Designing Adaptive Systems for Disaster Mitigation and Response: A comparative analysis of organizational adaptation

by

Namkyung Oh

B.A. Seoul National University, 1999

M.A. Seoul National University, 2001

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This dissertation was presented

by

Namkyung Oh

It was defended on

JANUARY 18, 2010

and approved by

Dr. Angela Williams Reynolds, Assistant Professor,
Graduate School of Public and International Affairs

Dr. Phyllis D. Coontz, Associate Professor,
Graduate School of Public and International Affairs

Dr. Ravindranath Madhavan, Associate Professor,
Joseph M. Katz Graduate School of Business

Dissertation Advisor: Dr. Louise K. Comfort, Professor,
Graduate School of Public and International Affairs

DESIGNING ADAPTIVE SYSTEMS
FOR DISASTER MITIGATION AND RESPONSE:
A COMPARATIVE ANALYSIS OF ORGANIZATIONAL ADAPTATION

Namkyung Oh, PhD

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Operating under rapidly changing conditions, organizations face various challenges that can damage core competencies and collaborative partnerships that have been developed for normal operations. To address these challenges, organizations need to learn from previous events, develop relevant strategies, and seek to evolve in resilient ways. The critical task in designing adaptive systems is to determine the bases for the effective organizational adaptation. This study seeks to explore evidence of organizational learning, identify the most critical factors that facilitate organizational adaptation, develop strategies for change, and assess the effects of these strategies on the performance and evolution of the system. To achieve these purposes, this study applies a mixed approach of qualitative and quantitative methods including content analysis of newspaper articles and situation reports, social network analysis, and agent-based computational simulation.

To explore processes of organizational learning, I conducted a comparative analysis of two hurricane response systems; Hurricane Katrina, 2005 and Hurricane Gustav, 2008. This analysis documented gaps in the performance of the two systems. The organizations in the Hurricane Katrina response systems suffered from a lack of personnel, plans, and equipment for the effective communication. Accordingly, they were unable to create a common knowledge base of operations and failed to allocate resources as requested. Evidence from organizational analysis documents that organizations in the Hurricane Gustav response system learned from the experiences of Hurricane Katrina and upgraded their performance in response operations in various ways. They invested significant resources and effort to improve organizational capacity in communication and

strengthened their collaboration links with expected and spontaneous partners from public, private, and non-profit sectors.

Based on findings from this analysis, I offer a set of policy implications for guiding effective organizational adaptation to changing conditions. First, organizations need to collaborate under strong leadership to develop trust that is critical to effective coordination and collaboration. To make effective use of established mutual trust, adaptive systems need to address the problem of turnover in major positions of organizations. Second, while organizations in the system work on the institutionalization of joint operations for the development of mutual trust among agencies, they also need to develop policies to retain experienced core personnel for effective collaboration with partners. Third, operations need to integrate advanced information technologies into their operations to support effective communication, knowledge management, and diffusion of organizational learning. Combined with the cultivation of experienced personnel, the integration of advanced information technology into disaster mitigation and response represents the construction of a socio-technical system. To build a socio-technical system for organizational adaptation, organizations need to focus on the technical design of advanced communication equipment and data management tools that facilitate the processing, transmitting, storing, and extracting of critical information both for enhanced performance and organizational learning. Further, they need to focus on the organizational training and education of strategic learning to develop more experienced and collaborative personnel.

Based on accumulated experience and memory of collaboration, enhanced capacities, and reinforced partnerships, organizations in an adaptive system can achieve a creative mental leap to a new practice of action. Findings from this study document that organizations can successfully address challenges from rapidly changing conditions and eventually, evolve in a resilient form of adaptation.

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PREFACE

1.0 THE ORGANIZATIONAL ADAPTATION TO CHANGING CONDITIONS

Organizational adaptation to rapidly changing conditions has long been a major topic in organizational studies. This study, in an effort to address the issue of organizational adaptation, deals with the situation in which organizations face harsh challenges from complex and uncertain conditions. Under rapidly changing conditions, organizations' core competencies for accurate decision makings can be lowered (Comfort, 1999) and links for collaboration and coordination become vulnerable to the outer impacts to the system (Isbell & Goldstein, 2006). When facing these limitations, organizations need to analyze their strengths and weaknesses, explore the critical factors that facilitate adaptation, and develop strategies to make use of learning from previous events, and finally, align them with changing factors in their operating environment (Bryson, 1988) to make them more adaptive to changing conditions.

For the achievement of an effective adaptation to changing conditions, I address the following critical question, how to make organizations develop and maintain an appropriate level of capacities and collaborative partnerships. To address this question, I focus on the learning aspects of organizations (Carley & Harrald, 1997) through which, organizations can engage in an iterative cycle of assessing core competencies, searching for the possible policy alternatives, applying them to the cases of changing conditions, and setting new standards for management. With the completion of this learning cycle, organizations can evolve over time in a more effective way in their adaptation to rapidly changing conditions.

1.1 CHALLENGES IN RAPIDLY CHANGING CONDITIONS AND ORGANIZATIONAL PERFORMANCE

In changing circumstances, organizations are forced to operate with previously inexperienced speed, cost, and intensity (Comfort, 1999); accordingly, they face various types of unexpected challenges that are difficult to address. Especially when organizations are forced to adapt to complex and uncertain conditions, they find that their established core competencies and collaborative partnerships designed for normal operations do not work properly, and their performance in response to crises can be seriously lowered. Then, what types of challenges do organizations face and need to address for the achievement of effective adaptation? This study sorted various challenges into the following four major categories.

The first challenge is the fragility of the pre-established linear model. In a traditional linear model, the relationship between cause and effect is smooth and proportionate (Rogers et al, 2001), especially when the linear model was designed for hierarchical structures. But organizations performing under complex and uncertain conditions face unexpected situations in which the pre-defined linear model affects the separate groups differently (Comfort, 1999; Ashmos et al, 2000; Urry, 2003) and if these differences are iterated over time, it is no longer certain that a given act can always produce a specific outcome. As a result, any pre-defined causation between solutions and outcomes is no longer able to work and there is a lack of proportionality between inputs and outputs. This situation can cause a severe problem of mismatches between established rules/procedures and demands for action. When organizations are forced to operate in this situation, they do not know what actions to take because any measure can ensure expected results and push them in chaotic conditions.

This challenge to the Newtonian paradigm of determinism can be supported by an example of the Mississippi river floods in the summer of 1993 (Kiel, 1995). For several decades prior to flooding in 1993, the Army Corps of Engineers (ACE) built a series of levees to protect many river front communities. These levees, however, led to unexpected changes in the course of the Mississippi in many areas and eventually exacerbated downstream flooding that inundated many riverfront communities (Burton and Gibson, 1993). The seemingly simple decisions or solutions to aid individual communities with levees led to a tangled web of cause and effect that, over time, had disastrous results many years later in other communities. This case shows how limited ability to predict all of the interactions and outcomes in a complex and nonlinear situation can cause a failure of pre-defined linear model.

The next challenge that organizations can face is the breakdown of collaboration links that are critical for integrated responses to changing conditions. Under complex and uncertain conditions, collaboration links in networked governance can become vulnerable to unexpected outer impacts and this might cause isolation of organizations from the other part of the system, leading to the break of the entire collaborative system (Siebert, 1995). More importantly, this problem of organizational isolation can block the proper channel of information. Without getting critical information in a timely manner, isolated core agencies cannot conduct an accurate assessment for the actual situation and accordingly, they can fail in employing proper operation strategies in their adaptations to changing conditions.

The case of 9/11 terrorist attack exemplifies how the isolation of core organizations from the main body of collaboration can cause the further damage to the entire system. According to 9/11 Commission staff statement No.17 (2004), there were critical communications failures at the federal level during and after the 9/11 attacks, and one of the most serious problems occurred

in an "Air Threat Conference Call" initiated by the National Military Command Center (NMCC) after two planes had crashed into the World Trade Center. But, according to this report, because the participants were unable to include the Federal Aviation Administration's (FAA) air traffic control command center, which had the most critical information about the hijackings, they failed in getting accurate information for action. Even though the highest level Defense Department officials relied on the NMCC's Air Threat Conference, the FAA did not join the call for the first 15 minutes because FAA's representatives had no access to decision makers, and had none of the information available to senior FAA officials by that time. The result was, shortly after the conference call, Pentagon was hit by the third airplane. As this case implies, the isolation of core organizations can cause severe breakdown of information sharing channels, and this can lead the failure of entire system in its adaptation to changing conditions.

When a pre-defined linear model does not work and the established collaboration links are disconnected, organizations try to create dense coordination and collaboration partnerships, but another challenge is that this increased demand for collaboration does not always guarantee effective joint operations. The increased demands can impose extraordinary burdens to core organizations (Comfort et al, 2007) and make their cognitive capacity and resources depleted in a short time. To address the problem of the lack of organizational capacity and resources, organizations may seek to secure additional resources from outer sources, but, under complex and uncertain conditions, they may fail in tapping resources from other sources. Moreover, this situation can be worsened in a bureaucratic culture because managers, operating under a rigid command and control structure, narrow work descriptions, and inward looking perspectives, tend not to foster collaborative culture necessary for addressing problems and transcending organizational boundaries (Goldsmith & Eggers, 2004).

The Northeast Blackout of 2003 shows clearly how overloaded demands in a part can cause the entire collapse of the system (NYISO, 2004). Theoretically, the increased demand load on any power grid must be matched by the boosted supply and its ability to transmit that power, but when there was an overload of a power line, it caused hard-to-repair and costly damage to the entire power grid. The major problem was when power lines carried more power than designed, they got hotter and caused cascading failures that resulted ultimately in a forced shutdown of more than 100 power plants in the entire network. As this case implies, keeping an appropriate level of workload for organizations is also critical for the achievement of effective organizational adaptation to changing conditions.

Increased demands for collaboration can cause another challenge to organizations due to the situation in which organizations are forced to have unplanned interactions with emerging organizations that differ in mission, size, and rule (Comfort, 2006). The challenge to organizations is that increased demands for collaboration with heterogeneous organizations can make the level of complexity become higher and the responsibility for operations unclear. To address this challenge, they need to develop new ways of coordination and collaboration to integrate efforts from all participating organizations and make them contribute to the achievement of shared goal of the system. But, due to the lack of experience and the absence of protocols, it is hard for organizations to develop those strategies for effective collaboration and coordination in a short time.

Some examples of system failure due to the difficulties in coordinating distributed efforts can be found in water conflicts cases. Historically, there have been various litigations between local and state governments for securing right to use water from the Colorado River system (In 1952, the State of Arizona and the State of California had a dispute over the extent of each

State's right to use water from Colorado River system). Similarly, the disputes among 27 cities in the Metropolitan Water District (MWD) show how individual and heterogeneous agencies in the system can easily vie rather collaborate for the same resources when it is not properly coordinated (Los Angeles Times, 2008).

1.2 DESIGNING AN ADAPTIVE SYSTEM TO RESPOND TO RAPIDLY CHANGING ENVIRONMENT

To address previous challenges, organizations in the system need to develop appropriate management tools and strategies for building a resilient and reliable collaborative system. This concept of developing management tools for effective adaptation is closely related to Simon's term of "artifact" in his book of "The Sciences of the Artificial (1996)." According to Simon, organizations can design some modes of adaptation to create conditions in which they function better in a challenging environment. Even though organizations have limits in their capacity for adaptation, they can appropriately align their inner environment with their outer environment. And as a result of these efforts, organizations design an 'artifact' which is composed of new programs for operation, structural reengineering, and reinforced resources and capacities that contribute to the effective alignment of the inner with the outer environments.

In exploring an adaptive system, this study adopts the concept of "design" and "artifact" from Simon's argument. With these concepts, this study sees that organizational environments are subjects for design, and in this sense, "design" can be defined and composed of various tasks that include developing programs/procedures, improving capacities, and renovating collaboration structures. So, in this study, the meaning of design is not limited to the structural changes itself.

Rather, it pursues the balance between structural flexibility and operational stability in designing a new system for adaptation, and it focuses on the improvement of the organizational core competencies in creating, processing, and transmitting critical information in the system.

