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# An Evaluation of the Organizational Structure of Air Force Emergency Operations Centers Using Social Network Analysis and Design Structure Matrices

John W. Marshall

# AN EVALUATION OF THE ORGANIZATIONAL STRUCTURE OF AIR FORCE EMERGENCY OPERATIONS CENTERS USING SOCIAL NETWORK ANALYSIS AND DESIGN STRUCTURE MATRICES

THESIS

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**DEPARTMENT OF THE AIR FORCE**
**AIR UNIVERSITY**

***AIR FORCE INSTITUTE OF TECHNOLOGY***

**Wright-Patterson Air Force Base, Ohio**

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## Abstract

The terrorist attacks on September 11, 2001 demonstrated that the United States' emergency response capability, while robust, was disorganized in that organizations were not prepared or equipped to coordinate response actions across multiple agencies at a national level. This research investigates whether NIMS and the AFIMS structure is optimal for Air Force emergency managers, or whether, while maintaining NIMS compliance, there is a more effective way for the Air Force to organize its emergency management and response forces. Specifically this research focuses on the organization of the EOC and investigates whether shifting from the current structure of the ESFs to the FLOP structure found in the ICS may be a more efficient use of personnel based on the organizational requirements of the Air Force. This research will employ DSMs to independently evaluate the merits of both the ESF and FLOP construct for specific scenarios based on the tasks outlined in the Air Force's CEMP 10-2. For seven of the eight scenarios examined, ESFs are reaching less than 60% capacity, in fact, most only reach 30% capacity or below. On the other hand, FLOP capacity is significantly increased, however, in some of the more demanding scenarios, capacities exceed more than 100%.

*Dedicated to those who are currently reading this.*

## Acknowledgments

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John W. Marshall

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# AN EVALUATION OF THE ORGANIZATIONAL STRUCTURE OF AIR FORCE EMERGENCY OPERATIONS CENTERS USING SOCIAL NETWORK ANALYSIS AND DESIGN STRUCTURE MATRICES

## I. Introduction

### Introduction

Emergency response was forever changed in the United States following the attacks on September 11, 2001. In an attempt to improve the United States's organizational interoperability during major disasters, the nation developed a new emergency response doctrine to be implemented at all levels, including local, county, state and federal agencies. As a federal agency, the Department of Defense (DoD) was required to implement the change to ensure military responders could easily integrate with local responders when necessary. This thesis researches the Air Force's implementation of the National Incident Management System (NIMS), specifically as it applies to the Air Force's Emergency Operations Centers (EOCs), investigating effectiveness of the current emergency operations center structures. This chapter outlines the background, objectives and justification for the research and briefly describes the research methodology, closing with a preview of the remaining chapters.

### Background

The terrorist attacks on September 11, 2001 demonstrated that the United States' emergency response capability, while robust, was disorganized in that organizations were not prepared or equipped to coordinate response actions across multiple agencies at a national level. Eleven days after the attacks President Bush announced the creation of the Office of Homeland Security by executive order to develop and implement a national strategy to prepare for and respond to terrorist attacks. The official announcement from the President's office stated:

> The mission of the Office will be to develop and coordinate the implementation of a comprehensive national strategy to secure the United States from terrorist threats or attacks. The Office will coordinate the executive branch's efforts to detect, prepare for, prevent, protect against, respond to, and recover from terrorist attacks within the United States. (Office of the Press Secretary, 2001)

On 25 November 2002, the Department of Homeland Security (DHS) was officially created with the passage of the Homeland Security Act of 2002, which recognized the new cabinet level position in the White House and moved 22 agencies related to homeland security within the new department (DHS, 2012). Shortly after the Department's creation, President Bush issued Homeland Security Presidential Directive/HSPD-5 which ordered DHS to develop and administer a National Incident Management System (NIMS) which would be adopted by all federal agencies including those within the Department of Defense (Office of the Press Secretary, 2003).

In response to the President's directive, the Air Force developed the Air Force Incident Management System (AFIMS) as a means of implementing NIMS within the unique framework of the United States Air Force. AFIMS is defined by Air Force Instruction (AFI) 10-2501, the governing regulation on Air Force Emergency Management as:

> A methodology designed to incorporate the requirements of HSPD-5, the NIMS, the NRP and OSD guidance while preserving the unique military requirements of the expeditionary Air Force. AFIMS provides the Air Force with an incident management system that is consistent with the single, comprehensive approach to domestic incident management. AFIMS provides the Air Force with the coordinating structures, processes, and protocols required to integrate its specific authorities into the collective framework of Federal departments and agencies for

> action to include mitigation, prevention, preparedness, response and recovery activities. (USAF, 2007)

A broad overview of the organizational structure of AFIMS can be seen in Figure 1 below. At the strategic level is the Crisis Action Team (CAT) and is chaired by the Wing Commander and manned with the wing staff and group commanders. The objective of the CAT is to evaluate the overall strategic objectives of the base and the current emergency. For example, is the base capable of continuing its primary mission and function while this emergency is ongoing? Does the base have the necessary resources to respond to the emergency? What needs to be reported to higher-headquarters? At the tactical level is the incident command staff. The incident command staff is lead by the incident commander and is organized by four major functions into the Finance, Logistics, Operations, and Plans (FLOP) organizational structure. The Incident Command System (ICS) is designed to be extremely flexible and expandable to meet the needs of the current situation. The incident command staff, are the personnel responsible for expending the resources at the scene to achieve the tactical objectives of the emergency response. Finally the EOC operates as the hub of the emergency response and recovery. The primary role of the EOC is information and resource gathering and disseminating. The EOC is responsible for providing the resources necessary to the Incident Commander for use in response to the emergency. The EOC also develops a common operating picture by attempting to consolidate the information gathered by the personnel in the EOC. The EOC is organized by the Emergency Support Function (ESF) structure. The ESF structure is a standardized 15 organization structure grouping "federal resources and capabilities into functional areas that are most frequently needed in a national response" (FEMA, 2008). Finally, during emergencies, individual Unit Control Centers (UCCs) stand up, as a means to supporting the response. Typically, the UCCs provide information or resources as required through communication from the EOC. Currently there is no defined staffing or organizational structure for the UCC, each unit is responsible for adequately staffing the UCCs as required.

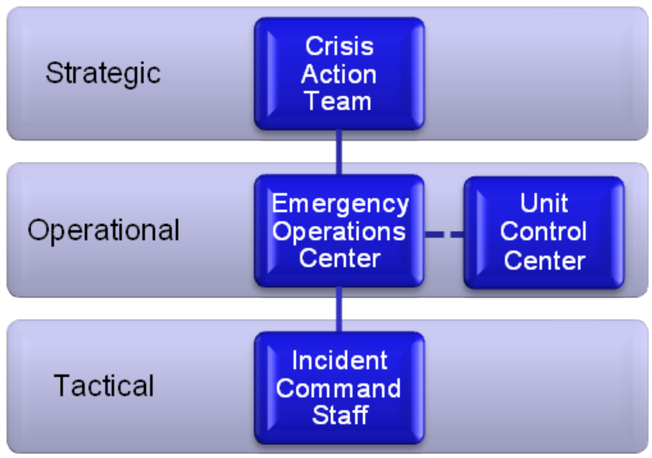



**Figure 1 - AFIMS Organizational Structure**

The National Response Framework (NRF) builds upon NIMS and "provides the structure and mechanisms for national-level policy and operational direction for incident management" (FEMA, 2008). The NRF stipulates that "EOCs may be organized by major discipline... by jurisdiction… by Emergency Support Function… or more likely by some combination thereof," indicating the flexibility offered within NIMS and the NRF to allow agencies to structure themselves in a method they deem optimal while still maintaining federal compliance (FEMA, 2008). The overwhelming majority of local and state EOCs are organized under the ESF construct. Because of the local and state EOC organization, and a lack of available research into alternatives, the Air Force chose to adopt the ESF construct as well.

The ESF structure was initially developed for use in the National Response Coordination Center (NRCC) "to achieve an effective national response to any incident that occurs" (FEMA, 2008). National Response Coordination Center (NRCC) has developed and standardized 15 ESFs as a "mechanism to coordinate functional capabilities and resources provided by… departments and agencies" (FEMA, 2008). However, the ESF construct became the primary method of organization because it easily aligned the primary functions of a local municipality in a standardized method in an attempt to simplify emergency response. Table 1 - Emergency Support Functions and Air Force Equivalent Units (United States Air Force, 2009) lists the ESFs, their basic responsibilities and the equivalent Air Force unit responsible to fill those roles.

While this method is efficient at the municipal and state level, the ESF method does not take into account the Air Force's unique organization. Many Air Force subject matter experts in the Emergency Management career field confirmed that the mismatch between the Air Force's organization and the ESF structure causes inefficiencies (Messina, 2012). First, there is a significant level of redundancy, while 15 separate organizations are designed to staff each ESF, based on the current construct, the Civil Engineer Squadron maintains primary responsibility on seven ESFs, and the Logistics Readiness Squadron and Medical Group holds primary responsibility for two ESFs. Additionally, ESF #6, Mass Care, Emergency Assistance, Housing, and Human Services, are Force Support Squadron functions, except for Housing which again falls to the Civil Engineer Squadron, thus further blurring the distinctions found within the ESF construct (United States Air Force, 2009). Moreover, the ESFs do not take into account a number of Air Force functions critical to emergency response, including Finance, Contracting, Airfield Operations, Aircraft Maintenance, Chaplaincy, Wing Safety, Bio-Environmental Engineering, and Judge Advocate Generals. Table 1 below lists the 15 ESFs and Air Force equivalent units.

**Table 1 - Emergency Support Functions and Air Force Equivalent Units (United States Air Force, 2009)**

| ESF | Responsibility | Air Force Equivalent |
|---|---|---|
| **ESF #1** | Transportation | Logistics Readiness Squadron |
| **ESF #2** | Communications | Communications Squadron |
| **ESF #3** | Public Works and Engineering | Civil Engineer Squadron |
| **ESF #4** | Firefighting | Civil Engineer Squadron |
| **ESF #5** | Emergency Management | Civil Engineer Squadron |
| **ESF #6** | Mass Care, Emergency Assistance, Housing, and Human Services | Force Support Squadron |
| **ESF #7** | Logistics Management and Resources Support | Logistics Readiness Squadron |
| **ESF #8** | Public Health and Medical Services | Medical Group |
| **ESF #9** | Search and Rescue | Civil Engineer Squadron |
| **ESF #10** | Oil and Hazardous Materials Response | Civil Engineer Squadron |
| **ESF #11** | Agriculture and Natural Resources | Medical Group |
| **ESF #12** | Energy | Civil Engineer Squadron |
| **ESF #13** | Public Safety and Security | Security Forces Squadron |
| **ESF #14** | Long Term Recovery | Civil Engineer Squadron |
| **ESF #15** | External Affairs | Public Affairs |

However, another method of organization is available to the Air Force. The Incident Command Staff (ICS) on scene is organized via the FLOP structure. Mirroring that structure at the EOC has the potential to widen the lines of communication between the ICS and the EOC, from just the Incident Commander (IC) and the EOC Director to each primary member of the FLOP staffs. Additionally, it allows for greater flexibility within the EOC by allowing each FLOP functional leader to augment his or her staff with the appropriate units to specifically tailor the response to the emergency at hand. This research will attempt to compare the two organizational structures, and attempt to identify which is better tailored to meet the needs of Air Force Emergency responders.

