is a reminder that developing these processes and policies before the disaster are essential.

The planning assumptions of 500 surge beds per million population previously discussed and offered by HRSA Critical Benchmark 2-9, are based on expert judgment (Altered Standards of Care in Mass Casualty Events, 2004). While there is no empirical data that mathematically confirms the absolute accuracy for those targets, given the real events used in Simulations 1-5, the targets are
This work also assumes the inclusion of a mechanism to identify open beds at Regional Burn Centers and to distribute patients to those beds. The first iteration of a burn bed tracking system; Burn Asset Resource Tracking System (BARTS) was later merged into the current national system, Hospital Available Beds for Emergencies and Disasters, (HAvBED). Each state, through the Hospital Preparedness Program (HPP), is required to have a system that collects data regarding available beds, a means of immediately demanding a current count of open beds, and an interface between the state systems and the national HAvBED system.

This dissertation also assumes that payer source is no barrier to interstate cooperation during a burn disaster. Nevertheless, that can be a false assumption without a known payer source. Burn patients have an average length of stay that is exponentially greater than most any other patient with critical traumatic and medical conditions. The typical length of stay for a patient with a 50% Total Body Surface Area (TBSA) burn will include on average, a 50 day stay in the ICU with an additional 25 to 75 day stay until discharge with substantial ongoing outpatient and rehabilitation care. Several papers have discussed burn care related costs, including the work by Dr. Holmes in 2008, (Holmes, 2008) and Dr. Richard Kagen M.D. in 2007 (Kagan, Edelman, Solem, Saffle, & Gamelli, 2007). However, both papers looked at existing payment sources and discussed the challenges faced with those sources.
The American Healthcare System relies on business principles which include the need for payer sources. If there is a request for mutual aid transfers of significant numbers of seriously burned patients, and there is no confirmed payer source, I think it is unlikely that all of these patients will be welcomed at all of Regional Burn Centers without payer source being factored into the agreement to receive the patient.

If the disaster involved a workplace (generally assuring the payer source was Workman’s Compensation) then there are fewer barriers, since this payment source is common for all Burn Centers and generally covers at least the cost of providing burn care. However, if a disaster with significant numbers of burn patients were to involve a group such as parishioners at a church or shoppers at a local mall (patients without a clear payer source other than the patient’s own insurance, or lack therein), a significant surge of patients with a questionable payer source could be financially devastating for a Burn Center and their parent hospital. The limitation of payer source is not a considered factor in the development of this dissertation, but does represent a significant barrier to regional disaster planning for long term patients such as burn patients.

There are a number of assumptions made in this dissertation that may not reflect the real environment in a catastrophic disaster. The greatest threat for the type of major disaster that would create a surge of thousands or tens of thousands of patients with thermal burn injury is one of the greatest terrorist threats we face today, the detonation of a nuclear device and the subsequent thermal wave
generated by the detonation of such a device (Hick, Weinstock, et al., 2011). If such a disaster were to occur, we would most likely lose portions of the critical medical and transportation infrastructure needed to care for and transfer patients, and the remaining infrastructure would have exponentially more patients than typically seen on a day to day basis.

To further complicate matters, patients with less significant injuries would be able to self-evacuate and arrive at medical facilities closer to the site of the event, further overwhelming the remaining medical facilities. These assumptions are consistent with most mass casualty published works, with (Kanter & Moran, 2007) being one such example.

One final limitation not widely explored in this work includes capability to manage the patient which includes the bed, appropriately credentialed staff and sufficient working equipment needed for each patient. The capacity in terms of a “bed” does not always equal the capability to manage a critical patient assigned to that bed. While that aspect was not explored in this work, papers such as the one by (Kanter & Moran, 2007) arbitrarily assign increasing numbers of patients to known facilities where high intensity, high acuity, and low volume patient types are managed, such as Pediatric Intensive Care Units (PICUs). In their work, Kanter and Moran expand the capacity for the PICU by arbitrarily doubling, tripling, and quadrupling the numbers of assigned patients in their model. As an example, a 15 bed Pediatric Intensive Care Unit (PICU) is assigned 30 patients (2:1 ratio), 45 patients (3:1 ratio), and 60 patients (4:1 ratio) because that is most likely where the
greatest number of healthcare experts and their related equipment is located for those types of patients.

Under certain circumstances, (having no other surge of patients other than acutely ill or injured pediatric patients) a hospital can transfer or discharge adult patients, and admit the acutely ill pediatric patients to the hospitals with pediatric beds, resources and staff. While the capacity in terms of beds may now exist mathematically, there may be a distinct lack of sufficient pediatric clinical experts, or sufficient amounts of critical equipment such as monitors and ventilators. Thus, the capacity exists to manage these patients, but not the capability.