This study assumes that organizational adaptation is closely depends on determining the appropriate balance between structural stability and operational flexibility. To provide public services reliably under rapidly changing conditions, the administrative structure among the parts of the system need to be stable. At the same time, it should be sufficiently flexible to make the system resilient to outer impacts and let organizations function properly in response to environmental changes (Kauffman, 1993). But sometimes there is a tension between them in extreme situations. Too much focus on structural stability does not allow chances for flexibility and too much emphasis on flexibility cannot provide stability that is necessary for consistent operation.

Then, why is the balance between stability and flexibility important for organizational adaptation? To answer this question, this study considers the concept of resilience (Peltokorpi, 2008). Resilience is about how the collective action of multiple organizations can be properly coordinated to let the entire system go back to normal operation (ISDR, 2007) after perturbations from rapidly changing conditions. According to discussions on resilience, an adaptive system needs to have structural stability that is resistant to major impacts from the outer environment and, at the same time, operational flexibility so that they can create an innovative method of collaboration when any regular interactional structure is severely damaged or weakened.

In addition to the balance between structural stability and operational flexibility, this study considers improvements in organizational capacities such as personnel, equipment and resources in designing an adaptive system to the changing environment. Especially, this study

deals with organizational capacities for effective communications because the problem of communication meltdown can cause severe delay in recognizing risk and, accordingly organizational reaction to crises. The problem of communication breakdown can further deteriorate when there is no pre-defined protocol for collaboration among those heterogeneous organizations. So, another meaning of design is the improvement of organizational capacities in addressing the challenges from communication system breakdown and the improvement of organizational capacities in collecting, processing, and transmitting accurate information to other organizations in a timely manner.

1.3 RESEARCH PURPOSES OF THIS STUDY

To address the question of organizational adaptation to rapidly changing conditions, this study conducts multi-faceted analyses to provide a knowledge base for the development of possible sets of policy alternatives to make organizations more adaptive to changing conditions. The purposes of multi-faceted analyses include a meticulous examination of current system's capacities and the complex features of surrounding environments, an identification of structural weaknesses and strengths of the system, an exploration of critical factors that facilitate effective organizational adaptation, and an assessment of effects of those factors when applied to the actual operations under complexity and uncertainty.

To achieve those purposes, this study conducts comparative examinations of two systems that are structured through one-time or constant interactions among same set of organizations. The main advantage of this network comparison is that it can reveal whether there is evidence of organizational learning between two systems. If there is little evidence of organizational learning

between two systems, it is hard to expect an effective organizational adaptation and evolution either. Further, this study seeks to identify how accumulated and combined organizational learning can work as a major driving force for system-wide adaptation to changing conditions.

The evidence of organizational learning provides the critical intervention point in collaboration structures and organizational capacities in adaptation because it reveals what factors are most critical in facilitating organizational collaboration and adaptation to changing conditions. Using those identified factors, this study checks how critical factors can be arranged together in developing strategies for intervention, and finally, in designing adaptive system, this study assesses the changes in the performance of entire adaptive system when any individual or combined strategic management tools are applied to the existing system. For the assessment of organizational performance with targeted strategies, this study develops a performance measurement metric that is composed of previously identified critical factors. The findings from this performance measurement and its evolution pattern can be used as the knowledge bases for the effective organizational adaptations.

1.4 SIGNIFICANCE OF THIS STUDY

An issue of organizational adaptation to changing environment is critical issue for any system to survive in complex and uncertain conditions. If organizations have unsuitable resources, competencies, and collaboration partnership, they cannot respond properly to challenges from rapidly changing conditions and eventually these challenges can cause collapses of systems and lower the probability of organizational adaptation to changing conditions.

The problem is that imperative demands for creative adaptation under rapidly changing conditions can happen any time and any place. Specifically, considering recently increasing level of interdependency among organizations in various systems, the significance of study for organizational adaptation under crisis augments. For example, the sudden collapse of international financial system in 2008 showed how intricately interwoven network could be vulnerable to partial failures of the system and how the adverse impact could be enlarged and expanded to other core parts of the system.

To provide an applicable knowledge base for organizations seeking to creatively adapt to changing conditions, this study tries to combine the factors of organizational capacity interaction structures for securing effective collaborations. Also, this study tries to integrate and create a link between an identification of core factors for organizational adaptation, a development of possible policy alternatives, and an assessment of its effect on actual organizational performance which currently has not been fully established. Accordingly, this study expects that the findings from analyses can be applied to other policy areas and help managers of core organizations in those systems to design and develop more relevant policy alternatives for building adaptive systems.

2.0 THEORETICAL BACKGROUND AND CONCEPTUAL FRAMEWORK FOR GUIDING RESILIENT AND STABLE SYSTEM EVOLUTION

As organizational environments become more complex and uncertain, demands for effective organizational adaptation increase (Terreberry, 1968). In efforts to meet these increased demands, organizations develop strategies in various ways to improve stability and flexibility in their responses to crises. First, they change the collaboration structure to secure information sharing for effective decision making (Lawler et al, 1995), and they may invest resources to improve communication systems to create, process, and transfer critical information to partnering organizations (Argot et al, 2003). Also, organizations commit significant resources to human capital to improve capacities for creating and managing collective knowledge stock (Davenport, 1999) required for the creative adaptation to changing conditions.

To respond to increased demands for adaptation, organizations need to improve their adaptive capabilities for operating at multiple levels of organizational system (Kozlowski et al, 2006, Comfort, 2007), and as Cyert and March (1963) argue, they need to acquire capacities and develop strategies for maintaining the balance between stability and flexibility. To achieve effective organizational adaptation, many perspectives proposed factors to be considered in building capacities for adaptation. Among them, Huber and March (1991) argue the importance of information processing and communication for effective organizational decision making (Simon, 1997). Also Fiol and Lyles (1985) view organizational adaptation as mainly depending

on memory that is developed and shared by past and present members of organization. Finally, some researchers such as Argyris (1999) and Mintzberg (1982) see organizational adaptation as a process of organizational change and evolution based on accumulated practices of adaptation (Brown et al, 1991).

But the major problem of this diversity in determining critical factors for the achievement of effective organizational adaptation is that it can lead to so many differing interpretations (Ulrich et al, 1993) rather than synthesized conceptualization. Without integrated framework and the assessment of effects of individual or combined factors, it is hard to provide a set of policy alternatives that makes managers invest their limited resources in effective ways. In this sense, addressing extensive and multidisciplinary nature of literatures regarding organizational adaptation, this chapter develops an integrative framework that provides a theoretical foundation for this study. With this integrated framework, this study determines the primary factors that drive an effective organizational adaptation to changing conditions. Before forming an integrated framework, this chapter starts by highlighting Simon's arguments on *science of design* (1997) in which Simon mentioned that the science of design involves creating artificial systems to function in specific outer environments.

2.1 THE MEANING OF SCIENCE OF DESIGN AND ORGANIZATIOAL ADAPTATION TO COMPLEXITY

2.1.1 Simon's concept of designing artificial system for organizational adaptation

Defining the meaning of *designing* an adaptive system, this study adopts Simon's (1996) arguments on the science of design. Simon argues that the fulfillment of organizational adaptation involves a relation among three terms: the purpose or goal of the system or artifact, the character of the artifact, and the environment in which the artifact performs. To Simon (1997), the external environment is a context in which humans function and have interaction, and an artifact is an interface for interactions between an inner environment (the substance and organization of the artifact itself) and an outer environment (the environment where the artifact performs). Simon's idea of aligning three terms: goal, artifact, and environment provide the basic meaning of design for this study. Especially, for the successful adaptation to changing conditions, Simon suggests that individuals (or individual organizations) should make a correct administrative decision (Simon, 1997) in selecting appropriate means to reach designated ends, thus, a creative adaptation to changing conditions. But, at the same time, according to Simon, decision making and human problem solving rejects the full rationality necessary for maximizing or selecting the best alternative from all available to individuals or organizations. Rather, an administrative decision making to address problems from complexity can be done with bounded rationality of the behavior of human beings who satisfice rather than maximize. This means that decision makers in organizations might face a situation in which they are forced to choose one alternative without examining all possible alternatives and without ascertaining that these are, in fact, all the alternatives.

For effective decision making, the problem originated from bounded rationality that could be worsened in complex conditions, especially when organizations fail at an alarming rate (Starbuck & Nystrom, 1981). To address the problem of bounded rationality in adapting to changing conditions, Simon counted effective communication systems as a key factor. According to Simon (1999), effective administrative decision making with proper information-processing systems will permit organizations to absorb and extract the needed information selectively. So, for this, he suggested the use of advanced computing systems that help individual organizations to learn instantly and to transmit, store, and process knowledge and information. Thus, Simon argued that organizations can increase the capacity of problem solving through information technology and the preparation of knowledge bases for common operation (Comfort, 2006).

In addition to the emphasis on communication and information processes for precise decision making, Simon suggests the restructuring of organizational interaction structure and the underlying cognitive processes at a corresponding pace for facilitating organizational learning and innovation for adaptation. About this, Simon (2002) suggested an incorporation of "near decomposability" in designing an interaction structure. The key concept of nearly decomposable systems is in the coordination and communication efforts that align individual organizations' activities to the shared goal of entire system. Organizations operating in this kind of system balance the gains from coordination against its costs while retaining hierarchy. With this balance, they determine the level of interdependency that will benefit from coordination, and then minimize the amount of coordination in a way requiring much less interaction between subunits. Simon's concept of near decomposability has been tacitly adopted as a central concept in the present national disaster response plans, the National Response Framework.

2.1.2 Reduction in the level of entropy

As Simon suggested, by reinforcing organizational capacity for decision making and renovating collaboration structure, organizations may address problems from environmental complexity and uncertainty. Regarding this issue, systems theory (General Systems Theory, GST; Bertalanffy, 1968) focuses on the achievement of negative entropy in the system through openness and feedback (Senge, 1990; Zheng, 2003). According to these authors, organizations in the system should continuously deal with entropy both from circumstances and from the inner interactions because, if not controlled, entropy in the system will decrease the system's overall energy and prevent creative adaptation to changing conditions. As a method for decreasing the level of entropy in the system, Simon (1996) once more suggests the use of effective communication systems. According to him, if information cannot be processed or transmitted properly, mere increase in frequencies of communication could result in increased entropy in the system (Shannon, 1948). Usually, outside influences of crisis may diminish the integrity of the communication and, possibly, distort the message for the receiver in the system. In this sense, entropy in information sharing may occur in instances in which incomplete or blurred messages are transmitted to other agencies and the quality of information deteriorates easily through several steps of information transmission (Mitchell, 2003). Further, when information is transmitted, some organizations may not know the value of that information (Shannon, 1948).

Therefore, the level of entropy in a complex adaptive system needs to be reduced through more advanced coordination mechanisms with a reliable communication system to reduce noise in information transmission and to help organizations avoid the dispersal of efforts (Prokopenko & Wang, 2003). Facilitated by advanced technologies of communication, the reduction of entropy will allow organizations to coordinate their responses. This organizational effort to

balance between entropy and negentropy has a direct relationship with a system's evolution over time because, for that balance, organizations continually interact with complex conditions. These interactions affect the possible evolution of the system either toward a higher resilience or the system's collapse (Ludovico, 1988). In this sense, the level of entropy in the system is the force that affects effective organizational behavior and leads to a steady and predictable state of system evolution with resilience and stability.

2.1.3 Auto adaptive systems and complex adaptive systems (CAS) perspective

To analyze organizational efforts to address problems of complexity, complex adaptive systems theory (CAS) sees networked governance as an independent unit of analysis. Networked governance addresses how to mobilize the entire system's overall capacities, and how to reengineer its structure to make it effectively adapt to a changing environment. Axelrod and Cohen's concept of *harnessing complexity* (1990) suggests that organizations need to deal with complexity through designing effective interactions between organizations or mechanisms for interoperability. According to Axelrod and Cohen, organizational interactions and efforts impact not only the outcome of activities, but also influence the probabilities of later events. So they suggest that, rather than eliminating complexity, organizations should harness this complexity by taking advantage of variation that can foster successful changes.