**Research Problem**

This research investigates whether NIMS and the AFIMS structure is optimal for Air Force emergency managers and responders in its current form, or whether, while maintaining NIMS compliance, there is a more effective way for the Air Force to organize its emergency management and response forces. Specifically this thesis focuses on the organization of the Emergency Operations Center (EOC) and investigates whether shifting from the current structure of the Emergency Support Functions (ESFs) to the FLOP structure found in the ICS may be a more efficient use of personnel based on the organizational requirements of the Air Force.

**Research Objectives**

In order to determine which organizational structure provides the most effective capability for response and recovery, an analysis of individual personnel capacity should be conducted for each individual in the EOC. Capacity in this context is "the capability to complete tasks and usually refers to the volume of resources available for task realization" (Horman, 2001). By evaluating individual capacities, a quantitative analysis can be accomplished to determine individual workloads of personnel in the EOC to conduct direct comparisons between the two organizational structures.

## Research Approach

In order to calculate individual capacities, and given the fact that each emergency scenario is inherently unique; a comprehensive list of tasks along with who is responsible for them is required. In attempt to develop a comprehensive list of tasks, the Comprehensive Emergency Management Plan 10-2 (CEMP 10-2) was used. According to Air Force Instruction 10-2501, *Air Force Emergency Management Program Planning and Operations,* the CEMP 10-2 "provides comprehensive guidance for emergency response to physical threats resulting from major accidents, natural disasters, conventional attacks, terrorist attack and CBRN attacks" (United States Air Force, 2009). To accomplish this research a Design Structure Matrix (DSM) methodology was used. Design structure matrices (DSMs) can take the tasks and responsibilities, and develop a response timeline in the form of a Gantt chart that can be used to determine the total response duration, and individual personnel durations to determine individual capacities (Eppinger & Browning, 2012). DSM analysis will simulate the estimated time to complete the tasks outlined in the CEMP 10-2, and determine the capacity of each EOC position. This information can then be used to develop an optimal organizational structure based on actual response requirements for specific emergency scenarios.

## Scope, Assumptions and Limitations

This study focuses solely on the organizational design of the Air Force Incident Management System and Air Force EOCs. Those organizations outside the USAF should evaluate the usefulness of this research towards their own organizations carefully as its applicability may vary. While the facts and figures are specifically tailored for Air

Force Emergency Management, it is likely that others may find the methodology beneficial for their own organizations. However, application of these results towards other organizations may require further research prior to implementation outside of the United States Air Force.

Some assumptions were required in order to accomplish this research. First, while the CEMP 10-2 calls itself a comprehensive plan, it is impossible for it to be truly comprehensive as each emergency has an infinite number of unknowns that cannot otherwise be planned for. As such, the CEMP 10-2 is "comprehensive" in the sense that it includes all the tasks that are universally common for each emergency scenario. Therefore the checklists of the CEMP 10-2 offer the maximum level of detail available for planning purposes, thus providing the data required for the DSM analysis. Furthermore, the CEMP 10-2 has approximately 28 standard emergency checklists, spanning four incident types. In attempt to narrow the scope, only eight checklists were chosen in only two most common incident types, major accidents, and natural disasters. The eight scenarios were chosen based on their dissimilarities in consequence/impact and complexity to evaluate a wide range of scenario types without being required to analyze every single scenario. Additionally, task duration estimates were required to conduct the DSM analysis. Because task duration estimate data are not readily available, an assumption was made that the task durations for each task was approximately the same. This assumption is considered valid because typically the role of the EOC is to gather and disseminate information to those actually accomplishing the tasks, rather than accomplishing the tasks themselves. Because the role is to primarily gather and disseminate information, it is valid to assume that this takes approximately the same amount of time regardless of the task, in comparison to the duration times required to actually accomplish the task.

Furthermore, some limitations arose from the DSM model used for the simulation. Due to the way the simulation model is written, the maximum duration is limted to 256 time-step intervals, (the maximum number of columns in a Microsoft Excel spreadsheet). Because of the complexity of the scenarios that were researched, and that they have a relatively long duration, a five-minute time-step duration was used as a means to overcome this limitation. While using a five-minute time-step duration slightly lowers overall simulation fidelity as compared to a one-minute time-step duration, it was necessary to ensure the results stayed within the 256 time-step maximum. Finally, a fundamental assumption of the DSM model is that completion times are identical for both the ESF and FLOP organizational constructs because the Gantt chart is based on the required checklist tasks, and are accomplished in the same order regardless of who accomplishes them.

**Preview**

The remaining chapters focus on presenting additional detail related to the problem statement, proposed solutions and results. Chapter II provides a review of past research into Emergency Management and the implementation of NIMS, a foundation in Network Analysis and Design Structure Matrices setting the framework for the organizational design of the EOC. Chapter III outlines the method for evaluating the current EOC structure against different alternatives. Specifically, it explains the use of DSMs, and how individual capacities are calculated for each individual EOC personnel.

Results will be presented in Chapter IV, and includes the average process duration times, average capacities for both the ESF and FLOP constructs, and a visual comparison of the two constructs based on the eight scenarios evaluated. Finally Chapter V offers a conclusion and recommendation for the organizational structure of the EOC, and provides a decision support tool for EOC Directors to optimally staff the EOC based on the given emergency.

# II. Literature Review

## Introduction

While little research has been accomplished on AFIMS itself, many scholars have researched the effectiveness of current emergency management doctrine and policy, to include NIMS and the NRF. This chapter will review the literature including a background of Social Network Analysis (SNA) and Design Structure Matrices (DSM) and their link to emergency management and EOC organization. Specifically, this chapter will investigate research by A. Dekker (2002) on Force, Intelligence Networking and Command and Control (C2) (FINC) and the role organizational structure plays in military unit effectiveness through use of SNA. Robert Houghton, et al. (2006) expanded upon Dekker's (2002) research by examining the ICS of United Kingdom (UK) police and fire response and evaluating them through Dekker's SNA C2 architecture methodologies. Finally, Maj. Joseph Legradi took the results of Dekker (2002) and Houghton, et al. (2006) and applied the research specifically to military and civilian EOCs. Legradi concluded that significant differences existed between how military and civilian EOCs operate despite the similar organizational structure, and recommended further research on whether military EOCs could be better organized to suit the specific needs of military emergency response. This literature review investigates this line of research and sets the framework for the introduction of DSMs to evaluate EOC organizational structure.

**Network Theory and Social Network Analysis**

Network theory has a broad range of applications in areas of biology, computer science, economics, operations research, particle physics, statistical physics, and sociology. Specifically, the use of network theory in sociology has grown since the mid-1930s, and has now become a standard methodology of research to understand and map the interactions of people in a number of environments from office and family culture to international diplomacy and politics. With the rise in the popularity of research on emergency management (EM) in the decade following the terrorist attacks on September 11, 2001, it was only a matter of time before SNA would be used to investigate the internal and external networks found in many of the EM fields. Articles by Dekker (2002), Houghton, et al. (2006), and Legradi (2009) set a framework for the discussion and appropriateness of use of SNA in military and EM organizations. However, it is important to first develop a basic foundation in SNA itself, its history and its application.

Social Network Analysis can trace its roots to three distinct academic disciplines: psychology, anthropology, and sociology (Knoke & Yang, 2008, p. vii). Psychologist Jacob Moreno, the founder of the journal *Sociometry,* developed and first used the methodology in 1937 by measuring the strength of social relations to "better study the relationship between social structures and psychological well-being" (Knoke & Yang, 2008, p. vii). However, the most famous early social network analysts are psychologist Elton Mayo and anthropologist W. Lloyd Warner whose studies of the Hawthorne Plant of the Western Electric Company in Chicago Illinois in the mid-1930s set the standard for future research within the field. Their use of SNA developed the foundation for what has since been described as the Hawthorne Effect, or the principle that a research participant's behavior may be "related only to the special social situation and social treatment they received" (French, 1950, p. 82). However, SNA as a scientific method did not truly gain popularity until the 1970s, and has continued to grow exponentially since then. Only a handful of published journal articles used the term "social network" in their abstract in 1970 but more than 2500 articles included the term in 2005 (Knoke & Yang, 2008, p. 1).

According to Knoke and Yang, there are three basic underlying assumptions to SNA. The first assumption is that "structural relations are often more important for understanding observed behaviors than are such attributes as age, gender, value, and ideology" (2008, p. 4). In other words, it is the relationship between the two actors that is significant, not the unique characteristics of the individuals. A good example is the student-teacher relationship, or the relationship between coworkers. There is an expectation of behavior of both actors that is unique to the relationship, but those same individuals may act differently when placed in another contextual scenario. The difference isn't heavily influenced by the attributes of the individuals, but instead the social context of the relationship itself.

The second assumption Knoke and Yang introduce is that "social networks affect perceptions, beliefs, and actions through a variety of structural mechanisms that are socially constructed by relations among entities" (2008, p. 5). This assumption has been popularized through the common saying that "it isn't what you know, but who you know." Individual relationships within the social network affect the flow of information and the capabilities of the organization significantly. It is not uncommon to observe that information often flows fastest through informal networks and cliques rather than through more official chains of communication. Understanding and exploiting those informal networks within an organization can lead to increased productivity and office capabilities; however, they can also "reinforce prejudices and fan conflicts with out-groups" making it important to properly manage and mitigate potential issues derived from informal networks (Knoke & Yang, 2008, p. 5).

Finally, the third assumption is that "structural relations should be viewed as dynamic processes" (Knoke & Yang, 2008, p. 6). That is to say change should be expected because humans are involved. If one person is underperforming due to illness, or a relationship is strained due to personal differences between the individuals, the entire social network can be affected. Additionally, the social network is inherently affected when people are introduced to or removed from the network. The new network must re-adjust to accommodate these changes which can significantly disrupt the workflow until the network can rebalance itself.

A key to understanding and researching social networks came with the introduction of the sociogram. A sociogram, as seen in Figure 2 below, is a series of nodes which represent individuals within a social network and lines which indicate the relations between the individuals. To take expand upon the sociogram, weightings and directional vectors can be applied to relation lines allowing for further mathematical analysis and interpretation. A foundation for this analysis was introduced via graph theory by Dorwin Cartwright in 1956, by broadening Heider's theory of balance from the mathematical series of linear graphs to "configurations of many different sorts, such as communication networks, power systems, sociometric structures" and much more (Cartwright, 1956). Cartwright's generalization also expanded Heider's theory from the typical linear "x" and "y" graph to a more general collection of "axioms and formulas used to analyze the points and lines" (Legradi, 2009, p. 15).