Nevertheless, going forward, efforts should be made to model and evaluate the likelihood that a Burn Center could take patients in the 2:1, 3:1 and 4:1 volumes. This dissertation has focused on capacity in the conventional sense. Future efforts should explore expanding capacity and measuring capability to identify what point the break down occurs and patients do not receive care as previously defined as conventional or contingency surge capacity.

Capacity was made available and put to use at Rhode Island in their response to the Station Night Club Fire as discussed by (Harrington et al., 2005). Nevertheless, there remains a certain degree of skepticism by those in the profession regarding the decision to convert beds and expand capacity given the proximity to other nearby Burn Centers with available beds, capacity and an intact infrastructure.

Regardless, one critical aspect of this dissertation is the use of data from of
actual disasters that have occurred in the past 25 years, and involve scenarios that could reasonably reoccur, and testing the capacity for existing Burn Centers to manage the surge of patients. While a theoretical patient count was used in the final simulation, stressing the model to the point it failed allowed me to better understand where we begin to manage the surge of patients in what Dr. Hick described as “Crisis Surge Capacity.” Disaster planners must identify those points and develop “Altered Standards of Care” policies that have been reviewed by the hospital ethics committee long before the disaster occurs. Waiting until the surge of patients arrives in the midst of a disaster to make such policy decisions will create its own disaster.

**Conclusions**

One response following the 9/11 terrorist attack was to compel medical disaster planners to reconsider the risks and threats of potential disasters, and to expand planning assumptions which addressed what had previously been considered absurd or implausible. In the years that followed—with four 2004 Florida Hurricanes, Hurricanes Katrina and Rita in 2005, the Indian Ocean Tsunami, and the Pakistani Earthquake—national and international planners had come to realize that existing medical disaster planning was woefully inadequate. While the 9/11 attack was seen by some as a “wake up call,” for others it was thought to be an anomaly. Nevertheless, by 2006 the magnitude of these disasters dramatically expanded our view of “worst case scenarios”.

For critical medical needs that are best addressed by specialized critical
medical care such as Trauma Centers, Pediatric ICUs and Burn Centers, it remains essential that we have a more finite understanding of our capacities and our capabilities. As our knowledge expands and potential threats emerge that could exceed our conventional and contingency surge capacities of the healthcare system, knowing where those lines are is vitally important for developing our response to these sorts of disasters.

There will always be scenarios that exceed our capacities and capabilities. Nevertheless, through modeling, we can better understand where the boundaries are disaster planning and identified by the points where the model exceeded capacity. This aspect of the model will prompt us to develop and propose strategies and solutions well before we actually face real events that produce real problems.

One unique and critical component to this dissertation includes developing models which rely on actual experiences from historical events that used the same healthcare resources currently in use today. Understanding the processes and boundaries that occur as the arrival rate of patients grow exponentially following a catastrophic event, and having those processes in place well before the disaster occur, gives providers the best chance to provide the best available care for the most patients. Furthermore, making these life and death decisions based on processes put in place well before the disaster, will reflect the best available science and limit those “off the cuff and sometimes catastrophic” decisions. The training and preparedness that grows out of efforts such as this dissertation will save lives and better position responders for that next great catastrophe, not if but when it
The value of this work is it uses real events to quantify the surge of patients and examine real capabilities to manage them in a conventional sense. This work includes addressing a surge of patients first from the institutional perspective, then the intrastate level and finally the interstate level.

At this time, there are 1,895 burn beds in the inventory of staffed burn beds across the nation. Mathematically, to meet the need of 5,000, 10,000 or 20,000 burn injured patients would surely require extraordinary planning efforts. While this work takes only a superficial look at burn disaster capacity, as we begin to better address the smaller components of disaster planning are we better equipped to confront the larger events.

This work did not address some of the more horrific burn disaster scenarios such as capacity and capability questions related to 10,000, 50,000 and 100,000 burn injured patients. In fact, this work serves more as a harsh reminder that the numbers are small when measuring what we can manage relying on conventional surge capacity. Nevertheless, to plan for the larger burn disasters, we must better understand our capacities and capabilities for the smaller ones. This dissertation gives the disaster preparedness profession the first quantitative analysis regarding our capacities and limitations both as a state and a region.
REFERENCES


Table 7. Burn Centers in the American Burn Association Southern Region as of January 1, 2011.

Distance to the Burn Center considers center of Chapel Hill, NC to the center of the city location for the related hospital. Hospitals identified in gray are included in ABA Southern region but are greater than 900 miles from Chapel Hill.