Axelrod and Cohen's argument relates to the main assumption of this study; organizations in an adaptive system can manipulate conditions for successful adaptation and they can support those conditions that are most viable to the successful adaptation of the system. Further, discussions regarding complex adaptive systems suggest that managers of organizations need to design strategies for actions that make adaptive mechanisms more efficient and effective

under complexity. Regarding the possibility of building adaptive systems with strategic designs, Comfort (1999) identifies four distinct steps of adaptation to complexity: non-adaptive, emergent adaptive, operative adaptive and auto-adaptive systems. These four steps show a process of transition to self-organization in which organizations have high flexibility, adaptive technical structure, and high cultural openness. According to Comfort, due to its self-organizing elements, an auto-adaptive system is the most effective in managing complexity. In the following sections, this study discusses strategic designs of organizations' capacities and interaction structures for achieving an auto-adaptive system.

2.2 DESIGNING EFFECTIVE INTERACTION STRUCTURE

Under complex conditions, the traditional organizational boundary between public and other sectors has become blurred (Stoker, 1998). Especially, during the actual response to crisis, public organizations face exceptionally higher needs for inter-jurisdictional and inter-sectoral coordination and collaboration. In addition, factors such as circumstantial ambiguity and complexity require the transformation of interorganizational relationships into broader, but loosely coupled forms (Orton &Weick, 1990). Thus, a new structural design for building a complex adaptive system needs to be based on network perspectives rather than the traditional command and control approach that is limited to intergovernmental relationships. The reason for considering interconnectedness in designing effective interaction structure is that, as Watts (2003) argues, the embeddedness of organizations in networked system (Granovetter, 1985) influences the pattern of sharing information and resources.

According to Watts, policy makers can use networks as an 'instrument of a social action' to influence group behavior in addressing challenges from complexity. Within networks, organizations form structures as lasting patterns of interactions, and these patterns determine, limit, or improve interactions among participants. Also, as Nohria and Eccles (1992) argue, defining structural characteristics makes possible an analysis of how the structural characteristics affect organizational performance. Combining the concepts from Watts and Nohria & Eccles, the basic idea of designing structure in this study is that it explores the structural effects on organizational performances in adaptations to changing conditions. In this context, this study aims to unravel the "web of organizations" or other complex sets of relationships, and tries to design relational structures to improve the performance of the system in information and resource sharing. With an application of social network analysis, this study offers a mean of measuring social relationships more rigorously, and develops a systematic characterization of complex structures (Wasserman and Faust 1994).

2.2.1 Self-organization and organizational adaptation

Organizations in a complex adaptive system have dynamic interactions with other organizations and the environment to increase its possibility for survival. But when any standard operational procedures and collaboration protocols do not function as planned, the theory of self-organization suggests that agencies need to adapt to this unexpected crisis through creating unplanned interactions. Thus, the creation of new operational procedures and new collaborative partnerships allows the system to adapt to changing environments more effectively. According to Kauffman (1995), self-organization is a process in which various components in a system interact independently but still exhibit a spontaneous emergence of order and system structure

that is not pressured or guided by exogenous forces outside of the system. This system with self-organization is characterized by positive/negative feedback, balance of exploitation and exploration (March, 1991), and creative adaptive interactions among organizations.

In the processes of self-organization, systems can be stable and respond effectively to demands to adapt to changing conditions. But the policy problem to be addressed is how to complement the official structure with self-organized sets of relationships. About the alignment two different interactions, Laughlin (2005) suggested a differentiation between weak emergence and strong emergence in self-organization. According to him, weak emergence means new properties arise in systems as a result of interactions at an elemental level. If, on the other hand, systems have qualities not directly traceable to its components after the iteration of such relationships, these new qualities are irreducible to the system's constituent parts and constitute strong emergence (Corning, 2002)[1]. Like this, emergent structures are patterns not created by a single event or rule, rather, the interaction of each component with its immediate surroundings causes a complex chain of processes leading to some order.

The implication of Laughlin's argument for the design of effective collaboration structure is the potential benefit of exploring the evidence of weak emergence of self-organizing patterns and formalizing them in the design of new interaction structures. The value of self-organization in this study is that it gives rise to a decentralized, distributed, but still self-healing system which functions more effectively than hierarchy under changing conditions. In self organization, the network as a whole exhibits a distinctive synergistic behavior through the combination of behaviors of individual actors in the network. The process is guided by a common goal shared by all participants in the network. Also, self-organization is vital to this study because it deals with

1 Corning (2002) insisted that this structure may be co-determined by the context and the interactions with its environments.

the structural flexibility among organizations. The flexibility in interaction can bring a resilient characteristic to adaptive systems, but at the same time, as Simon suggested in his concept of nearly decomposable systems (2002), these individual efforts for self organization need to be coordinated by some set of pre-defined interaction protocols or structures. In this sense, managing the balance between flexibility and stability becomes important in designing a new collaboration structure. The formalization of weak emergence of self-organizing interactions with the structure of hierarchical coordination, or the balance between man-made and grown-order will be the major direction in designing new collaboration structures.

Regarding the relationship between self-organization and regular coordination protocols, Hayek (1973) argues that a difference between 'made-order' and 'grown-order' needs to be balanced. The made-order is a pre-defined relationship governing interaction and grown-order is related to the emergence of new interaction structure that is discussed in the self-organization. Hayek (1973) states that this made-order is the most important social structure, including the laws (nomos) governing the relations among individual entities. Accepting Popper's idea (1945), he criticizes the practice of admitting the current state as made-order while emphasizing the importance of grown order in the system. The balance between made-order and grown-order is important in designing an effective interaction structure because, when any pre-defined or planned interaction structure cannot function in conditions of complexity and uncertainty, a possible grown-order will be necessary to replace or complement the made but inflexible order and to facilitate system's adaptation. In this sense, the importance of self-organization comes from unplanned interaction among organizations.

Once established, a contractual relationship is quite rigid and inflexible and a breach of contract implies severe penalties in most cases, but the benefit of a contract-based model (made-

order) is that it facilitates organizational planning and the development of robust organizational structure that does not easily collapse under external impact. Also a participatory-model (grown-order, self-organization) lessens the rigidity and inflexibility of the system by building resilience into the system. The importance of self-organization and its alignment with planned structure becomes more important under crisis. To respond to uncertain conditions, organizations in adaptive systems need to create collaborative relationships with unplanned or unexpected organizations that differ in mission, size, capacity, and historical path of evolution. If activities of these heterogeneous organizations can be coordinated effectively, their dynamic interactions will produce more appropriate structures for collaboration as the system evolves over time. Thus, the issue of adaptation, self-organization, and system evolution are important points to consider in building an effective collaboration structure.

2.2.2 Hybrid use of network and hierarchy

The relationship between grown-order and made-order is not always clear and thus, the question arises how to make these structures complementary to one another. Many times, there is a tension between the two types of organizational structure (Davies, 2005) because, if self-organization leads to an unauthorized effort for adaptation, it could be instantly punished by a strict rule of bureaucracy. In addition to bureaucratic inertia or rigidity, a collective action problem (Ostrom, 1990; Olson, 1971) can also lead to competition among organizations rather than collaboration. This rigidity of bureaucracy and collective action problem requires a well-designed coordination system for improved performance and adaptation. Facing rapid change, traditional solutions through bureaucracy rarely function well because bureaucratic procedures that operate under command and control, narrow work restrictions, and inward looking cultures

are not effective in addressing problems that transcend organizational boundaries (Goldsmith & Eggers, 2004). To make both approaches complementary to each other, Moore (1997), and Goldsmith & Eggers (2004) suggest the web of multi-jurisdictional and multi-sectoral interactions that can manage complex, interdependent relationships. They argue that this web of various interactions can encourage collaboration.

Traditionally, organizations built massive, hierarchical structures to gather, process, certify, and store all information necessary for effective response to their environments. But as Coase (1960) observed, if there is more partnership and more collaboration among organizations, the process of information management increasingly becomes more cost efficient. Also, with the advance of information technology, the cost of information processing has meaningfully decreased. With advanced information technology and close collaborative partnerships, organizations can easily share data and integrate their business processes with external partners in real time. In this sense, organizations with advanced information technology strongly favor networked organizational forms over the traditional hierarchies. Table 2-1 compares the key organizational features of market, hierarchy, and network and how the network, as a hybrid form of market and hierarchy, can lead to the balance between stability and flexibility.

Table 2-1 Comparison of Two Perspectives, Hierarchy and Market vs. Network

Key Features	Market	Network	Hierarchy
Means of Communication	Prices	Relational	Routines
Methods of Conflict Resolution	Haggling -Resort to courts for enforcement	Norm of Reciprocity – Reputational Concerns	Administrative fiat – Supervision
Degree of Flexibility	High	Medium	Low
Amount of Commitment among the parties	Low	Medium to High	Medium to High
Tone or Climate	Precision and/or Suspicion	Open-Ended, Mutual Benefits	Dependent
Actors Preferences of Choices	Independent	Interdependent	Dependent

Source: Revised Powell (1990)'s comparison of market, hierarchy, and network.

The key issue in designing an effective adaptive system is how to combine the good features of each type of structure, hierarchical and non hierarchical, rather than choosing one of them exclusively. As Watts (1997) argued, 'formal interaction' provides stability to the system

and ‘informal interaction’ complements it with high flexibility[2]. In this sense, this study’s inquiry into designing effective structures for organizational interaction needs to be reoriented to making the two sub-structures in one network cooperate together. About this, Sydow & Windeler (1993) argued that, compared to markets, a network is more structured, but produces more interaction among the component organizations. In doing so, it provides 'thicker' information channels, demands more loyalty and trust, and prefers voice to exit. Also, Webster (1992) argued that a network is a loose and flexible coalition that can be guided from a ‘hub’. The key functions of hub organizations include i) development and management of the alliances among components, ii) coordination of resource allocation and technology use, iii) management of core competencies and strategy, and iv) management of information resources that bind the network. This study reviews the strengths and weaknesses of current structures and suggests the combination of two different structure types into a ‘network structure’ as the most appropriate organizational form for organizational adaptation[3] because as Sydow (1992) and Siebert (1995) suggest, there is a ‘white’ area in which the market needs ‘internalization’ and hierarchy needs an ‘externalization’. Therefore, in an effort to design an effective collaboration structure, this study seeks a hybrid arrangement to use the best of both worlds[4] and to create collaborative value.

2 In the study of Virtual Software Company (Weber et al, 2004), they found that the centralized and hierarchical structure is good in rapid development but not adequate for cooperation with new participants into system. So the advantage of decentralized and egalitarian structure of system is that it’s comparatively easy to assimilate new entrants to the system

3 Because this study assumes the ‘network’ form as an appropriate structural type, the disaster management ‘system’ and the disaster management ‘network’ represent the similar management structure after this part.

4 About this, he suggested the mixture of good features for both structure. Functional specialization and Market pressure from Market and Trust and Information integration from Hierarchy.

2.3 SOCIO-TECHNICAL SYSTEM AND THE ROLE OF COMMUNICATION

2.3.1 Role of communication for creative adaptation

When focusing on partnered and networked structures, this study also discusses organizational capacities that support collaborative partnerships. For creative adaptation to changing conditions, organizations need the ability to communicate and share information. Under crisis, demands for accurate administrative decision making increases. To improve decision making, Simon (2002) and Axelrod and Cohen (1999) suggest the role of communication to harness complexity in designing a system for successful adaptation. Also, Kauffman (1993) emphasizes the role of information sharing and communication in designing a complex adaptive system. With his concept of the "edge of chaos", Kauffman argues that we can design a structure that supports information exchange among organizations, and also, can allow enough flexibility to adapt to the dynamics of the environment. This shows that, under the constraint of complex environments, organizations can adapt to changing conditions.

The role of communication is more critical to make the system resilient to outer impacts. After the shock or perturbation, the state of the system needs to come back quickly to continue operations. If the system stays under malfunction for a long time, given the importance of initial conditions from chaos theory (Prigogine, 1984), the destructive effect of crisis will drive the overall system to collapse. To improve the resilience of the system, Oliver et al (1997) argue that the major goal of designing adaptive systems is to organize technical support for the lifecycle of the system. This technical support includes more efficient processing of critical information, defining effectiveness with the development of proper measurement tools, creating behavioral or structural models, and building/testing action plans. Regarding the role of information processing

for systems engineering, or from Simon's term, building artifacts for the creative adaptation, Luhmann (1995) suggests the concept of 'evolution of communication' and considers social systems as the product of communication. With communication systems, he argues that the level of complexity could be reduced in the internal system (he called it the 'reduction of complexity'). Also, he asserts that communication can create meaningful information for all entities in the system. Considering the challenges from complex conditions, the formation of a common knowledge base typically can be reinforced by 'Positive feedback,'[5] and this feedback can be facilitated through the use of advanced communication technology. In this sense, Luhmann's concept of *self referentiality* can be applied to this study as a sociological application of self-organization theory. For Luhmann, human beings are sensors in the environment of the system and the interaction among them represents 'self-producing communications' which produces further communications, hence a social system can reproduce itself as long as there is dynamic communication among organizations.