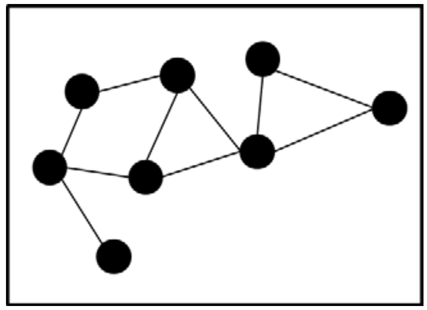


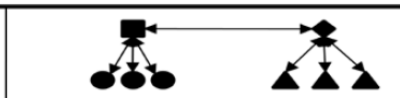
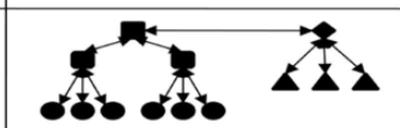
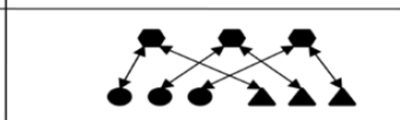
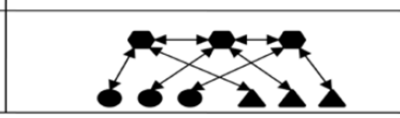
**Figure 2- Sociogram**

**Emergency Management and Social Network Analysis Research**

Dekker (2002) recognized that there are four primary goals, or outputs, of SNA. The first goal is to "visualize communication and other relationships between people and/or groups by means of diagrams" (2002, p. 2). Secondly, SNA creates a capability to study factors that influence and correlations between relationships (Dekker, 2002, p. 2). The third goal Dekker identifies is the ability to "draw out implications of the relational data" to identify the shortcomings and "bottlenecks" found within the network (2002, p. 2). Finally, and most importantly, according to Dekker, is the goal to develop recommendations based on the SNA to improve communication, "and (in military terms) to speed up the orient-observe-decide-act (OODA) loop or decision cycle" (2002, p. 2).

With those goals in mind, Dekker developed four primary archetypes of command and control (C2) based on SNA. These archetypes, summarized by Legradi (2009) can be seen in Table 2 below. To help illustrate the archetypes, Dekker identified actual

**Table 2 - Command & Control Archetypes, (Legradi**

| | | |
|---|---|---|
| Centralized |  | USAF: AWACS to Strike aircraft |
| Split |  | Army: Localized commanders |
| Distributed |  | Spec Ops or Terrorist Cells |
| Negotiated |  | Peer to Peer |


military units that are organized under a similar C2 architecture. The four types include Centralized C2, used by Airborne Warning and Control Systems (AWACS) aircraft who gather intelligence from multiple sources to control and prioritize targets for strike aircraft. The second archetype is the Split C2. This model is often used by land forces when centralized C2 becomes too cumbersome due to the geographical separation of the units. The Split C2 archetype allows for the addition of "tactical adjustments to new information by subordinate units" but can be criticized "since the delays inherent in the hierarchy may negate the benefits of centralized planning" in high operations tempos (Dekker, 2002, p. 5). The Distributed C2 archetype places a high level of confidence in the personnel on the ground to make decisions based on the current conditions in a highthreat environment. Dekker (2002) notes that this archetype is often employed by special operations units, and can also be seen in how most terrorist cells operate due to the continually changing circumstances in which they operate, where it is impractical to pass information up to decision-makers. The final archetype is the Negotiated C2 archetype. This is often employed by emergency services personnel (fire and ambulance) when they are responsible for a fixed area, but may negotiate with units outside their area of responsibility (AOR) for assistance during a large scale emergency (Dekker, 2002).

Finally, Dekker doubles the number of archetypes (for a total of eight) by adding an additional variable to accommodate for information sharing, which allows units on the ground to pass information to all higher headquarters for information to be fused and redistributed again at the lower levels. While this information sharing attribute does not change the sociograms of the archetypes in Table 2 above, Dekker recognizes it adds one additional "time step" to each of the archetypes for analyzing associated time delays from initial command to execution (2002, p. 9). The addition of the information sharing attribute becomes exceptionally important when evaluating the Negotiated C2 architecture, as it allows for units on the ground to negotiate directly with other units through "self-synchronization" setting the foundation for the emergence of Network Centric Warfare (NCW) in military doctrine by maximizing a ground unit's autonomy and capabilities (Dekker, 2002).

To test his archetypes, Dekker developed his own SNA methodology called "Force, Intelligence, Networking, and C2" or FINC (Dekker, 2002, p. 2). Using a Java-based application developed by the Electronics and Surveillance Research Laboratory of the Australian Department of Defence called CAVALIER, Dekker was able to input his four archetypes into the program to see how each C2 archetype would respond to a specific scenario he developed by measuring the time-lag introduced by each C2 archetype and measuring the number of "turns" required to complete the mission. By incorporating attributes including intelligence quality, communication delays, and geographic area covered, Dekker was able to quantify four network measures, the information flow coefficient, the coordination coefficient, the intelligence coefficient, and intelligence volumes (Dekker, 2002, pp. 14-17). The key point, as noted by Legradi (2009, p. 20) is "that once the network is discovered, quantifiable values can be assigned and the network can be analyzed and adapted to find better functioning networks to accomplish the mission" thus setting a foundation for the validity of this research stream.

As a follow-on to Dekker's (2002) research, Houghton, et al. (2006), from the University of Birmingham, United Kingdom, chose to conduct an SNA applying Dekker's archetypes to the C2 mission in emergency services operations, specifically focusing on police and fire services in the UK. Houghton, et al.'s (2006) hypothesis stated that if an organization was structured contrary to the way the network naturally operated, a tension could develop leading to impaired team performance. Additionally, due to the changing nature of organizations, whether from an increasing reliance on technology, the employment of larger geographical AORs, or any other myriad reasons, it is becoming clearer that traditional C2 structures of the past may no longer be the optimal C2 structures of today (Houghton, et al., 2006).

Houghton, et al. (2006) point out that with the increase in ease of information sharing over time, networks are, from an SNA perspective, becoming denser. Increasing the density of networks has the potential to introduce both benefits and drawbacks. One benefit is that since most individuals are interconnected within a denser network, those individuals can more naturally create sub-teams as necessary to attack specific challenges (Houghton, et al., 2006). Additionally, Houghton, et al. (2006) recognize that information will likely flow more quickly in dense networks, as the individuals rely less upon formal communication by employing informal methods instead. As a drawback, a denser network has the potential to develop additional intermediate C2 elements resulting in greater information processing delays (Houghton, et al., 2006, p. 8).

To investigate their observations further, Houghton, et al. (2006) created a SNA of six emergency responses, three fire responses and three police responses respectively. The research of Houghton, et al. (2006) examined the tactical response level of the Incident Command Staff (ICS), specifically focusing on the communication between the Incident Commander (IC) and the different actors/organizations below the IC. After developing the social network, Houghton, et al. (2006) assigned a relative importance value to each node and compared them using a sociometric and centrality index and identified the key players based on these calculations. After identifying the key players in the response, Houghton, et al. (2006) then attempted to categorize each response into one of Dekker's (2002) archetypes.

The findings of Houghton, et al. (2006) did not support Dekker's assertion that emergency response networks modeled the negotiated C2 archetype. Instead, Houghton, et al. (2006) observed that all the police networks demonstrated the split C2 architecture, two of the three fire response networks modeled the distributed C2 architecture and the final fire network modeled a slight modification to a centralized C2 architecture. However, Houghton et al.'s research validated that Dekker's archetypes effectively apply to the emergency management community and that many attributes can be quantified to conduct SNA to evaluate sociometric status and centrality.

Legradi's 2009 research attempted to expand the research of Houghton et al. and Dekker by determining the similarities and differences of civilian and Air Force emergency response efforts. Legradi (2009) chose to focus his research at the EOC level to better understand how social networks played a role in that level of response. In order to accomplish his research, Legradi (2009) surveyed both civilian and Air Force ESF personnel to compare response characteristics between the two types of organizations. For the purpose of the survey, Legradi (2009) developed a Chemical, Biological, Radiological, Nuclear, High Yield Explosive (CBRNE) scenario happening just outside the gate of a fictional military installation. Legradi (2009) left the scenario intentionally vague to allow for broad interpretation by the respondents of the survey. Beyond simple demographic information, Legradi (2009) asked only two questions of the respondents based on the scenario. Quoted below are the two survey questions Legradi used in his survey:

> On the following scale please select the frequency you would need to communicate with each ESF or function listed below during the crisis event, in order to exchange information, documents, schedules and other resources **to get your job done** [emphasis Legradi's] (Legradi, 2009).
>
> On the following scale please select the frequency you would need to communicate with each ESF or function listed below during the crisis event, in order to seek inputs, advice and **before making a key decision** [emphasis Legradi's] (Legradi, 2009).

The scale referenced the respondents used to answer the questions used the descriptive words never, very rarely, rarely, occasionally, frequently and very frequently. With this information, Legradi (2009) was able to develop task and decision networks for analysis and determine key attributes of both civilian and military EOC social networks including, a network closeness index (NCI), flow betweenness centrality (FBC), and a network flow betweenness index (NFBI). Specifically, with these metrics, Legradi (2009) was able to mathematically identify distinct differences between military and civilian EOC networks. In comparison of both NCI and FBC, Legradi determined that the civilian and military EOCs have "very few key players in common" which breaks from the expectation that in an identical emergency both organizations would respond similarly (Legradi, 2009). This lack of similarity has the potential to "lead to confusion, time delays, duplication of efforts and a reduced level of performance" when both organizations are expected to work together in the joint environment (Legradi, 2009). These differences are particularly interesting due to the fact that since both EOCs are required to adopt the NRF, in theory both social networks "would handle the scenario in a similar manner" (Legradi, 2009). However, in addition to these differences, Legradi (2009) observed that the centrality of both networks is very high, recognizing that ESF members are exceptionally good at interacting with other ESFs when they are required to make decisions or accomplish tasks.

Because of the distinct differences in how the two organizations responded, Legradi recommended future research be applied to military EOCs to determine if performance could be improved by a new organizational structure. Legradi speculated that the four main components of the ICS (Finance, Logistics, Operations and Plans) are likely present in the EOC and proposed that the ICS may be a strong starting point for research into a new organizational method for military EOCs.

## Design Structure Matrices

As another methodology of network theory, Design Structure Matrices (DSMs) span both operations and systems research and SNA. DSMs are exceptionally powerful for modeling and analyzing complex organizations and processes. "As a tool for system analysis, DSM provides a compact and clear representation of a complex system and a capture method for the interactions/interdependencies/interfaces between system elements (i.e. sub-systems and modules)" (DSMweb.org, 2009). Eppinger and Browning highlight five advantages that DSM analysis offers in their book *Design Structure Matrix Methods and Applications* (2012).