Luhmann's idea of utilizing communication to combine all the technical contributors to unified efforts and to create a structured process for reducing complexity has been developed and expanded to the development of tools and methods to better comprehend and manage complexity in systems. However, Luhmann's discussion on how to create information for system evolution covers only some of the many factors required for successful system evolution. Luhmann's model of the evolution of communication discusses narrowly communication technology factors. In this context, the socio-technical systems approach covers this problem and includes more factors by suggesting that organizations should balance among five critical factors - personnel,

5 A system in which there is positive feedback to any change in its current state is said to be in an unstable equilibrium, building an adaptive system is the continuous processes of pursuing equilibrium in its response but this state is also hard to achieve because of complexity and uncertainty

structure, technology, task, and environment - to achieve a successful evolution of the system (Coakes et al, 2002). Like this, socio-technical systems perspective discusses the interrelatedness of social and technical aspects of an organization with a shared emphasis on achievement of both excellence in technical performance and quality in organizational operation. Accordingly, it argues that the interaction between technical factors and organizational factors produces the conditions for desirable system evolution. So, the application of this socio-technical system theory in defining critical factors for a system's adaptation has significant implications for designing an adaptive system.

2.3.2 Socio-technical systems and organizational learning

The previous discussion on the role of communication reveals how the application of advanced communication technology can contribute to the construction of knowledge bases that are necessary for effective organizational adaptation. The discussions regarding the construction of a socio-technical system requires a strengthened communication system with the application of the most advanced technology, and with this advanced system, organizations can generate, transform, and deliver critical information to other organizations. Like this, using an advanced communication system, organizations dynamically exchange and combine various information from individual organizations and create meaningful information for the effective collaboration and coordination in their adaptation to changing conditions.

The value of information created through this dynamic interaction is that it can generate a knowledge base for effective organizational adaptation. The most well-known tool for the dynamic interaction in the design of a knowledge base is the use of forward and backward feedback across the boundaries of the system. According to Argyris and Schon (1978), *double*

loop learning is a possible mechanism for the creation of valuable information. In double-loop learning, the adaptive system may question the values, assumptions and policies that led to the actions in the first place. If they are able to view and modify them based on previous experiences, then a new convention for problem solving emerges. Through this organizational learning, the disaster management system accumulates 'explicit knowledge' rather than 'tacit knowledge' (Polanyi, 1983)[6] and this new knowledge contributes to the process of sensemaking (Weick, 1995). The learning processes that enable creative adaptation have been discussed as strategic learning processes (Kuwada, 1998). According to strategic learning processes, system wide knowledge is accumulated from organizational learning and can be used to support the system's adaptation.

2.4 GUIDING SYSTEM EVOLUTION: CYBERNETICS AND STRATEGIC INTERVENTION

The concept of feedback derives from the theory of cybernetics. According to this approach, in a double loop learning system, actions taken by the system cause change in the environment and that change is manifest to the system through feedback, and again causes the system to adapt to the new conditions (Ashby, 1956). This "circular causal" relationship is necessary and sufficient for the construction of an adaptive system because the essential goal of cybernetics is to understand and define the functions and processes of systems that have goals. Organizations operating in such a circular causal system follow the causal chains that move from action,

6 Tacit knowledge is personal, context specific, subjective knowledge, whereas explicit knowledge is codified, systematic, formal, and a knowledge easy to communicate (Polanyi, 1983)

sensing, to comparison with the desired goal, and again to action. In this comparison, cybernetics argues that, organizations can have a means for examining the design of a current disaster management system. In this section, this study examines how the circular causal processes can contribute the development of adaptive strategies for organizations in the system.

2.4.1 Cybernetics and the meaning of strategic intervention

The concept of cybernetics developed from the study of organizational systems. It deals with the issue of control, decision making, and modeling to increase the possibility of system's adaptation to changing environments. Control is still significantly important in managing organizations because it officially forms the organization's strategy, structure, and motivation of personnel. In addition to the issue of power and influence in organizational management, organizational cybernetics emphasizes the strengthening of decision making capacity with the use of technology in information processes. Simon's (1996) emphasis on strategic intervention for more effective decision making tools requires modeling in computational simulation to explore strategies of organizational learning in practice for possible adaptation. The starting point of modeling is to describe the basic operational activities of the system. If operations do not succeed in bringing expected performance, then management cybernetics attempts to provide managers with a number of tools that enable them to intervene to regular operations procedures. In this sense, the concept of cybernetics can be combined with the idea of strategic control to guide an adaptive system to function properly in the short term and finally evolve to effective performance over the long term (Viable system model; Beer, 2000).

The next question in designing strategic control for better performance is how to control or intervene in the current operations of the system. Socio-cybernetics discusses several ways of

intervention with social forces that influence system performance. The theory of socio-cybernetics seeks to devise better ways of intervening in the operation of current systems. Snook (2000) defines five types of interrelations among organizations[7] in the system, and impact on the system evolution. In the dynamic adaptation, Snook's five interrelations exist as actual patterns of interaction in a complex adaptive system. There can be a problem of aggression and competition in sharing resources when many organizations were operating under severe scarcity. The policy challenge in designing a more effective disaster management system is how to coordinate the strategy of individual organizations with that of other organizations participating in the system toward convergence into the system's shared goal (Decision and Empathy level).

To achieve coordination, Bookchin (1996) suggested that individual organizations in the system not be organized by some center in hierarchy, but by a network of feedback (cybernetic) processes that will provide the system with a capacity of evolution. Through constant interaction with the environment and with other organizations, the social structure does not endure forever. It adapts and should adapt to the continuous and rapid changes of the environment. Also, this structure evolves through the iterative and cumulative interaction among organizations in a disaster management system and through creative efforts for adaptation by managers of individual organizations.

7 Those five interrelations are; Type A. Aggression: organizational survival or death, Type B. Bureaucracy: following norms and rules, Type C. Competition: zero-sum game among organizations (my gain is your loss), Type D. Decision: disclosing individual feelings, intentions, and Type E. Empathy: cooperation in one unified interest

2.4.2 Dynamic system evolution and resilience

Dynamic systems theory focuses more on the system's evolution over time. The main interest of this theory is not in finding any precise solution, or equilibrium of the evolving system of disaster management. Rather, it explores the possible range of a system's performance toward a steady state over the long term. What are the possible states of system evolution over time and how do internal interactions among organizations affect the evolution pattern are crucial questions to be answered in this study. The study of dynamic evolution in a complex adaptive system is complicated because the parameters of the successful system evolution may not be known precisely or may be missing from the equations. This uncertainty reduces the validity and reliability of estimates of the system's evolution. Some trajectories may be periodic, whereas others may wander through many different states of the system, so the type of trajectory may be more important than one particular trajectory pattern. Accordingly, the study of possible trajectories of evolution as a function of a parameter is essential for an application of this dynamic system approach to the evolution of complex adaptive systems.

Among the various types of system evolution, this study seeks the adaptive system evolution that is most closely related with resilience of the system. In systems theory, resilience is the rate at which a system returns to a single steady or cyclic state following a perturbation. Also, it is a system's capacity to endure and rebuild its system after a major crisis. This definition of resilience assumes that the behavior of a system remains within the stable domain (Walker et al, 2004) after the outer adversarial impact and keeps its core capacity for operation. Every complex adaptive system tries to avoid risks and system collapse, but if it cannot tolerate the perturbation with its existing system, it will pursue adaptation, reorganize, and finally shift from one domain of stability to another through mutually reinforcing processes. This system

resilience requires an effective management of organizational operation and collaborative relationships among agencies in the complex adaptive system. To decrease a risk to the system, managers try to decrease vulnerability and increase resilience. If any system is vulnerable to change and its current configuration can't handle change effectively, management efforts for system reconstruction to recover collaboration among its partners needs to be introduced to the complex adaptive system.

2.4.3 Agent-based modeling and computational simulation

The previous discussion of cybernetics theory suggests strategic intervention is required for guiding better system evolution. As a tool for the cybernetic interventions, this study uses agent-based modeling as a method of checking the effect of possible strategic interventions on the system's evolution. Agent-based modeling is a computational model for simulating the actions and interactions of organizations in a system to assess their effects on the system as a whole. Such a model simulates the simultaneous operations of multiple agents in an attempt to re-create and predict the actions of complex phenomena for disaster management. The agent-based models are composed of: i) numerous entities with heterogeneity, ii) decision-making heuristics, iii) learning rules and adaptive processes, iv) interaction topology, and v) the non-agent environment.

Unlike other types of computational modeling, agent-based modeling does not search for any kind of equilibrium. Rather, it uses comparatively simple rules and seeks results in far more complex behavior. It can reach equilibrium in the short term, but it is difficult to define equilibrium in a complex adaptive system when the logic of its processes is inductive. In this case, agent-based modeling results in an emergent pattern or an unintelligible mangle (Axelrod, 1997). The more important issue is that agent-based modeling focuses more on the emergence of

higher order patterns and robustness, or the ways in which complex systems adapt to internal and external pressures to maintain their functionality.

The crucial areas for systems engineering are organizational capacity for adaptation and its interaction structure. Specifically, through dynamic communication of information, organizations can achieve the effective operations and better collaboration in the system. Also, this study assumes that strategic intervention in interaction structure among organizations is critical. Particularly important is the bridging role of core organizations in information and resource sharing in the complex adaptive system. In this context, Burt's (1992) concept of 'Structural Holes'[8] is relevant to this study because it refers to issues of how to devise a 'strategic partnership' in the newly emerging network or how to reinforce existing relationships through the management of relationships in the system. Burt's main argument is that no information can be completely and perfectly shared in the system. To address this problem of partial communication, the cluster with high and strong relationships should be motivated to circulate information at a high velocity, and as a result, information should be correctly retrieved with perfect recall. In this process, the core actors who fill the structural hole[9] between contacts should be able to broker communication while displaying different beliefs and identities to each contact (Breiger, 1995). According to Burt, the structure itself does not matter; the important factor is the existence of a player with high structural autonomy from the structural hole. This person is positioned best for the benefits of information sharing that networks provide, and adds value by brokering connections between others (Burt, 1992). These entrepreneurs are people who

8The original definition of structural hole is that there are gaps between non-redundant relationships in network that generates information and control benefits, giving certain players in a competitive arena an advantage in negotiating their relationships

9 Structural hole is a static hole that can be strategically filled by connecting one or more links to link together other points.

build interpersonal bridges across structural holes and who speed the process of information sharing by building bridges between disconnected parts of network.

Value is created as network entrepreneurs' move strategically to increase accurate information diffusion among people in the routine flow of information. The information and control benefits of bridging the holes reinforce one another at any moment in time, and cumulate together over time. These characteristics enlarge the original concept of brokerage to 'Sensemaking' (Weick, 2001). With early access to information, people can expect to find themselves synthesizing new understanding, and they implement their adaptations creatively. With creativity, participants in the disaster management system will be able to increase the probability of knowing alternative ways for their adaptation to a changing environment and they will become aware of trouble sooner. Early detection of threats leads the network to be more flexible in reshaping a project to adapt to exogenous change.

Agent-based modeling is used in this study to develop an analytic tool for building and guiding a more robust and resilient system. Multi-agent simulation (MAS) has been used since the 1970s to analyze the interactions and emergent behavior of complex systems and to estimate the impact of situational changes on the system (Moon, 2008). For example, when a functional death happened to any core organizations in the disaster management system, it is possible to measure the impact of this event on the performance of the entire disaster management system and to assess how to recover the functionality of the system in short time. The advantage of computational agent-based simulation is that it can draw an analogy to human organizations and actors in the actual disaster management system. Considering the difficulty in conducting experiments in social science settings, this tool of multi-agent based computational simulation brings an analytic advantage to the study of disaster management. Using computational agent-

based modeling, this study can estimate the evolution of an organizational structure for disaster response and mitigation. This approach has been used by many other researchers. For example, the 'virtual design team' (Kunz et al, 2002) project aims at developing computational tools to analyze and simulate decision making and communication behavior to support organizational reengineering. Also, Lin and Carley (1997) identify strong factors of an organization's performance and its weaknesses by using computational simulation. In their paper, they simulated an organization's performance based on a model of agents' information processing and an organization's resource dependency.

2.5 CONCEPTUAL MODEL OF THIS STUDY: GUIDING RESILIENT AND STABLE SYSTEM EVOLUTION

This study tries to build a complex adaptive system that continuously tries to adapt itself to its changing environment. This study first determines the most critical factors for effective organizational adaptation, it develops a set of intervention strategies to guide effective adaptation and evolution, and finally, it assess the effect of those strategies to explore the applicability of strategies. Ideally, through continuous interactions with its environment and inner elements, a complex adaptive system can coordinate a large number of interacting elements. This study further assumes that a complex adaptive system is able to evolve to a more resilient and stable state through organizational learning and strategic intervention. To answer how to make the system learn, adapt, and evolve dynamically over time, this study searches for the integration of different perspectives into a common base of understanding and for the guidance of multiple types of action.

First, as an operating entity, the system needs to adapt itself to the complexity and uncertainty of its environment, and it also should recover as quickly as possible from the adversarial effect of disasters. From this definition, three capacities of the adaptive system needs to be considered in this study, the 'capacity to collaborate', the 'capacity to learn', and eventually the 'capacity to evolve'. Besides the challenges from the environment, pressures for successful adaptation come from relationships among organizations within the system. Accordingly, an effective design of a complex adaptive system needs confront complexity and uncertainty from the environment and also manage problems of heterogeneity among participating organizations in an effort to seek the best mode of collaboration. To enhance collaboration among participants, the system's capacities for processing information and communication are the most critical one. Under complexity and uncertainty, a rational model is not effective in information exchange because its independent decisions are constrained in quantity and quality due to the individual's limited cognitive capacity in reasoning. It also does not acknowledge the different concepts of time for different subsets within the system nor interdependence among the actors within and between systems (Comfort, 2007).

Second, for designing a complex adaptive system, most problems cannot be solved by individuals, but require many actors who are involved in interdependent decisions. Also, given the limits of human cognitive capacity for cooperation and coordination, reinforcement of the structure and technology for communication is essential in the process of designing a better disaster management system. Organizational learning using this advanced communication is an important capacity for any organization in a complex adaptive system. As an integrated set of organizations, the system should detect internal and external changes, adopt new ideas, and

develop new patterns of interaction. To increase organizational learning in a disaster management system, individual learning needs to be enhanced in component organizations.

Finally, a complex system should evolve with resilience and stability. If it is unstable and vulnerable to external impacts, it is very hard for organizations in the system to recover and come back to normal operations. This study assumes that this resilience can be attained through continuous efforts for adaptation. Adaptation, as a continuous effort for the system survival, is an ongoing process that is continuously constructed and reconstructed during interaction with environment. There exists a pattern or trajectory of evolution, but we cannot guarantee that this evolution moves toward effective performance under complexity and uncertainty. Therefore, as Parkhe (1993) suggested, it is essential for organizations to have the perspective of looking backward (the cooperative history of the partners) at the same time as looking forward because the network evolves with continuing interactions and this evolution is path dependent. In this sense, achieving resilience is considered as one of the critical goals to be achieved through strategic intervention. From the network perspective, resilience is the ability of the network to provide and maintain an acceptable level of service in the face of various challenges to normal operation (ResiliNets, 2004). In the midst of the tradeoffs between efficiency and persistence, constancy and change, and predictability and unpredictability, a resilient network should have the capacity to tolerate disturbance without collapse through adaptive capacity. This study seeks to identify the criteria for a 'resilient network' in a complex adaptive system which looks for ways to enhance the ability of organizations to create processes that are robust yet flexible, and to use resources proactively in the face of disruptions.

In this study of building adaptive systems, failure does not mean a permanent breakdown of a normal system, but rather represents the emergence of demands for adaptation that are

necessary to cope with the real world complexity. Under the threat of extreme events, voluntary efforts to participate in the existing system should be connected and mutually reinforced through the resilient efforts of those organizations. Encouraging that type of voluntary participation and coordination through an open system model is another key issue to consider in designing complex adaptive system. As discussed, several researchers have suggested the concept of 'self organization' and applied it to a complex adaptive system[10]. In self organization, the network as a whole exhibits distinctive synergistic behavior through the combination of the behaviors of individual actors in the network and is guided by a common goal shared by all participants in the network. Figure 2-1 shows the basic conceptual structure and components of designing a complex adaptive system.

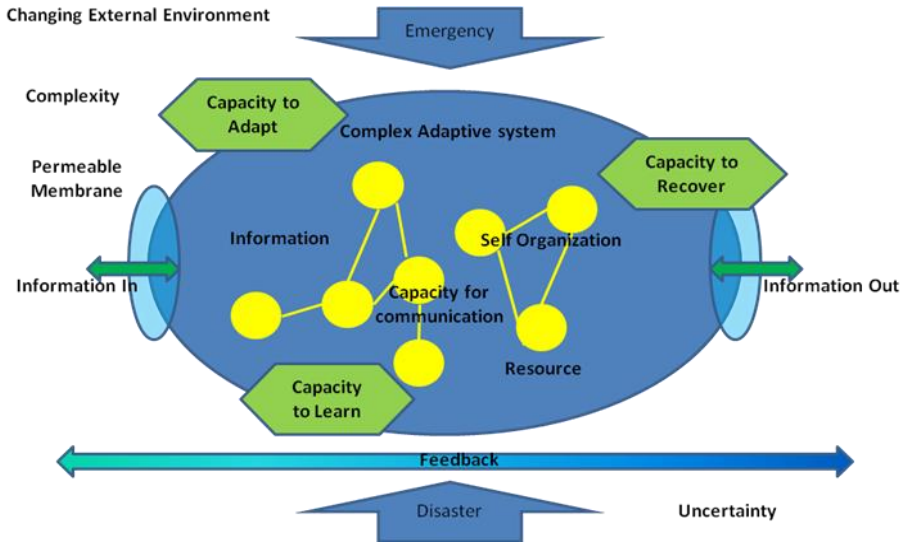


Figure 2-1 Components of designing a complex adaptive system

10 For example, Comfort (1999) suggested that self organization process can emerge to enable the community to act voluntarily for the public good under some conditions such as disaster.

3.0 RESEARCH QUESTIONS AND COMPARATIVE ANALYSIS OF HURRICANE KATRINA AND HURRICANE GUSTAV RESPONSE SYSTEMS

In the previous chapter, this study defined characteristics of complex adaptive systems and clarified that building a 'complex adaptive system' requires an enhanced capacity and collaboration structure for adaptation, learning, and evolution. From these theoretical discussions, this study set the main premise; when collaborative partnership and organizational capacity are combined strategically, organizations can effectively adapt to a changing environment and the accumulated organizational learning can be incorporated for the system's resilience and stability.

Based on these theoretical discussions, this chapter introduces detailed research questions and their links to individual research methods of this study. In the first chapter, this study set up three major research purposes of, 1) identifying the core factors necessary for building adaptive systems, 2) examining networks as a form of organizational adaptation to changing conditions, and 3) assessing the effects of intervention strategies on performance of organizations. For the achievement of these three research purposes, this study employs a small-N comparative case study as the basic research methodology and a mixed set of quantitative and qualitative research methods.

3.1 MAJOR RESEARCH QUESTIONS OF THIS STUDY

3.1.1 Identifying core factors necessary for designing adaptive systems

To identify the most critical factors for system adaptation to changing conditions, this study will conduct a comparative analysis of two crisis cases and check the gap in performance between two extreme events in which organizations were required to communicate, learn, and adapt to rapidly changing conditions. With this comparison, what changes in organizational capacities and interaction structure contributed to the effective organizational adaptation?

> ***Research Question 1****:* What are the core factors that affect the successful adaptation to rapidly changing environments?

To answer this question effectively, this study identifies the challenges from changing conditions, checks the strength and weaknesses of an adaptive system, and determines how those factors affected the performance of the system in response to crises.

3.1.2 Examining network as a form of organizational adaptation to changing conditions

In addition to the identification of core factors, to design an effective adaptive system, it is necessary to examine the existing interaction structure and patterns among organizations in the system. By examining and comparing interaction structures of two extreme cases, this study will reveal how organizational interaction structure was formed and who took the key role in collaboration for information sharing and resources allocation. Also, it will show how embedded interaction structure can create vulnerabilities and opportunities for organizations that actively seek collaboration opportunities in the system. This examination of network structure is crucial to this study because it will reveal where managers of organizations can strategically intervene

and decide how to invest their resources to improve organizational capacity in adaptation. Sub-research questions related with this question are;

> ***Research Question 2***: What are the actual interaction patterns among organizations and how do they create vulnerability and opportunities for organizations in a complex adaptive system?

The main advantage from answering this question is to get the practical knowledge of how a large complex system is formed from smaller components and what factors influence its formation. Also, the examination of existing interaction structure reveals what organizations are structurally important and who takes the key role in collaboration. The findings from the answers to these questions will be used for the structural renovation in building an adaptive system.

3.1.3 Assessing effects of intervention strategies on performance of organizations

Based on the findings from previous research questions, managers in participating core organizations can develop a set of policy alternatives that allow their organizations to more effectively collaborate, create a knowledge base, and adapt to changing conditions. But without the proper metrics for performance measurement and analytic methods for checking a system's evolution, managers struggle to decide how to apply policy alternatives within an adaptive system under changing conditions. So, the third research question of this study is how can identified core factors be converted to policies and applied to effective adaptation and evolution. This study develops a performance measurement metric and checks how to assess the effects of intervention strategies on the performance of organizations in complex adaptive system.

> ***Research Question 3:*** How can identified core factors be converted to policies and applied to guide a successful evolution of complex adaptive systems?

3.2 SMALL-N CASE STUDY OF TWO HURRICANE RESPONSE SYSTEMS

In order to identify the most critical factors for organizational adaptation to changing conditions, to examine networks in actual interaction responding to crisis, and to assess the effects of possible policy alternatives, this study uses a small-N comparative analysis. Network comparison as a major research methods allows the exploration of various phases of organizational interaction in response to crisis, especially how critical contextual factors shape the interaction pattern among organizations. In this sense, it is different from a variable-centered study that tends to overlook contextual information (Ragin, 1987).

The two cases for this small-N comparative analysis are the response system of Hurricane Katrina (2005) and Hurricane Gustav (2008). With this small-N case comparative analysis, this study will conduct an exploratory as well as explanatory analysis for the two networks of hurricane response systems. It is explorative because it searches for what are the most critical factors in designing adaptive systems for resilience and stability. At the same time, it is also explanatory because it provides in-depth pictures of actual interaction among organizations (Creswell, 1998). The examination of two response networks for hurricanes will reveal the hidden relationship among organizations and how the hurricane response systems were formed and responded to crisis.

From the comparative analysis of two hurricane response systems, this study will explore whether there is any evidence of organizational learning and if so, how organizational learning contributed to improvements in performance of Hurricane Gustav response system. As Pezeworski & Tenue argue (1970), this purpose of explaining differences and similarities of two hurricane response systems is quite well aligned with the purpose of small-N comparative

analysis because this study tries to find the common and the most critical factors in designing adaptive systems while controlling external variances as much as possible.

3.2.1 Rationale of case selection for small N comparative case study

As cases for small-N comparative analysis, this study selected the Hurricane Katrina (2005) and Hurricane Gustav (2008) response systems because similarities and differences in two hurricane response systems provide an unusual chance for a quasi-experimental comparative study. The comparison of the two hurricane systems can reveal the evidence of organizational learning and provide the most critical factors for organizational adaptation under crisis.