1. Conciseness
2. Improved Visualization
3. Easily Understood and Interpreted
4. Powerful Analysis
5. Flexibility

(Eppinger & Browning, 2012)

Eppinger and Browning recognize the DSMs ability to provide substantial information of complex processes in a relatively small space. "The DSM highlights relationship patterns of particular interest to a system designer" (Eppinger & Browning, 2012). Additionally, DSMs provide a system-level view which can support "globally optimal decision making and help orient those focused on particular elements" (Eppinger & Browning, 2012). Furthermore, because DSMs are matrices, application of graph theory and matrix mathematics can be easily applied to the DSM to determine a number of quantifiable characteristics of the system. Moreover, DSMs have the capability to be used and modified to fit the current system or scenario. Since the introduction of DSMs, "more than three decades ago, many researchers and practitioners have modified and extended the basic DSM with helpful graphics, colors, and additional data. New possibilities continue to develop every year" (Eppinger & Browning, 2012). Because emergency response is an inherently complex process of managing multitudes of people and resources, the DSM becomes a powerful tool to simplify and quantify the characteristics, responsibilities and tasks of emergency response.

The DSM has its start in the product and systems architecture realm, and has since evolved over the years. The first commonly used square matrix model designed to represent a system's components was called the N-square diagram, first formally introduced to the academic community by R. J. Lano in his book titled *A Technique for Software and Systems Design* in 1979, however it is believed that various U.S. aerospace companies have employed the technique since as early as the 1950s or 1960s (Eppinger & Browning, 2012). While N-square diagrams are still used today, most notably as a tool incorporated in the U.S. Department of Defense Architecture Framework (DoDAF), the DSM itself was not introduced until 1994 when researchers at Massachusetts Institute of Technology introduced the benefits of "distinguishing different types of interactions among components and of analyzing the model to prescribe alternative architectures with improved modularity" (Eppinger & Browning, 2012).

Three basic task relationships can be described by the DSM, the *parallel* configuration, the *sequential* configuration and the *coupled* configuration which can all be seen in Figure 3 below (Yassine, 2004). An empty square in the DSM indicates tasks can be completed simultaneously in parallel, while a single entry below the diagonal indicates the tasks must be accomplished in series. Additionally, two entries on the DSM, one below and one above the diagonal indicate the tasks are coupled and must be accomplished simultaneously in a feedback loop in order for either task to be accomplished. “The DSM provide insights about how to manage a complex project and highlights issues of information needs and requirements, task sequencing, and iterations” (DSMweb.org, 2009).

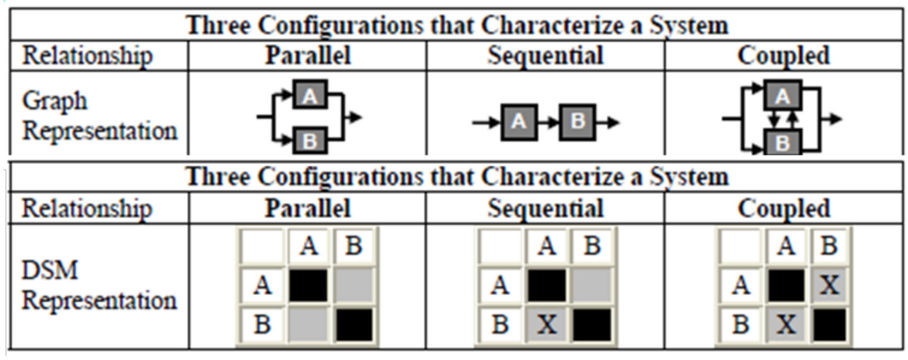



**Figure 3 - Three Configurations that Characterize a System (Yassine, 2004)**

***Product Architecture and Organization Architecture DSMs.***

Eppinger and Browning also identify four primary application types of the DSM. The four types are the Product Architecture DSM, Organization Architecture DSM, Process Architecture DSM, and the Multidomain Architecture DSM. The Product Architecture DSM is “a mapping of the network of interactions between a product’s components” (Eppinger & Browning, 2012). Product Architecture DSMs have minor applicability to this research. The second type of DSM is the Organization Architecture DSM. The Organization Architecture DSM is a “mapping of the network of interactions among the people or units within an organization” (Eppinger & Browning, 2012). This

DSM model is in many ways simply another method of visualizing and analyzing a social network. While not specifically a DSM, Legradi's (2009) survey research used similar techniques to the Organizational Architecture DSMs to calculate his SNA metrics. Organizational Architecture DSMs typically show three attributes of a social network, the hierarchical decomposition, the lines of authority, and the lateral relationships (primarily through information flow) (Eppinger & Browning, 2012). Product Architecture and Organization Architecture DSMs alike can use clustering to strengths of the dependencies of the components within the system. Usually clustering in an organizational architecture DSM, is to assign people with similar needs in such a way that promotes communication and team integration, while clustering in product architecture DSMs are used to group dependent features within a product together.

***Process Architecture DSMs.***

The Process Architecture DSM is a "mapping of the network interactions among the activities in the process" (Eppinger & Browning, 2012). In many ways, the Process Architecture DSM is a reformatting of more common process flow diagrams such as the Gantt chart or work flow diagram. Eppinger and Browning paraphrase Eberhardt Rechtin's book *System Architecting: Creating & Building Complex Systems* (1991) by recognizing that:

- Relationships among [activities] are what give [processes] their added value.
- The greatest leverage in [process] architecting is at the interfaces. (Eppinger & Browning, 2012)

Because clustering simply doesn't make sense in Process Architecture DSMs as it does in the previous two applications, the most common form of analysis of the Process

Architecture DSM is sequencing. Sequencing is the process of logically ordering the activities based on the DSM inputs to determine the optimal progression of tasks and activities (Eppinger & Browning, 2012). While sequencing algorithms in many DSM software packages exist, they cannot be used outside the use of reason and critical thinking by those conducting the analysis. It is typically an iterative process, as the software can only read what is on the DSM and cannot logically understand the activities behind the numbers.

***Process Architecture DSM Applications.***

Process Architecture DSMs grew in popularity in the late 1980s and early 1990s with major enterprises such as the National Aeronautics and Space Administration (NASA) (Rogers, 1989), Boeing (Browning T. R., 2012) and General Motors (Black, Fine, & Sachs, 1990) adopting the technique for use within their organizations. James L. Rogers, a researcher at the NASA Langley Research Center, recognized that within multidisciplinary organizations with "novel concepts, like large space platforms, the determination of the subsystems, interactions, and participating disciplines" cannot always be defined by previously well-established work practices (Rogers, 1989). As such, Rogers recommended an architecture design process (such as the DSM) to develop a "hierarchical structure before the planning documents and milestones of the project are set" (Rogers, 1989).

As part of MIT's 1997 Lean Aerospace Initiative, Boeing brought in a team of MIT researchers to document their processes in designing various unmanned combat aerial vehicles (UCAVs) for the US military. Through detailed interviews with key stakeholders and follow-up surveys, the researchers were able to develop a process architecture DSM of 26 conceptual and preliminary design phase steps and determine the interactions between each phase. The owners of each design phase then provided the MIT researchers with estimated phase duration times and costs (optimistic, pessimistic and most likely), and likelihood of rework and rework impacts due to the inputs/actions of the other phases in the process. The researchers then developed a model using the compiled matrices, and a Monte Carlo simulation which allowed the researchers the ability to create detailed process duration and cost estimates for the entire process. Then through the use of sequence analysis the researchers were able to find the process order which resulted in the most optimized cost and duration estimates. Because of the analysis, and due to Boeing's priority to minimize process duration over cost, Boeing saw a 7% decrease in new UCAV project durations, but saw a slight increase in cost overruns (Browning T. R., 2012).

**Multidomain Architecture Models**

As DSMs have expanded and evolved over the years, a desire grew to develop a way to represent systems across multiple domains such as the product, process, and architecture discussed above, as such, the multidomain matrix (MDM) was developed. The MDM provides for the capability to link multiple DSMs together through the use of (typically) non-square Domain Mapping Matrices (DMMs) as can be seen in Figure 4 below. As an example, to link a Process Architecture DSM with an Organization Architecture DSM, a Process-Organization DMM can be used. The Process-Organization DMM would have the same number of rows as the Process Architecture DSM and the same number of columns as the Organization Architecture DSM. The

Process-Organization DMM's use would provide information on who in the organization is responsible for each task of the process DSM.

Because DSMs across multiple domains can now be linked together the value of the DSM analysis increases exponentially. Value can be created by "identifying needs for cross-functional, cross-team interactions in an organization based on interactions among product components or process activities" (Eppinger & Browning, 2012). Furthermore, MDMs can help infer interactions between domains where specific information may be lacking. Additionally, MDMs can develop a more comprehensive plan for product or process architecting by incorporating more elements, to include tools and equipment, and strategic goals and objectives (Eppinger & Browning, 2012). Finally, by incorporating task duration estimates and costs across multiple domains, individual and team capacities can be estimated, and comprehensive cost analysis across every domain can be conducted.

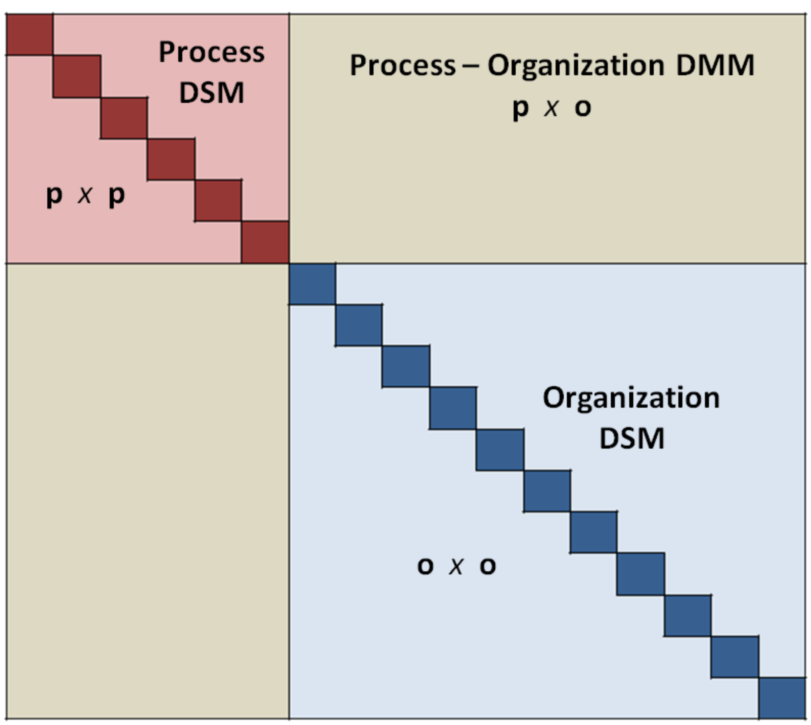



**Figure 4 - Example of a DMM Linking Two DSMs Together. Adapted from (Eppinger & Browning, 2012)**

## FLOP and ESF DMM Construct Design

While the ESF DMM construct is already defined by the 15 ESFs plus auxiliary EOC members, the FLOP construct required some development as there is currently no set organizational design to integrate the FLOP structure with the current Air Force organization at the EOC level. By using the definitions of the FLOP functions as defined by FEMA, the Air Force organizational units fit relatively easily into each category.

### *Finance & Administration Cell.*

"Provides accounting, procurement, time recording, and cost analyses" (FEMA, 2007). The primary Air Force units in the finance and administration cell are:

- Comptrollers
- Contracting
- Force Support Squadron

### *Logistics Cell.*

"Provides support, resources, and all other services needed to meet the operational objectives" (FEMA, 2007). The primary Air Force units in the logistics cell include:

- Civil Engineer Squadron
- Communications Squadron
- Force Support Squadron
- Logistics Readiness Squadron
- Maintenance Group

***Operations Cell.***

"Conducts tactical operations and directs all tactical resources" (FEMA, 2007). The primary Air Force units in the operations cell include:

- Explosive Ordinance Disposal (EOD) Flight
- Fire & Emergency Services Flight
- Medical Group
- Readiness & Emergency Management Flight
- Security Forces Squadron
- Shelter Management Team

***Planning Cell.***

"Prepares and documents the Incident Action Plan, collects and evaluates information, maintains resource status and documentation" (FEMA, 2007). The primary units in the planning cell include:

- Judge Advocate General
- Operational Weather Squadron
- Readiness & Emergency Management Flight
- Wing Chaplain

While this is not an all inclusive list of every organization that could be required in an emergency response situation, it covers all those required to respond based off the CEMP 10-2 checklists for the eight scenarios researched. Should other units or stakeholders be required to be integrated into the response, using the definitions of each management cell should make it clear where the unit belongs. Furthermore it is important to note that some units may fall to multiple cells. For example the personnel management functions of the Force Support Squadron fall to the finance and administration cell while Force Support Squadron's services-type functions fit best in the logistics cell.

**DSM Modeling**

The DSM simulation model developed by Browning, Dong, Yassine, and later updated by Mirshekarian "uses a discrete event simulation to compute the distributions of duration" for the given DSM inputs. Each task in the DSM is assigned three task durations, a *best case value* (BCV), *most likely value* (MLV), and *worst case value* (WCV) which develops the vertices of a triangular probability distribution function (Browning & Eppinger, 2002) (Browning, Dong, Yassine, & Mirshekarian, 2000). In addition to the DSM, two additional matrices are introduced as well to indicate the probability of rework for each given task, and the impact the rework would have on the entire system. When the model is initially run, each task starts with 100% of the work yet to be accomplished. The model then determines, based off the DSM inputs, what tasks can be accomplished and then subtracts the amount of work that can be accomplished based on the task duration and the assigned time-step interval. The model continues by repeating itself, progressively accomplishing all tasks until no tasks remain. A single-run Gantt chart is then developed and the total process duration is recorded (Browning, Dong, Yassine, & Mirshekarian, 2000). Because variability is introduced through both rework and task duration estimates, the simulation is run an assigned number of times to develop a more comprehensively accurate process duration estimate through Monte Carlo simulation until running averages are stabilized around a certain value.

**Lean Value Principles**

As DSMs were gaining popularity within industry, MIT was also researching a new management philosophy based on Toyota's product development system. The philosophy, later coined as Lean Enterprise Value, "is [the] process of eliminating waste with the goal of creating value" (Murman, et al., 2002). Lean Enterprise Value is based on five underlying principles, they are:

- Principle 1 – Create lean value by doing the job right *and* by doing the right job.
- Principle 2 – Deliver value only after identifying stakeholder value and constructing robust value propositions.
- Principle 3 – Fully realize lean value only by adopting an enterprise perspective.
- Principle 4 – Address the interdependencies across enterprise levels to increase lean value
- Principle 5 – People, not just processes, effectuate lean value. (Murman, et al., 2002)

DSMs become a tool that has application to analyze enterprises against many of these principles. Murman, et al. recognized that:

> More powerful methods are emerging based on the application of design structure matrices (DSMs) which provide a powerful visual and analytical tool to understand how the partitioning of work can affect not only the schedule but also the information flow throughout the program value stream (Murman, et al., 2002).

Therefore, by incorporating process-organization DMMs, individual capacities can be calculated to analyze the overall level of effort each individual is required to expel in order to accomplish the objective. Capacity is "the capability to complete tasks and usually refers to the volume of resources available for task realization" (Horman, 2001). In his paper, *Modeling the Effects of Lean Capacity Strategies on Project Performance,* Horman (2001) recognized that increasing personnel capacity as a means of eliminating waste and thus, increasing value, resulted in "yielding significant improvements to project time and cost performance" (Horman, 2001). Horman further noted that through his simulations, the "capacity added to generate optimal performance is approximately 80% of that originally provided to the project" (Horman, 2001). Therefore, according to his research, optimal personnel management should seek to task their personnel as close to 80% of their capacity as possible.

Additionally, Mihaly Czikszentmihalyi (1997) recognized that flow is an integral component to optimal performance. "Flow tends to occur when a person faces a clear set of goals that require appropriate responses. (Czikszentmihalyi, 1997)" An EOC is a prime example of where flow can occur because each individual is working towards a common and very clear objective. This sense of flow in the EOC, has the potential to increase individual performance as each is attempting to meet the needs of those responding to the emergency.

## Conclusion

This chapter introduced the concepts of SNA and their application to the field of Emergency Management. It discussed the application of DSMs in product, organization and process architectures, and discussed how they can be linked through the use of DMMs. Finally, this chapter introduced the principles of Lean Enterprise Value, which become the foundation for research in optimizing organization, in particular Emergency Operations Centers through the use of capacity calculations. The chapters ahead will outline the methodology adopted to evaluate performance between the ESF and FLOP constructs, the results of the analysis and the conclusions and applications generated from the research.

# III. Methodology

## Introduction

This chapter outlines the method used for investigating the effectiveness of Air Force EOC organization. This research will employ DSMs to independently evaluate the merits of both the ESF construct and FLOP construct for specific scenarios based on the required tasks outlined in the Air Force's Comprehensive Emergency Management Plan 10-2 (CEMP 10-2). The DSM analysis will simulate the estimated time to complete the tasks outlined in the CEMP 10-2, and measure the individual capacities of EOC personnel under both organizational constructs. With this information, the best organizational structure can be determined, allowing the EOC director to tailor the EOC staffing based on the current scenario.

## Research Plan

While many intermediate steps exist, the general strategy of this research simplifies to four basic steps. Step one is data acquisition. Process Architecture DSM analysis requires the specific tasks required to execute the project. While emergencies inherently introduce uncertainty, the CEMP 10-2 checklist offers a near "comprehensive" list of tasks that can be expected every time a specific scenario occurs. The second step is to input the tasks into the Process Architecture DSM. To do this, the dependencies between tasks are identified to communicate which tasks can be run in parallel, series or through coupled iterations. The third step is to augment the Process Architecture DSM with a Process-Organization DMM. The CEMP 10-2 provides responsibility data for each task identified which is used to populate the Process-Organization DMM. The final step is to run the DSM/DMM simulation model to calculate the individual capacities, and use this information to assess the effectiveness of the two EOC organizational structures being evaluated.

**Data Requirements**

The key data requirement to conduct a DSM analysis is a comprehensive list of tasks or processes that are required to accomplish a given objective. In the case of an EOC activation and response, this list is never fully complete, as responders could experience an infinite number of unknowns during any given scenario. However, the CEMP 10-2 is a valuable document that lists the tasks likely to be accomplished every time a generalized scenario occurs rather than listing every possible task for every variation of a given scenario. Therefore the checklists of the CEMP 10-2 offer the maximum level of detail available for planning purposes, thus providing the data required for the DSM analysis.

Eight of twenty-eight checklists from the CEMP 10-2 were chosen based on their dissimilarities in regards to incident type and complexity, allowing for evaluation of the constructs through multiple criteria to determine what trends, if any can be identified. The eight scenarios are listed in Table 3 below.

**Table 3 - CEMP 10-2 Scenario Checklists (United States Air Force, 2008)**

| Checklist | Incident Type | Complexity |
|---|---|---|
| Nuclear Weapons Accident Checklist | Major Accident | High (100 Tasks) |
| Off-Base Aircraft Accident Checklist | Major Accident | High (76 Tasks) |
| HAZMAT Response Checklist | Major Accident | High (73 Tasks) |
| Response Task Force (RTF) Reception Checklist | Major Accident | Low (14 Tasks) |
| Natural Disaster Checklist | Natural Disaster | High (96 Tasks) |
| Disease Containment Checklist | Natural Disaster | Medium (45 Tasks) |
| Peacetime Disaster Sheltering | Natural Disaster | Low (20 Tasks) |
| Flood Checklist* | Natural Disaster | Low (15 Tasks) |

* The Flood Checklist is an augmenting checklist designed to be run in conjunction with the more generic Natural Disaster Checklist.

### DSM Model Construction

With the eight scenarios selected, individual DSMs were constructed by identifying the interdependencies of the tasks identified in the checklists. Understanding that the tasks of the CEMP 10-2 checklists are not necessarily listed in sequential order, and recognizing that mutually independent tasks can be accomplished simultaneously, it becomes relatively easy to identify which tasks are dependent upon one another, which tasks can be run in parallel and which must be run in series. Once these dependencies are identified they are inputted into the DSM model.

### Simulation Characteristics

As discussed in Chapter I, it is reasonable to assume that EOC tasks are information based, unlike actions occurring at the incident or event. Because the tasks are based on information flows, the research assumes that task completion durations remain fairly constant. Table 4 below shows the BCV, MLV, and WCV values and other characteristics used for this simulation. The rework probabilities and impacts were placed at 5% because the work in the EOC during an actual emergency is relatively simple but with high-stakes, therefore the likelihood of task completion errors is relatively minimal. Furthermore, to accommodate for maximum possible scenario variation, one-thousand simulation runs were accomplished to develop comprehensive process duration estimates. As discussed in Chapter I, a five-minute time-step duration was used as a means to overcome the limitation of the maximum 256 time-step intervals allowed for in the simulation.

**Table 4 - DSM Simulation Characteristics**

| Characteristic | Value |
|---|---|
| BCV, MLV, WCV | 15min, 30min, 45min |
| Rework Probability | 5% |
| Rework Impact | 5% |
| Simulation Runs | 1000 |
| Time-step Duration | 5 min |

**DMM Model Augmentation**

Because the DSM can only develop an overall process duration, a second matrix is required to draw out individual personnel capacity based on the Gantt chart created by the DSM simulation. As a means of evaluating individual EOC personnel capacity two DMMs were added to the simulation process. For each run an ESF and a FLOP task/personnel matrix was matched against the single-run Gantt chart to calculate the time requirements of each individual for every DSM task. To take into account the fact that in many cases multiple organizations have shared responsibilities for many of the identified tasks, three numerical estimates were used to indicate the relative level of responsibility.

Currently, no research exists on assigning values by relative level of responsibility, however preliminary simulation results indicated illogical capacities in positions such as the EOC Director (whose required capacities exceeded 300%), who stays apprised of the majority of tasks within the EOC. Through testing, the following inputs brought the results back to reasonable capacities.