Hurricane Katrina hit the Louisiana Gulf Coast on August 29, 2005 as a Category 3[11] storm and Hurricane Gustav struck nearly the same geographic area in the summer of 2008 as a Category 2 storm (downgraded to a Category 1 hurricane soon after landfall). Both hurricanes: 1) struck roughly the same geographic area with similar strengths, 2) occurred over similar time spans, 3) mobilized response systems of local, state, and federal organizations, and finally, 4) saw the activation of major disaster management plans just several months before landfall (the National Response Plan, seven months before Hurricane Katrina, and the National Response Framework, five months before Hurricane Gustav). Despite these similarities, the consequences of each hurricane were quite different in relation to the damage to the affected area. The death toll of Hurricane Gustav was 112 with $6.61 billion cost. These number are quite small when

11 The Saffir-Simpson Hurricane Scale is a classification used for most Western Hemisphere tropical cyclones that exceed the intensities of tropical depressions and tropical storms. The scale divides hurricanes into five categories distinguished by the intensities of their sustained winds. In order to be classified as a hurricane, a tropical cyclone must have maximum sustained winds of at least 74 mph (33 m/s; 64 kt; 119 km/h). The highest classification in the scale, Category 5, is reserved for storms with winds exceeding 155 mph (69 m/s; 136 kt; 249 km/h). Source: FEMA, Hurricane Glossary of Terms.

compared to the 1,464 deaths and over $100 billion in losses cost incurred by Hurricane Katrina (statistics from FEMA[12]).

Considering these similarities and dissimilarities, analyzing the response operations for two hurricanes offers an unusual opportunity for comparative analysis to examine the evidence of learning of disaster response systems. Moreover, the three year difference between 2005 and 2008 allows sufficient time for the disaster management system to reflect its learning and reorganize its structure and operational protocols. During the three years between Hurricane Katrina and Hurricane Gustav, the disaster response system developed a new action plan, strengthened its communication protocols and equipment, worked and carried out exercises together, and invested enormous resources to build a more resilient disaster management system.

Through a comparative analysis of these two hurricanes, it will be possible to determine whether there were any system wide efforts to improve the disaster response system's effectiveness and if so, what factors were critical in improving its performance. If the gap between two hurricane response systems can be identified, then this study can identify critical factors that contributed to gaps in performance between the two hurricane response systems. Finally, it is possible to use implications from this comparative study to develop policy alternatives on how to strategically design a collaborative relationship and strengthen organizational capacity for learning and adaptation.

12 http://www.fema.gov/hazard/hurricane/2005katrina/statistics.shtm

3.2.2 Links between research questions and research methods

To examine the issue of system adaptation to complexity and to identify the evidence of organizational learning between two hurricane response systems, this study uses a set of mixed methods, including several quantitative and qualitative approaches such as: content analysis, semi-structured interviews, social network analysis, and multi-agent based computational simulation. The main reason to use a mixed methods approach is to explain organizational adaptation to complexity and uncertainty, which cannot be easily explored with the application of only one or two research methods.

Mixed methods or 'triangulation' in social inquiry invites multiple models to the inquiry space for the purpose of collectively generating a better understanding of the topic being studied (Green, 2007). As Wolcott (1988) argues, the triangulated techniques are helpful in "cross-checking", or "ferreting out" varying phenomena in complex issues and events of this study. However, the critical problem of using a mixed methods approach is to integrate different levels of analysis into one study. To address this problem and to structure the role and relations of each research method within the analysis, this chapter makes links and clarifies the relationships between multiple research methods and research questions.

The combination of quantitative and qualitative analysis allows this study to achieve the three major research purposes of this study; the examination of the actual interaction structure of two hurricane response systems, the identification of core factors that will contribute to the design of an adaptive system, and the assessment of network performance with the application of strategic policy alternatives. More specifically, content analysis provides the basic data for all other analyses of this study. From the content analysis, this study developed structured data sets

for social network analysis and this study will be able to identify the major problems in response to Hurricane Katrina and Hurricane Gustav.

Based on structured data from content analysis, I conducted social network analysis to examine the actual interaction pattern among participating organizations in the Hurricane Katrina and Hurricane Gustav response systems. With social network analysis, this study addresses the second research question of how a large system was formed from smaller components, what organizations were most structurally important, and who took the key roles in collaboration and response to changing conditions of crisis. The findings from content analysis and social network analysis will be verified through semi-structured interviews with managers of organizations that actively participated in both hurricane response systems. Using managers' insights and experiences from semi-structured interview, this study aims to identify the most critical factors to be considered in designing more effective adaptive systems.

Finally, with agent-based computational simulation, this study will assess the effects of intervention strategies on the performance of organizations adapting to changing conditions. As Simon argued (1999), computational simulation is the virtual experiment that will check the effects of policy alternatives on the system's overall evolution. Especially for this study, developed policy alternatives from the findings of content analyses and semi-structured interviews will be used to improve information sharing among organizations and see how those alternatives eventually contribute to an effective system evolution over time. The links between major research questions and research methods is presented in figure 4-1.

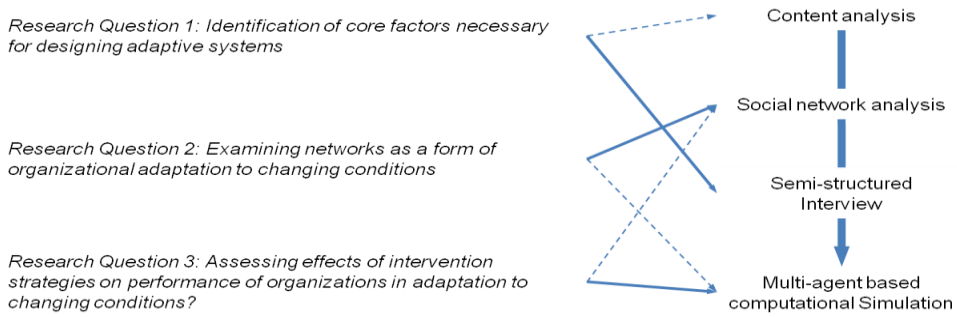


Figure 3-1 Links between research questions and research methods

3.3 EXAMINING PATTERNS OF ORGANIZATIONAL INTERACTION IN HURRICANE KATRINA AND HURRICANE GUSTAV: CONTENT ANALYSIS

3.3.1 Analytic purpose of content analysis of newspaper articles and situation report

This study used content analysis as a standard methodology for studying the pattern of interaction and communication among organization in the disaster response system because, as Babbie (2003) and Lasswell (1969) defined, content analysis is the study of recorded human communications and interactions. This study conducted content analysis to elicit information from textual data and to structure data that was extracted and coded by content analysis. More specifically, the role of content analysis in this study is to expose binary relationships or reciprocal collaboration links between two organizations. Each reciprocal collaboration link was marked with pre-defined coding procedures. Based on the coded interactions among organizations, this study created specially structured data sets that show the actual interaction and collaboration pattern of organizational response to Hurricanes Katrina and Gustav. The coded data for the interaction pattern in the disaster response system to Hurricanes Katrina and Gustav is a necessary input for social network analysis and computational simulation in the later

part of this study. The findings from content analysis further show the major problems that organizations faced during their response to Hurricane Katrina and Hurricane Gustav.

3.3.2 Data sources of content analysis

For the content analysis, this study used two sources of data: the first are newspaper articles from the *Times-Picayune* and the second are situation reports from the Louisiana Office of Homeland Security and Emergency Preparedness (LOHSEP/GOHSEP[13]). The data for content analysis document a daily record of actions undertaken to cope with Hurricanes Katrina and Gustav by the various organizations in the system. Through the content analysis, this study identified each organization that participated in the response operations, and interactions among them by date in response to both Hurricanes Katrina and Gustav.

The first data sources used for the content analysis are newspaper articles from the *Times-Picayune*, the local newspaper published in New Orleans and the major newspaper for the state of Louisiana, from August 27 to September 19, 2005 (one week before and three weeks after landfall of Hurricane Katrina). The same time frame for *Times-Picayune* newspaper articles were used for the content analysis response operations for Hurricane Gustav, from August 26 to September 21, 2008 (one week before and three weeks after the landfall). The second data source is the set of situation reports produced and managed by the Louisiana Office of Homeland Security and Emergency Preparedness (LOHSEP) for Hurricane Katrina and similarly managed by the Governor's Office of Homeland Security and Emergency Preparedness (GOHSEP) for Hurricane Gustav. The reason for using two different sources of archival data is to avoid missing

13After Hurricane Katrina, LOHSEP was placed under direct authority of the Governor and renamed Governor's Office of Homeland Security and Emergency Preparedness (GOHSEP). In this study, LOHSEP refers to Katrina response and GOHSEP to Gustav response.

meaningful transaction data that can happen when a content analysis relies on any single data source. If only newspaper articles are used, many unpublicized transactions within governmental organizations may be missed. Likewise, if only the State of Louisiana situation reports are used, the main body of information for interactions of private and nonprofit organizations may be missed. Because the range of identifying and coding collaborative interactions are broad interactions among public, private, and nonprofit organizations, the use of both types of archival data are necessary and complementary to each other. Table 4-1 shows the data sources, duration, and total numbers of identified transactions in each data source.

Table 3-1 Data Sources of Content Analysis

Hurricanes	Data/Sources	Duration	Total Number of Transactions Identified
Katrina	Newspaper Articles/ *Times Picayune*	August 27, 2005 – September 19, 2005	1398
	Situation Reports	August 27, 2005 – September 6, 2005*	2498
Gustav	Newspaper Articles/ *Times Picayune*	August 26, 2008 – September 21, 2008	753
	Situation Reports	August 29, 2008 – September 18, 2008	419

*Situation Reports were not available for August 31, 2005.

3.3.3 Coding procedures of content analysis

To handle large amounts of textual data, and to categorize the main information from content analysis, I used a classification scheme developed at the Center for Disaster Management[14] that facilitates effective data analysis[15]. Especially, in developing the coding scheme, we addressed the questions of i) who initiated the interaction, ii) who actually responded to requests for

14 The coding of newspaper reports was done by graduate student researchers at the Center for Disaster Management, University of Pittsburgh. I participated in this work and acknowledge the contribution of my colleagues; Thomas Hasse, Steve Scheinert, and Gunes Ertan in the creation of the data base.

15 For effective content analysis, Krippendorff (2004) suggested that six questions must be addressed in every content analysis. These questions are, 1) which data are analyzed? 2) How are they defined? 3) What is the population from which they are drawn? 4) What is the context relative to which the data are analyzed? 5) What are the boundaries of the analysis? 6) What is the target of the inferences?

collaboration, and finally iii) what were the content of their interactions (revised Krippendorff, 2004). We began coding processes by scanning all newspaper articles and situation reports focusing on information that reveals any binary interaction between two organizations. For example, in performing analysis on the newspaper article titled "Parts of Old Metairie, Airport area still under some water; Jefferson getting better grip on security" in September 3, 2005, *Times-Picayune*, we focused on the content of interaction such as:

> "Department of Homeland Security, United States instructed the American Red Cross to hold off at least 24 hours before delivering aid to East Jefferson and West Jefferson Medical Center in Marreo so that 30,000 National Guard troops could secure the storm-ravaged New Orleans area."

This specific content contains some important information of interaction that needs to be coded. First, it identifies two interacting organizations: the initiating organization (Department of Homeland Security) and the responding organization (American Red Cross). Second, it contains the content of interaction or communication between two organizations. In this instance, the Department of Homeland Security coordinated response activities of the American Red Cross and National Guard. Third, it shows when this interaction occurred, in this case, September 3, 2005. With this basic information (again, who interacted with whom, when, and what was their interaction), this study created additional categories for management purposes of data. First, this study assigned a system number as an identification number for each organization in the Hurricane Katrina and Hurricane Gustav response systems. Additionally, we sorted every organization by funding sources and level of jurisdictions and assigned those attributes to each organization in the system.

For the content analysis of situation reports, this study added several more attributes to binary transactions because the content of situation reports contains more detailed information such as the types of transaction, status of requests from initiating organizations, and the quantity of requested resources to responding organizations. For the types of interaction, this study used

'Emergency Support Functions[16] (ESFs)' for the categorization of interactions. These ESFs were defined by the National Response Plan (NRP, 2004) for Hurricane Katrina and by the National Response Framework (NRF, 2008) for Hurricane Gustav. Using ESFs categories, this study sorted the all transactions into 15 categories of 'transaction type' which include: search & rescue, heavy equipment, light equipment, supplies, security, evacuation, shelter, emergency response, communication & coordination, personnel, utility, transportation, medical, damage assessment, and others. The set of variables that this study created for the creation of structured data listed in table 4-1 below.