- 1.0 – Those with primary responsibility
- 0.5 – Those with secondary responsibility
- 0.2 – Those with tertiary or minimal requirements to only stay apprised of task accomplishment

In all cases, at least one organization held primary responsibility for each individual task. However, the 0.5 and 0.2 values were chosen as an assumption, as no prior research was found on this topic. Further research could investigate the true amount of effort those with secondary and tertiary levels of responsibility typically expend to add further fidelity to the model. Mathematically, these values show the relative percent the individual contributes based on the estimated task duration. For example, a task that that is estimated to take 30 minutes calculates that those with primary responsibility spend 30 minutes on the task, those with secondary responsibility will spend 15 minutes on the task, and finally those with tertiary responsibility only spend 6 minutes. The DSM/DMM model ran 1000 iterations for each of the eight scenarios under both the ESF and the FLOP constructs, resulting in stabilized average time durations and percent capacity for the entire process and each individual.

## DMM Construct Design

Chapter II discussed in detail the DMM development for use with the ESF and FLOP constructs. The ESF construct was pre-defined by its current organizational structure, however, the FLOP structure was required to be developed based on FEMA's ICS definitions for each of the four FLOP cells. The following units fell to each of the four FLOP cells.

***Finance & Administration Cell.***

- Comptrollers
- Contracting
- Force Support Squadron

***Logistics Cell.***

- Civil Engineer Squadron
- Communications Squadron
- Force Support Squadron
- Logistics Readiness Squadron
- Maintenance Group

***Operations Cell.***

- Explosive Ordinance Disposal (EOD) Flight
- Fire & Emergency Services Flight
- Medical Group
- Readiness & Emergency Management Flight

- Security Forces Squadron
- Shelter Management Team

***Planning Cell.***

- Judge Advocate General
- Operational Weather Squadron
- Readiness & Emergency Management Flight
- Wing Chaplain

**Descriptive Statistics**

Descriptive statistics, as the name implies, "are used to describe the basic features of the data in a study" (Trochim, 2006). Univariate descriptive statistics examine data across one variable at a time. In univariate analysis, the most common statistical tools used in descriptive statistics are the mean, median, mode, and standard deviation. The mean is the most common averaging technique used to describe central tendency. To calculate the mean all values are summed together and divided by the number of values. The median is the central most value. The median is found by listing all values in numerical order and finding the value in the center; for example, if 5 values are used, the third value numerically is the median. The mode describes the value that is most frequently occurring. Finally, the standard deviation shows how much variation exists in the set of values by comparison to the mean. A high standard deviation indicates high variability, while a low standard deviation indicates low variability (Trochim, 2006). The research results of this thesis use both means and standard deviations to describe and evaluate the data in order to develop conclusions discussed in Chapter V.

**Analytical Statistics and Monte Carlo Simulation**

Monte Carlo simulation is an analytical statistical simulation technique "that approximates solutions to quantitative problems through statistical sampling" (Eckhardt, Ulam, & von Neumann, 1987). Through use of probability distributions, and random number generation, a Monte Carlo simulation runs a scenario a large number of times each of which is equally likely to occur. While each individual result provides little information for risk analysis, the aggregate of all the results provides a statistically valid probability distribution researchers can use to develop predictions (Eckhardt, Ulam, & von Neumann, 1987).

**Simulation Process**

The final output of the DSM/DMM model collected the overall process duration estimates for each of the 1000 runs and collected the overall amount of time each individual EOC member expended during the scenario's duration. The individual member's time expended was summed across all tasks and then divided by the overall scenario duration to develop each individual's percent capacity as seen in Equation 1 below.

$$\text{Capacity} = \frac{\text{Individual Time Required}}{\text{Total Process Duration}} \quad \textbf{(1)}$$

Percent capacities were calculated for each of the ESFs, each of the FLOP positions, the EOC Manager, the EOC Director, and those positions required to respond, but who are not included in one of the previous categories. This data can then be used to directly compare between constructs to determine overall efficiency between the two organizational structures. Results of the simulation will be discussed in depth in Chapter IV, Results while application and significance of the results will be discussed in Chapter V, Conclusion.

# IV. Results

## Introduction

This chapter introduces the results from the research methodology discussed in Chapter III. The DSM simulation model ran 1000 times and provided average process durations and standard deviations for each of the eight CEMP 10-2 checklists evaluated. Additionally, the model calculated individual capacities for both the ESF and FLOP constructs, providing a basis for quantitative comparison between the two organizational structures. This chapter outlines and discusses the results of the DSM model simulation and provides the tabulated information below. Furthermore, a figure has been provided at the end which evaluates average capacities between the two organizational structures for each of the eight scenarios, which provides a visual ability to compare the differences based on scenario complexity, and incident type.

## DSM Mean Process Durations

Table 5 below lists the average process duration time as calculated by the 1000 simulation runs of the Browning, Dong, Yassine, and Mirshekarian DSM simulation model. These values are only model estimates designed for comparative research purposes, and therefore unreasonable to use them as an expectation for a real-world incident's duration.

**Table 5 - DSM Mean Process Duration Time (min)**

| | Natural Disaster | HAZMAT Response | Nuclear Weapons Accident | Disease Containment | Off-Base Aircraft Accident | Peacetime Disaster Sheltering | Flood Checklist | RTF Response Checklist |
|---|---|---|---|---|---|---|---|---|
| **Average Process Duration (min)** | 721.14 | 633.55 | 872.36 | 470.57 | 909.71 | 248.64 | 240.29 | 269.68 |
| **Process Duration Standard Deviation** | 30.49 | 27.75 | 34.41 | 22.86 | 32.42 | 17.24 | 17.73 | 19.13 |

## Mean ESF Personnel Capacities

Table 6 below displays the mean ESF personnel capacity. These rates were calculated by summing the amount of time each individual ESF member spends on their assigned checklist tasks based on the ESF task assignment DMM and dividing by the overall process duration times from Table 5.

**Table 6 - Mean ESF Personnel Capacities**

| | Natural Disaster | HAZMAT Response | Nuclear Weapons Accident | Disease Containment | Off-Base Aircraft Accident | Peacetime Disaster Sheltering | Flood Response | RTF Reception |
|---|---|---|---|---|---|---|---|---|
| **ESF 1** | 66.00% | 39.74% | 36.97% | 23.03% | 20.86% | 0.00% | 24.20% | 34.68% |
| **ESF 2** | 57.26% | 44.54% | 29.83% | 16.65% | 20.85% | 14.67% | 15.29% | 11.60% |
| **ESF 3** | 157.82% | 30.01% | 26.25% | 47.33% | 17.57% | 41.91% | 79.59% | 69.04% |
| **ESF 4** | 97.51% | 142.12% | 118.59% | 16.65% | 54.40% | 2.47% | 26.43% | 23.12% |
| **ESF 5** | 79.80% | 152.67% | 132.81% | 15.38% | 43.82% | 136.91% | 37.42% | 23.12% |
| **ESF 6** | 84.23% | 39.67% | 33.40% | 69.56% | 29.11% | 76.30% | 15.29% | 57.57% |
| **ESF 7** | 54.03% | 30.01% | 26.25% | 23.01% | 20.88% | 39.05% | 15.29% | 11.60% |
| **ESF 8** | 120.43% | 110.39% | 151.80% | 132.24% | 63.59% | 46.43% | 15.29% | 23.12% |
| **ESF 9** | 50.00% | 30.01% | 26.25% | 14.09% | 17.57% | 0.00% | 15.29% | 11.60% |
| **ESF 10** | 50.00% | 34.85% | 26.25% | 14.09% | 17.57% | 0.00% | 15.29% | 11.60% |
| **ESF 11** | 50.00% | 30.01% | 26.97% | 14.09% | 17.57% | 0.00% | 15.29% | 11.60% |
| **ESF 12** | 50.00% | 30.01% | 26.25% | 14.09% | 17.57% | 0.00% | 15.29% | 11.60% |
| **ESF 13** | 90.25% | 90.94% | 123.21% | 58.83% | 66.78% | 29.30% | 26.49% | 23.12% |
| **ESF 14** | 50.00% | 30.01% | 26.25% | 14.09% | 17.57% | 0.00% | 13.06% | 11.60% |
| **ESF 15** | 78.21% | 59.19% | 51.21% | 31.25% | 27.38% | 36.67% | 40.74% | 11.60% |
| **ESF Average** | 75.70% | 59.61% | 57.49% | 33.63% | 30.21% | 28.25% | 24.68% | 23.11% |

### Mean FLOP Personnel Capacities

Mean FLOP capacities were calculated by the same method as the ESF capacities but using the results from the FLOP task assignment DMM. The results can be found in Table 7 below.

**Table 7 – Mean FLOP Personnel Capacities**

| | Natural Disaster | HAZMAT Response | Nuclear Weapons Accident | Disease Containment | Peacetime Disaster Sheltering | Off Base Aircraft Accident | Flood Response | RTF Reception |
|---|---|---|---|---|---|---|---|---|
| **FINANCE** | 57.21% | 38.73% | 29.85% | 12.80% | 0.00% | 27.40% | 13.06% | 46.21% |
| **LOGISTICS** | 201.56% | 48.41% | 51.27% | 92.66% | 110.67% | 34.00% | 79.59% | 91.90% |
| **OPERATIONS** | 127.72% | 227.66% | 244.76% | 152.33% | 85.77% | 137.96% | 35.40% | 22.82% |
| **PLANS** | 101.60% | 92.10% | 61.93% | 56.39% | 61.00% | 50.74% | 62.76% | 11.31% |
| **FLOP Average** | 122.02% | 101.73% | 96.95% | 78.55% | 64.36% | 62.52% | 47.70% | 43.06% |

### Mean ESF/FLOP Capacities Comparison

Figure 5 below summarizes the mean ESF and FLOP capacities. The figure is ordered by average percent capacities from highest to lowest for the ESF construct. Coloring was used to distinguish between incident type, browns for major accidents and blues for natural disasters. Additionally, the use of dark and light color was used to show the variation in scenario complexity as described in Table 3 from Chapter III above.

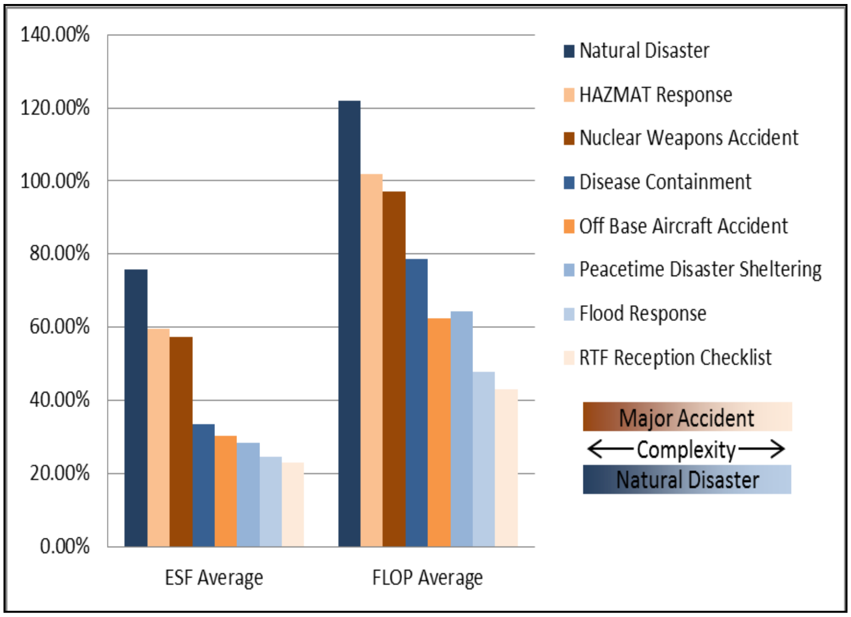



**Figure 5 - Comparison of Mean Capacities by Org. Structure**

## Conclusion

Results showed a significant increase in required capacities when transitioning from the ESF construct to the FLOP. While in some cases, the average capacities significantly exceeded 100%, the majority of capacities under the FLOP were simply brought closer to the goal of 80% capacity as described by Horman's (2001) research on lean capacity strategies described in Chapter II. Chapter V will discuss these results in-depth and offer conclusions and recommendations on the most effective staffing strategies based on the results of this research.

|Task|1|2|3|4|5|6|7|8|9|10|11|12|13|14|15|16|17|18|19|20|21|22|23|24|25|26|27|28|29|30|31|32|33|34|35|36|37|38|39|40|41|42|43|44|
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|1|1|||||||||||||||||||||||||||||||||||||||||||||
|2|1|2||||||||||||||||||||||||||||||||||||||||||||
|3|1|1|3|||||||||||||||||||||||||||||||||||||||||||
|4|1|1|1|4||||||||||||||||||||||||||||||||||||||||||
|5|1|1|1|1|5|||||||||||||||||||||||||||||||||||||||||
|6|1|1|1|1|1|6||||||||||||||||||||||||||||||||||||||||
|7||||1|1|1|7|||||||||||||||||||||||||||||||||||||||
|8||||1|1|1|1|8||||||||||||||||||||||||||||||||||||||
|9||||1|1|1|1|1|9|||||||||||||||||||||||||||||||||||||
|10||||1|1|1|1|1|1|10||||||||||||||||||||||||||||||||||||
|11|1|1|1|1|1|1|1|1|1|1|11||||||||||||||||||||||||||||||||||
|12|1|1|1|1|1|1|1|1|1|1|1|12|||||||||||||||||||||||||||||||||
|13|||||||||||1|1|13||||||||||||||||||||||||||||||||
|14|||||||||||1|1|1|14|||||||||||||||||||||||||||||||
|15|||||||||||1|||1|15||||||||||||||||||||||||||||||
|16|||||||||||1||||1|16|||||||||||||||||||||||||||||
|17|||||||||||1|1|1|1|1|1|17||||||||||||||||||||||||||||
|18|||||||||||1|1|1|1|1|1|1|18|||||||||||||||||||||||||||
|19|||||||||||1|1|1|1|1|1|1|1|19||||||||||||||||||||||||||
|20|||||||||||1|1|1|1|1|1|1|1|1|20|||||||||||||||||||||||||
|21|||||||||||1|1|1|1|1|1|1||1|1|21||||||||||||||||||||||||
|22|||||||||||1|1|1|1|1|1|1|1|1|1|1|22|||||||||||||||||||||||
|23|||||||||||1|||||||||||1|23||||||||||||||||||||||
|24|1|1|1|1|1|1|1|1|1|1|1|||||||||||1|1|24|||||||||||||||||||||
|25|1|1|1|1|1|1|1|1|1|1|1||1|1|1|1|1|1|1|1|1||||25|||||||||||||||||||
|26|1|1|1|1|1|1|1|1|1|1|1||1|1|1|1|1|1|1|1|1|||||26||||||||||||||||||
|27|1|1|1|1|1|1|1|1|1|1|1||1|1|1|1|1|1|1|1|1||||||27|||||||||||||||||
|28|1|1|1|1|1|1|1|1|1|1|1||1|1|1|1|1|1|1|1|1|||||||28||||||||||||||||
|29|1|1|1|1|1|1|1|1|1|1|1||1|1|1|1|1|1|1|1|1||||||||29|||||||||||||||
|30|1|1|1|1|1|1|1|1|1|1|1||1|1|1|1|1|1|1|1|1|||||||||30||||||||||||||
|31|1|1|1|1|1|1|1|1|1|1|1||||||||||||||||||||31|||||||||||||
|32|||||||||||1||||||||||||||||||||32||||||||||||
|33|||||||||||1|||||||||||||||||||||33|||||||||||
|34|1|1|1|1|1|1|1|1|1|1|1||1|1|1|1|1|1|1|1|1|||||||||||||34||||||||||
|35|1|1|1|1|1|1|1|1|1|1|1||1|1|1|1|1|1|1|1|1||||||||||||||35|||||||||
|36|||||||||||1||||||||||||||||||||||||1|36||||||||
|37|1|1|1|1|1|1|1|1|1|1|1||1|1|1|1|1|1|1|1|1||||||||||||||||37|||||||
|38|||||||||||1||||||||||||||||||||||||||1|38||||||
|39|||||||||||1||||||||||||||||||||||||||||39|||||
|40|||||||||||1||||||||||||||||||||||||||||1|40||||
|41|||||||||||1|||||||||||||||||||||||||||||1|41|||
|42|||||||||||1|||||||||||||||||||||||||||||1|1|42||
|43|||||||||||1|||||||||||||||||||||||||||||1|1|1|43|
|44|||||||||||1|||||||||||||||||||||||||||||1|1|1|1|44|
|FINANCE|||||||||||1|||1|||||||||||||||||||||||||||||||
|LOGISTICS|||||||||||1|1||1|||||1|1|||1||1|1||1|1||||1||1|||1|1|1|1|||1||
|OPERATIONS|1|1|1|1|1||||||1|1|1|1||1|1|1|1||1|1|1||1|1|1|||1|1|||1|1|1|||||1|1|1||
|PLANS||||||1|1|1|1||1|1|1|1||1|||1|1|1||||||||||||1|1|1||||||||1||
|EOC MANAGER|||||||||||1|1||1|||1||1|1|||||1|||||1|||1|1|||||||||1||
|EOC DIRECTOR|||||||||||1|1|1|1|1|1|1|1|1|1|1|1|1|1|1|1||||1|||1|1|1||1|1|1|1|1|1|1|1|
|IC||||||1|1|1|1|1|1||1|1|1|1|1|1|||||||1||||||1|1|||||||||1|1|1|1|1|
|CP|||||||||||||1|1|1|1|1|||||||1|||||||||||||||||1|||1|1|

**Figure 6 – Example Disease Containment DSM with FLOP Task Responsibility DMM**

# V. Conclusion

## Introduction

The goal of this thesis was to investigate whether NIMS and the current AFIMS structure is the most effective method of organization, or whether while maintaining NIMS compliance, there may be a better organizational structure the Air Force could implement in the EOC. To research this, two organizational structures were chosen, and were evaluated against the tasks of eight scenarios found in the CEMP 10-2 through use of DSMs. This chapter will discuss the research results and outcomes of the analysis, provide conclusions and application of the results, and finally end by discussing recommendations for the future of this research stream.

## Generalized Research Application

Before discussing the results of the analysis between ESF and FLOP, there was a more significant result that came through the development of this research. This research developed a methodology that quantitatively compares multiple organizational structures based on a set of pre-defined tasks. The methodology was augmented from the DSM analysis methodology to include a DMM which allowed for the quantitative analysis of each position in the organizational structure. This DSM-DMM methodology provides quantitative evidence to managers and operates as a decision support tool to help in determining which organizational structure to use based on the tasks and durations required by the organization. The following pages of this chapter will look specifically at the organization of Air Force EOCs as a practical example of the application of this methodology.

## Capacity Results and Discussion

Horman's (2001) lean capacity research on project performance indicates that personnel tasked to approximately 80% of their overall capacity increase their performance by 10-15% (Horman, 2001). Horman (2001) also noted that a decrease in performance is observed through simulations when capacity is decreased below 80% or increased above that value. This is additionally confirmed by Jensen (1989) in his stress management research that indicates that "as the level of attention and motivation increase (and stress), so does performance. However at very high levels of stress, panic ensues and performance deteriorates dramatically" (Jensen, 1989) Based on these two observations, managers should strive to task their personnel to 80% of their capacity. In relation to emergency response, due to the potential high stakes that can be experienced, EOC directors should seek to task their personnel up to 80%, but not exceed 80% to ensure stress and panic are appropriately managed.

Results from the simulations were as expected. There should be no surprise that by decreasing the number of positions in the EOC (from 15 ESFs plus auxiliary units to just the four FLOP positions), the required capacities will inherently increase. What this quantitatively shows however, is that for seven of the eight scenarios examined, ESFs on average are reaching less than 60% capacity. In fact most only reach 30% capacity or below. However, FLOP capacity is significantly increased. On the other hand, in some of the more demanding scenarios, particularly Natural Disasters and HAZMAT response, capacities exceed 100%, which is also problematic.

Of the two main research conclusions, the simplest conclusion is that FLOP is best suited for less complex events, while the ESF construct is still optimal for the more demanding scenarios. However, a second solution can also be developed. Because the organization of the ESF structure is inherently more compartmentalized by responsibility, tailoring the EOC staffing under the ESF construct is more risky for fear of losing specific emergency response and recovery capabilities. However, under the FLOP construct, it would be generally assumed that work within the individual cells can span multiple units. For example, the Logistics Cell leader under the FLOP construct would have ultimate responsibility for any logistical task whether it fell in a traditional logistics function or to another function such as public works. Because of this expansion of authority under FLOP, personnel tailoring becomes possible as a method to overcome exceedingly high workloads. Because tailoring under the FLOP construct is possible, the individual capacity rates from both the ESF and FLOP constructs can be used to develop an optimal EOC staffing plan based on the specific scenario. Table 9, below, was developed using the capacity results of the DSM analysis and attempted to target a maximum 80% capacity through manning of the FLOP cells. To accomplish this, the values found in Table 7 were divided by 80% and then rounded up to ensure no personnel were tasked greater than 80% of their required capacity to ensure those in the EOC were not subjected to panic. Table 8 below indicates the minimum number of personnel required for each scenario type.

**Table 8 - Personnel Required to Keep Capacities Below 80%**

| | Natural Disaster | HAZMAT Response | Nuclear Weapons Accident | Disease Containment | Peacetime Disaster Sheltering | Off Base Aircraft Accident | Flood Response | RTF Reception |
|---|---|---|---|---|---|---|---|---|
| **FINANCE** | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| **LOGISTICS** | 3 | 1 | 1 | 2 | 2 | 1 | 1 | 2 |
| **OPERATIONS** | 2 | 3 | 3 | 2 | 2 | 2 | 1 | 1 |
| **PLANS** | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 |

In areas where specific expertise is required over typical response and recovery execution, exceptions were made to ensure the expertise was available in the EOC. To determine which organization the personnel should be from, data from Table 6 were used because it indicated which organizations and positions were specifically relied upon during the response. Table 9 compiles information from Tables 6, 7, and 8 to provide a recommendation for staffing based on the given scenario and can be used as a decision support tool to allow EOC Directors to activate only those needed for the given emergency.