Table 3-2 Scheme of Data Transformation: Situation Report into Structured Data

Name of Variables	Content
Serial Number	Serial number given to each transaction
Time	Reported time of transactions in the situation report (Hurricane Katrina situation reports only)
Date	Reported date of transactions
System Number	Identification number assigned to each organization in the system.
Initiating Organization (I*)	Name of organizations which initiate interactions with other organizations
Source of Funding (I)	Source of funding for initiating organization (public, private, nonprofit)
Level of Jurisdiction (I)	Level of jurisdiction for initiating organization (international, federal, state, regional, sub-regional, parish/county, local)
Content of Transaction	Content of transaction which was actually realized between two organizations
Transaction Type	15 Categories of various transactions (Hurricane Katrina situation reports only)
Responding Organization	Responding organization that *interacted with* initiating organization
System Number (R**)	Assigned system number of responding organization
Source of Funding (R)	Source of funding of responding organization
Level of Jurisdiction (R)	Level of jurisdiction of responding organization
Status of request	Status of transaction (Hurricane Katrina situation reports only, No response (NR), Action Required, Cancelled, Pending, On-Scene, Enroute, Released)
Quantity of requested resources	Amount of resources which was shared between two organizations (Hurricane Katrina situation reports only)

* I: Initiating organization ** R: Responding organization

16 The Emergency Support Functions annexes the missions, policies, structures, and responsibilities of agencies for coordinating resource and programmatic support (National Response Plan, 2004, Department of Homeland Security, p12). They are mechanisms for grouping functions most frequently used to provide federal support to states and federal-to-federal support, both for declared disasters and emergencies under the Stafford Act and for non-Stafford Act incidents (National Response Framework, 22 Jan 08, DHS)

3.4 INSIGHTS FROM PRACTICING MANAGERS FOR THE IDENTIFICATION OF CORE FACTORS IN DESIGNING ADPATIVE SYSTEMS

3.4.1 Analytic purpose of semi-structured interview

The interactions of organizations identified from the content analysis of newspaper articles and situation reports are useful in documenting the actual interaction structure and patterns of the disaster response system to Hurricane Katrina and Hurricane Gustav. But, at the same time, the content analysis is limited in terms of exploring the critical factors that affect the effective collaboration in response to complex environments. These qualitative data can be obtained through in-depth and semi-structured interviews with the managers of organizations that actively participated in the disaster response systems to Hurricane Katrina and Hurricane Gustav. With semi-structured interviews, it was possible to validate relational data from the content analysis and to obtain important qualitative information regarding the actual organization's operation and interaction during the preparation and response phases of both hurricanes.

To identify the most critical factors to be considered in designing adaptive systems, this study relied on insights from managers of organizations who actively participated in Hurricane Katrina and Hurricane Gustav response systems. The semi-structured interview includes both open-ended and closed questions (Refer to Appendix A for the interview questionnaire). More specifically, with open-ended questions, this study provides rough categories of questions to make the interview less intrusive, to encourage two-way communication for exploring new information from interviewees, and to allow them to speak more freely about what they experienced during the response phase of Hurricanes Katrina and Gustav. With these open-ended questions, interviewees can more easily discuss sensitive issues and reveal hidden and

unexpected information that was not available through archival data analysis. Although the specific topics that this study seeks to explore are organized in advance, key questions could be posed during the interviews in open conversation, allowing the interviewer and interviewee the flexibility to probe for details (Lindlof & Taylor, 2002). This flexibility helps interviewees to focus on the topics at hand without constraining them to a particular format.

At the same time, using closed questions, this study asked interviewees to evaluate or rate the organizations' capacity in four major categories; communication, managerial entrepreneurship for adaptation, number of personnel, and training level of personnel, which were identified as critical factors for the effective operation and collaboration with partners in the system. As a tool for closed questions, rating was a useful way to measure an individual's attitudes toward the capacity and the performance of his or her organization, and how perceptions have changed since Hurricane Katrina. Sometimes, open conversation was used with closed questions together, particularly when asking about the reasoning behind the interviewee's rating of each category. For example, if respondent stated that the overall capacity for communication of her or his organization had been greatly improved since Hurricane Katrina, the interviewer could then ask her to explain what kinds of improvements have been made more in detail.

To achieve the overarching research question of organizational adaptation to changing conditions, this study needs to compare the organizational response to Hurricane Katrina with that to Hurricane Gustav, and to assess any improvements in the disaster response system between the two events, and to check whether there was any evidence of organizational learning. Figure 3-2 shows the logic of a semi-structured interview and how open-ended and closed-ended questions mixed for the complementary use to achieve the analytic purpose of semi-structured

interview (These purposes include, the exploration of new information mainly to identify core factors considered in designing adaptive systems, the verification of findings from content analysis of newspaper articles and situation reports, and the assessment of organizational performance to identify evidence of organizational learning between two hurricanes.

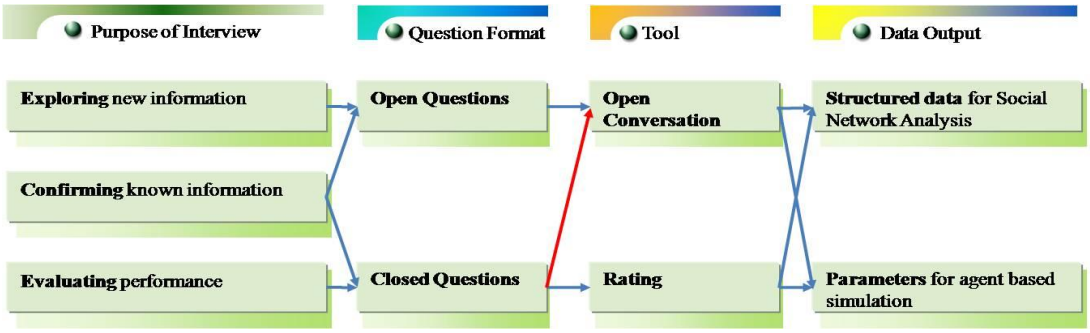


Figure 3-2 Logic of semi-structured interview and expected output

3.4.2 Sampling organizations for semi structured interview

This study uses several criteria to determine which organizations' managers to interview. This study did not use random sampling methods because the purpose of a semi-structured interview is to use insights from experienced managers of disaster response systems. Accordingly, rather than conducting interviews with randomly selected, but not core organizations, this study intentionally selected some core organizations that took the most crucial roles in information sharing and resource allocation in the hurricane response systems.

The first sampling criterion is the measurement of degree centrality by social network analysis. Among various kinds of centrality measures in social network analysis, I used total degree centrality[17] because it provides information about what organization takes the most

17 For a graph G: = (V,E) with n vertices, the degree centrality CD(v) for vertex v is: $C_D(v) = \frac{\deg(v)}{n-1}$

important position in sharing information and resources in the entire disaster response system by counting the number of links incident upon a node (i.e., the number of ties that a node has). Table 3-3 shows the top 15 organizations with highest total degree centrality in the entire response system for Hurricanes Katrina and Gustav. To measure the total degree centrality of each organization in the system, this study used structured data sets from content analyses of newspaper articles and situation reports.

Table 3-3 Top 15 organizations with high total degree centrality in hurricane response systems

Rank	Organization (Hurricane Katrina)	Degree Centrality	Organization (Hurricane Gustav)	Degree Centrality
1	FEMA	46	Governor's Office of Homeland Security and Emergency Preparedness, LA	51
2	Office of President, US	22	Department of Social Services, LA	43
3	Office of Governor, LA	21	FEMA	23
4	Police Department, New Orleans	20	National Guard	16
5	Parish of Jefferson	15	Office of Mayor, New Orleans	15
6	Louisiana National Guard	14	Army Corps of Engineers	14
7	Florida National Guard	13	Parish of Plaquemines	11
8	Office of Mayor, New Orleans	12	American Red Cross	10
9	Louisiana Office of Homeland Security and Emergency Preparedness	11	Parish of Jefferson	9
10	Department of Homeland Security, US	10	Louisiana National Guard	9
11	Army Corps of Engineers	10	American Humane Association	8
12	Louis Armstrong International Airport	10	Louis Armstrong International Airport	7
13	Public Health Service, US	7	Parish of St. Tammany	7
14	American Red Cross	7	Louisiana State Board of Regents	6
15	Parish of St. Bernard	7	Entergy	6

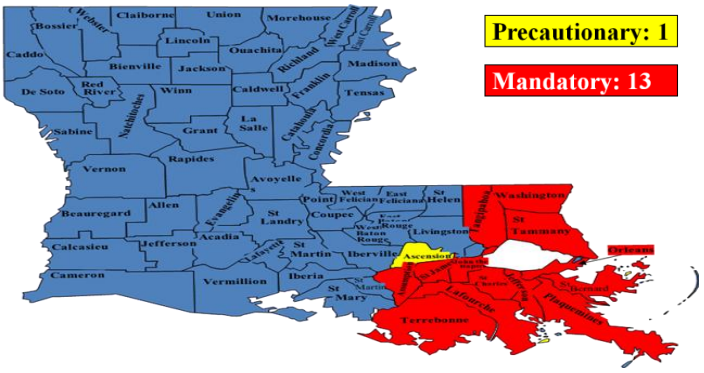
The second sampling criterion, especially for the state agencies, is the set of primary organizations that were assigned to Emergency Support Functions (ESFs) under Louisiana's emergency operations plan. Table 3-4 shows the ESFs and the primary organization for each ESF. Using this table, this study sampled all the primary organizations in each ESF and if there was more than one primary organization listed, I chose only one to make ensure that there was no duplication among ESFs.

Table 3-4 Emergency support functions and responsibility chart (P: Primary, S: Support)

	ESF #1 – Transportation	ESF #2 – Communications	ESF #3 – Public Works and Engineering	ESF #4 – Firefighting	ESF #5 – Emergency management	ESF #6 – Mass Care, Housing, and Human Services	ESF #7 – Resources Support	ESF #8 – Public Health and Medical	ESF #9 – Search and Rescue	ESF #10 – Oil Spill, Hazardous Materials, and Radiological	ESF #11 – Agriculture	ESF #12 – Energy and Utilities	ESF #13 – Public Safety and Security	ESF #14 – Community Recovery, Mitigation, and Economic Stabilization	ESF #15 – Emergency Public Information	ESF # 16 – Military Support To Civil Affairs
Governor's Office of Homeland Security and Emergency Preparedness		P			P	S	P			S				P	P	S
Louisiana National Guard	S	P	S	S	S	S	P	S	S	S	S	S	S	S	S	P
Department of Agriculture and Forestry	S	S		P	S	S	S	S	S	S	P		S	S	S	
Department of Corrections	S	S			S	P		S	S		S		S		S	
Department of Culture, Recreation and Tourism		S			S	S	S		S				S	S	S	
Department of Economic Development		S			S		S							P	S	
Department of Education	S	S			S									S	S	
Department of Environmental Quality		S		S	S		S	S		P	S	S		S	S	
State Fire Marshal				S		S		S	S	S					S	
Governor – Division of Administration		S	S		S		S						S	S	S	
Governor – Office of Elderly Affairs	S	S			S	S									S	
Governor – Office of Financial Institutions														S	S	
Governor – Office of Indian Affairs					S										S	
Governor – Oil Spill Coordinators Office		S			S					P					S	
Louisiana State University System		S			S	S	S	S	S	S	S			S	S	
Department of Health and Hospitals	S	S	S		S	S	S	P		S	S	S		S	S	
Department of Insurance						S								S	S	
Department of Justice		S			S								P	S	S	
Department of Labor		S			S	S	S							S	S	
Department of Natural Resources			S		S	S	S			S		P		S	S	
Louisiana Family Recovery Corps						S										
Louisiana Housing Finance Agency						S										
Louisiana Public Service Commission	S	S			S							P		S	S	
Louisiana Board of Regents	S	S			S	S	S	S			S		S	S	S	
Department of Revenue		S			S	S							S	S	S	
Department of Social Services		S			S	P	S							S	S	
Secretary of State					S									S	S	
Louisiana State Police	S	P			S		S		S	P			P	S	S	
Department of Transportation and Development	P	S	P	S	S		S	S	S	S	S		S	S	S	
Department of Treasury					S		S							S	S	
Department of Veterans Affairs						S		S								
Department of Wildlife and Fisheries	S	S		S	S				P	S	S		S		S	
Volunteer Organizations	S	S	S	S	S	S	S	S	S	S	S	S		S	S	
Louisiana Youth Services													S			

Source: *State of Louisiana Emergency Operation Plan*, 2007. Governor's Office of Homeland Security and Emergency Preparedness

The third and final sampling criterion, especially for Parish governments, is the level of damage caused by Hurricane Katrina. Figure 3-3 shows the parishes that were tagged for mandatory evacuation as of September 5th, 2005 and were, accordingly, most severely damaged by Hurricane Katrina. I conducted semi-structured interviews with emergency managers in all red colored parishes on the map, as those parishes were on the exact path of Hurricane Katrina.