**Table 9 - EOC Staffing Decision Support Tool for EOC Directors**

| F – Finance & Administration Cell<br>L – Logistics Cell<br>O – Operations Cell<br>P – Planning Cell | **Natural Disaster** | **Flood** | **Disease Containment** | **Peacetime Disaster Sheltering** | **HAZMAT Response** | **Nuclear Weapons Accident** | **Off-Base Aircraft Accident** | **RTF Reception** |
|---|---|---|---|---|---|---|---|---|
| **Chaplain** | P | P | | | P | P | P | |
| **Civil Engineer Squadron** | L | L | L | L | L | L | L | L |
| **Communications Squadron** | L | L | L | L | L | L | L | |
| **Comptroller Squadron** | F | F | | | F | F | F | F |
| **Contracting Squadron** | F | F | | | F | F | F | F |
| **Explosive Ordinance Disposal** | | | | | | O | O | |
| **Firefighting** | O | O | | | O | O | O | O |
| **Force Support Squadron** | L | L | L | L | L | L | | L |
| **Maintenance Group** | | | | | | | L | |
| **Medical Group** | O | O | O | O | O | O | O | |
| **Operational Weather Squadron** | P | P | | | | | | |
| **Readiness & Emergency Management** | O/P | O/P | O/P | O/P | O/P | O/P | O/P | |
| **Security Forces Squadron** | O | O | O | O | O | O | O | |

## Intangible Benefits

Beyond capacity, organizing the EOC based on the FLOP construct has many other non-quantifiable benefits as well. Because responders on the scene are organized via the ICS which utilizes the FLOP construct, organizational mirroring has the potential to open the lines of communication wider than just the Incident Commander and EOC Director to each of the four FLOP chiefs as well. By doing so, the workload (and therefore stress) of the incident commander can be significantly reduced, allowing him or her to focus on the response rather than communication with the EOC. However, this mirroring also opens the door for a potential drawback of micro-management from the EOC now that the two entities are similarly aligned. Additionally, by having an organizational structure that can be tailored to the given scenario, EOC directors can minimize the number of personnel that are activated during an emergency which lowers the number of those exposed to hazards during the unsafe period, and minimizes potential distractions from under-utilized personnel within the EOC. Furthermore, because the FLOP construct is expandable, additional units that have only specialized use in the EOC can be easily incorporated within the FLOP without the need for creating new positions. This adoptive organizational capability has the potential to drastically improve emergency response effectiveness, reducing organizational redundancy and ambiguities, and potentially lowering exposure risk by minimizing those who need to respond to the EOC.

**Future Research & Applications**

While this research is a starting point for developing optimal staffing during an emergency response in the Air Force, there are also many areas where this research can be furthered and expanded upon. First, this research operated under the assumption that the CEMP 10-2 was a comprehensive list of tasks. Greater fidelity in the results could be attained by instead observing actual emergency responses, to gather specific tasks actually being accomplished in the EOC. Furthermore, this would allow the capability to gather specific task durations for each event which would also increase result fidelity. Second, this research focused on eight scenario checklists within the Natural Disaster and Major Accident sections of the CEMP 10-2. Research should be conducted on the FLOP construct's applicability in the response of Terrorist Use of Chemical, Biological, Radiological, Nuclear and High-Yield Explosive (CBRNE), and Conventional Attack Actions.

An additional stream of research can be focused through the use of surveys. Both the ESF and the FLOP constructs can be analyzed, and an optimal EOC staffing structure could be developed through SNA survey results. Complementary SNA research has the potential to confirm or refute the results of this thesis, and/or develop an entirely new optimal organizational structure for consideration. Furthermore, it could be beneficial to conduct live exercises using both organizational constructs to achieve quantifiable evidence of the efficiencies of both organizational constructs.

To expand upon this specific research, individual values for BCV, MLV, and WCV could be researched along with more precise values of rework and rework impact. Research into secondary and tertiary responsibility criteria, and the approximation of how much work these responsibilities impose could also improve accuracy of the results. This has the potential to better predict the capacities, and develop a more precise decision support tool for EOC Directors.

Additionally, the DSM methodology has a number of applications outside the field of emergency management. It can be used, by itself or in concert with SNA on any task-based project or program with well defined tasks and personnel manning. To maintain an Air Force Civil Engineer perspective, for example, research could be conducted on the primary tasks and functions of the Civil Engineer Operations Flight, or the Civil Engineer Squadron as a whole. Furthermore, research could be narrowed to evaluate the efficiency of specific military construction (MILCON) projects, task by task to better understand the organizational and project management functions of military construction.

## Appendix A – Glossary of Terms

**AFIMS – Air Force Incident Management System -** A methodology designed to incorporate the requirements of HSPD-5, the NIMS, the NRP and OSD guidance while preserving the unique military requirements of the expeditionary Air Force. AFIMS provides the Air Force with an incident management system that is consistent with the single, comprehensive approach to domestic incident management. AFIMS provides the Air Force with the coordinating structures, processes, and protocols required to integrate its specific authorities into the collective framework of Federal departments and agencies for action to include mitigation, prevention, preparedness, response and recovery activities. (USAF, 2007)

**BCV – Best Case Value**

**C2 – Command & Control**

**Capacity –** "The capability to complete tasks… the volume of resources available for task realization" (Horman, 2001).

**CAT – Crisis Action Team** – The strategic level of the AFIMS emergency response organizational structure chaired by the wing commander and staffed by the wing staff and group commanders.

**CEMP 10-2 – Comprehensive Emergency Management Plan 10-2** – provides comprehensive guidance for emergency response to physical threats resulting from major accidents, natural disasters, conventional attacks, terrorist attack, and CBRN attacks (United States Air Force, 2009).

**DHS – Department of Homeland Security**

**DMM – Domain Mapping Matrix** – "A (typically) non-square matrix mapping othe domain of one DSM to the domain of another DSM." (Eppinger & Browning, 2012)

**DSM – Design Structure Matrix** – "A network modeling tool used to represent the elements comprising a system and their interactions, thereby highlighting the system's architecture" (Eppinger & Browning, 2012).

**EOC – Emergency Operations Center** - The C2 support element that directs, monitors, and supports the installation's actions before, during, and after an incident. (United States Air Force, 2009)

**ESF – Emergency Support Function** - The ESF structure is a standardized 15 organization structure grouping "federal resources and capabilities into functional areas that are most frequently needed in a national response" (FEMA, 2008) Currently used as the primary organizational structure of the EOC. A list of the 15 ESFs is found in Table 1 found on page 6.

**FEMA – Federal Emergency Management Agency** - The Federal agency tasked to establish Federal policies for and coordinate civil defense and civil emergency planning, management, mitigation, and assistance functions of Executive agencies. (United States Air Force, 2009)

**F - Finance & Adminstration Cell –** A cell within the FLOP organizational structure responsible for providing "accounting, procurement, time recording, and cost analyses" (FEMA, 2007)

**FLOP –** The organizational structure of the ICS. It is an acronym for the four major functions of Finance and Administration, Logistics, Operations, and Plans.

**IC – Incident Commander** – "The command function is directed by the IC, who is the person in charge at the incident and who must be fully qualified to manage the response. Major responsibilities for the IC include: performing command activities, such as establishing command; protecting life and property; controlling personnel and equipment resources; maintaining accountability for responder and public safety, as well as for task accomplishment; and establishing and maintaining an effective liaison with outside agencies and organizations, including the EOC when it is activated" (United States Air Force, 2009)

**ICS – Incident Command System** – "ICS is the model tool for command, control, and coordination of a response and provides a means to coordinate the efforts of individual agencies as they work toward the common goal of stabilizing the incident and protecting life, property, and the environment. ICS uses principles that have been proven to improve efficiency and effectiveness in a business setting and applies the principles to emergency response" (United States Air Force, 2009).

**L - Logistics Cell –** A cell within the FLOP organizational structure responsible for providing "support, resources, and all other services needed to meet the operational objectives" (FEMA, 2007).

**MDM – Multidomain Matrix** – "An extension of the DSM modeling in which two or more DSM models in different domains are represented simultaneously. Each single-domain DSM is on the diagonal of the MDM and the off-diagonal blocks are DMMs" (Eppinger & Browning, 2012)

**MLV – Most Likely Value**

**NIMS – National Incident Management System** - A system mandated by HSPD-5 that provides a consistent, nationwide approach for Federal, State, local, and tribal governments; the private sector; and nongovernmental organizations to work effectively and efficiently together to prepare for, respond to, and recover from domestic incidents, regardless of cause, size, or complexity. To provide for interoperability and compatibility among Federal, State, local, and tribal capabilities, the NIMS includes a core set of concepts, principles, and terminology. HSPD-5 identifies these as the ICS; multiagency coordination systems; training; identification, and management of resources (including systems for classifying types of resources); qualification and certification; and the collection, tracking, and reporting of incident information and incident resources. (United States Air Force, 2009)

**NRCC – National Response Coordination Center** – "A multiagency center that coordinates the overall Federal support for major disasters and emergencies, including catastrophic incidents in support of operations at the regional-level" (FEMA, 2008)

**NRF – National Response Framework** – "Presents the guiding principles that enable all response partners to prepare for and provide a unified national response to disasters and emergencies - from the smallest incident to the largest catastrophe" (FEMA, 2008).

**O - Operations Cell –** A cell within the FLOP organizational structure responsible for conducting "tactical operations and directs all tactical resources" (FEMA, 2007)

**P - Plans Cell –** A cell within the FLOP organizational structure responsible who "prepares and documents the Incident Action Plan, collects and evaluates information, maintains resource status and documentation" (FEMA, 2007).

**SNA – Social Network Analysis -** Social network analysis views social relationships in terms of network theory, consisting of *nodes* (representing individual actors within the network) and *ties* (which represent relationships between the individuals, such as friendship, kinship, organizational position, sexual relationships, etc.) (Knoke & Yang, 2008)

**UCC – Unit Control Center –** A secondary operational level response organization within AFIMS. Each unit is required to have a unit control center to assist the EOC and IC during emergencies.

**WCV – Worst Case Value**

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The terrorist attacks on September 11, 2001 demonstrated that the United States' emergency response capability, while robust, was disorganized in that organizations were not prepared or equipped to coordinate response actions across multiple agencies at a national level. This research investigates whether NIMS and the AFIMS structure is optimal for Air Force emergency managers, or whether, while maintaining NIMS compliance, there is a more effective way for the Air Force to organize its emergency management and response forces. Specifically this research focuses on the organization of the EOC and investigates whether shifting from the current structure of the ESFs to the FLOP structure found in the ICS may be a more efficient use of personnel based on the organizational requirements of the Air Force. This research will employ DSMs to independently evaluate the merits of both the ESF and FLOP construct for specific scenarios based on the tasks outlined in the Air Force's CEMP 10-2. For seven of the eight scenarios examined, ESFs are reaching less than 60% capacity, in fact, most only reach 30% capacity or below. On the other hand, FLOP capacity is significantly increased, however, in some of the more demanding scenarios, capacities exceed more than 100%.

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