Source: Situation Report, Louisiana Office of Homeland Security and Emergency Preparedness

Figure 3-3 Parishes under mandatory evacuation orders for Hurricane Katrina (As of Sept. 5, 2005)

Using these three criteria, this study selected 36 organizations for the semi-structured interview. All three sampling strategies were designed to identify the organizations that most actively participated in the hurricane response systems. The list of sampled organizations and their attributes is shown in Table 3-5, and this list also provides the position of the interviewed managers and total number of years they worked in that position. Seniority within position is critical for the comparison of Hurricane Katrina and Hurricane Gustav because after the barrage of criticisms of mismanagement during Hurricane Katrina, many manager-level personnel resigned from their positions and those positions were replaced by new personnel for the response to Hurricane Gustav. In order to compare performance of two hurricane response systems, interviewees needed to have been in their current positions for over three years. However, due to the turn-over, some directors did not have a working memory of Hurricane Katrina (6 out of 36 organizations, 17%). In these cases, to increase the relevancy of data, personnel who had working experiences from Hurricane Katrina, such as the deputy director or operations chief, accompanied the main interviewees and answered some of the questions. The second detail of 'total years in disaster management field' is also a critical measure because it

indicates how many experienced personnel kept their positions after the failure of Hurricane Katrina.

Table 3-5 List of organizations for semi-structured interview

Organization	Level of Jurisdiction	Source of Funding	Position	Years of Service in Position (>3)*	Total working years in disaster management field
American Red Cross	Federal/National	Nonprofit	Chief Executive Officer	9	20
Army Corps of Engineers	Federal/National	Public	Chief	4	13
Ascension Parish	Parish/County	Public	Deputy Director	2**	11
Assumption Parish	Parish/County	Public	Director	15	20
Coast guard	Federal/National	Public	Chief	5	13
Department of Agriculture	State	Public	Deputy Incident Commander	3	32
Department of Health and Hospitals	State	Public	Program Manager	2**	5
Department of Natural Resources	State	Public	Deputy Assistant Secretary	3	5
Department of Social Services	State	Public	Director	5	30
Department of Transportation	State	Public	Director	5	24
Department of Wildlife & Fisheries	State	Public	Administrator	4	31
Entergy	Regional	Private	Vice President	25	30
FEMA_Federal	Federal/National	Public	Principal federal official	5	19
FEMA_Local	Parish/County	Public	Operations Officer	2**	3
FEMA_Regional	Regional	Public	FCO	2**	20
GOHSEP	State	Public	Director	3	18
GOHSEP2	State	Public	Deputy Director	5	15
Jefferson Parish	Parish/County	Public	Director	3	13
Lafourche Parish	Parish/County	Public	Director	4	25
Louis Armstrong International Airport	Regional	Public	Manager	12	17
Louisiana State Police 1	State	Public	Superintendent	5	26
Louisiana State Police 2	State	Public	Director of Operation	3	15
Louisiana National Guard	State	Public	LNO	3	22
National Weather Service	Regional	Public	Officer	14	23
New Orleans Police Department	City	Public	Superintendent	4	28
NOFD	Parish/County	Public	Chief	8	25
Ochsner Hospital	Regional	Nonprofit	Vice President	13	25
Parish of Orleans	Parish/County	Public	Director	3	30
Parish of Terrebonne	Parish/County	Public	Director	11	33
Plaquemines Parish	Parish/County	Public	Director	3	12
Public Service Commission	State	Public	Director	10	30
St. Bernard Parish	Parish/County	Public	Office Manager	2**	13
St. Tammany Parish	Parish/County	Public	Director	4.5	38
State Fire Marshal	State	Public	Fire Marshal	1**	23
Verizon	Regional	Private	Director	7	9
Washington Parish	Parish/County	Public	Director	14	18
Average				**6.2**	**20.4**

* It should be over 3 years for interviewees to compare Hurricanes Katrina and Gustav
**shows that some of the interviewees took their current positions after Hurricane Katrina (years<3)

The cross-tabulation of the 36 organizations by level of jurisdiction and source of funding is presented in Table 3-6. When categorized by level of jurisdiction, the federal/national organizations make up 11.1%, parish/county organizations 36.1%, regional organizations 16.7%, and state organizations 36.1%. When sorted by source of funding, there are 2 non-profit organizations (5.6%), 2 private organizations (5.6%), and 32 (88.9%) public organizations.

Table 3-6 Cross tabulation of organizations by level of jurisdiction and source of funding

Source of Funding / Level of jurisdiction	Nonprofit		Private		Public		Total	
	Count	%	Count	%	Count	%	Count	%
Federal/National	1	2.80	0	0.00	3	8.30	4	11.10
Parish/County	0	0.00	0	0.00	13	36.10	13	36.10
Regional	1	2.80	2	5.60	3	8.30	6	16.70
State	0	0.00	0	0.00	13	36.10	13	36.10
Total	2	5.60	2	5.60	32	88.90	36	100.00

The portion of public organizations is large (88.9%) because the types of coded interactions from content analysis of newspaper articles are mainly about the preparation and response activities of public organizations and their transactions with private and nonprofit organizations. Especially, because the situation reports were mainly managed and published by public organizations, it contains more activities of public organizations than those of private and nonprofit organizations.

3.4.3 Checking validity and reliability of interview questionnaire

Like other research procedures, verifying reliability and validity of a measurement tool increases its applicability to the analysis. For the validity of the questionnaire, I conducted a pre-test with several experts in disaster management field. Specifically, this study focused on interrater reliability to check the extent to which two or more interviewees agree (Howell et al, 2005) and to confirm the consistency of a rating system that depends upon the ability of two or more individuals to be consistent in their answers. To assess validity[18], this study is concerned with

18 Validity refers to the degree to which a study accurately reflects or assesses the specific concept that the researcher is attempting to measure. While reliability is concerned with the accuracy of the actual measuring instrument or procedure, validity is concerned with the study's success at measuring what the researchers set out to measure (Howell et al, 2005)

‘criterion related validity (instrumental validity)’ because it demonstrates how the accuracy of a finding from an interview can be verified by comparing it with findings from content analysis of newspaper articles and situation reports. Specifically, the interviews deal with the issue of ‘content validity’ to guarantee that this questionnaire remains within the intended domain (Carmines & Zeller, 1991) that was identified from content analysis.

To improve the integrity of interview questions in reliability and validity, this study conducted several pre-tests with academic researchers and professionals who have over 10 years of experience in the disaster management field. Because it is a pre-test, sampling is not as serious an issue as in a real interview situation, but to make the pre-tests more relevant, I selected pre-test interviewees from various groups. I selected one director from a parish government’s office of homeland security and emergency preparedness (Lafourche parish), one person from a federal agency (FEMA), one staff member from a non-profit organization (American Red Cross), and one interviewee from a state organization (GOHSEP). From the academic field, I asked two researchers, one in New Orleans and one in Pittsburgh, to review interview questions and check the integrity of questions.

Based on the results of this pre-test of the interview questionnaire, I reorganized and reconstructed the interview questions to make them clearer and more consistent in measuring important factors in designing complex adaptive systems. First, I considered time management for this interview. Because most interviewees of this study are current directors of their respective organizations, they cannot afford more than one hour for this interview. Therefore, I omitted some duplicate or minor questions to get more important answers in a limited time span. Secondly, I introduced a 5-point ordinal scale to measure the levels of collaboration and organizational capacity more consistently. Finally, I changed the order of the set of questions for

Hurricanes Katrina and Gustav. Because this analysis is designed to compare the disaster response system's operation and collaboration in two hurricanes, the answers for Hurricane Gustav can interfere with the answers for Hurricane Katrina. To minimize this interference effect, I asked the set of questions for Hurricane Katrina first and then repeated the same questions for Hurricane Gustav.

3.4.4 Devising questionnaire

To achieve the analytic purposes of the semi-structured interview; the exploration of core factors for designing adaptive systems and the validation of findings from content analysis, the questionnaire for the interview is composed of three parts: diagnosis of organizational capacity for disaster response and mitigation, evaluation of collaboration partnership with other agencies, and suggestions for the design of future adaptive systems to major crisis. Each question was asked twice, once for Hurricane Katrina and once for Hurricane Gustav.

The questionnaire begins by asking about the organizations' role in the system and its preparation level. Also, it asked managers to evaluate their organization's capacity for four pre-defined categories: communication technology/equipment, managerial entrepreneurship for adaptation, number of personnel, and training level of personnel. Using the responses to these questions, this study identified the organization's major role in the disaster response system, evaluated the level of preparedness and source of information for disaster preparation, and the organizational capacities of the four critical categories that are required for the effective operation and collaboration.

The second section of the questionnaire includes questions about the effectiveness of organization's collaboration with other organizations in the system. This section uses both open

questions and closed questions, but mainly relies on open-ended questions in an effort to identify the most critical factors that improve organizational collaboration for information and resource sharing during the period of disaster response and mitigation. Given the responses to these questions, I evaluated the overall level of collaboration of organizations within the disaster response systems to Hurricane Katrina and Hurricane Gustav. Also, I tried to clarify who the major collaboration partners were, what kinds of information and resources they shared, what were the major problems in collaboration, and what they did to overcome difficulties in collaboration.

The third section of interview questionnaire seeks suggestions from interviewees. Based on their specialized expertise and experiences, they provide creative insights for improving organizational capacities and collaboration structure to make organization's adaptable to changing conditions. In this section, not all questions were designed and phrased ahead of time in order to get more extensive suggestions from managers. These questions were designed to determine what factors should be considered and how long-term system evolution could be guided through strategic intervention and policy recalibration. The aim is to develop the system to be more resilient and stable for future major crises and eventually allow the system to adapt more creatively to changing conditions. The last section contains questions of demographic information, questions about the interviewees themselves, including total number of years working in current position and in the disaster management field.

3.4.5 Developing coding procedures

This study used grounded theory methods to develop coding trees and categories. The grounded theory (Glazer, 1992) is a systematic qualitative research methodology emphasizing generation

of theory from data in the process of conducting research. After the semi-structured interviews, the key points are marked with a series of codes, which are extracted from the text. Then the codes are grouped into similar concepts in order to make them more workable. From these concepts, categories are formed, which are usually, in the grounded theory, the basis for the creation of a theory or a reverse engineered hypothesis (Strauss, 1998). But this process of developing codes, concepts, category, and theory in grounded theory stops at the category level because the purpose of semi-structured interviews is not in the development of theory but the identification of core factors for successful adaptation to changing conditions.

Using transcriptions from the recorded interview data, this study utilized the 'open coding' method. 'Open coding' or 'substantive coding' is used for the conceptualization of the first level of abstraction. Transcriptions were conceptualized line by line and each code from this open coding is compared and merged into new concepts, and eventually renamed and modified for the creation of categories. According to grounded theory, this coding process goes back and forth while comparing data, constantly modifying and sharpening the concepts for categorization. After the open coding procedure, I conducted axial coding procedures. Axial coding in grounded theory is the process of relating codes to each other through a combination of inductive and deductive thinking. With this axial coding, I reorganized a set of initial codes into preliminary concepts. During this reorganizing process, this study could create a new set of ideas and more comprehensive concepts that described the initially coded themes in more detail. With these new codes and ideas, I moved toward organizing the ideas or themes and identified the axis of key concepts in analysis (Neuman, 2006). The three major categories created from coding procedures are, improvements after Hurricane Katrina, major problems in response to Hurricanes Katrina and Hurricane Gustav, and suggestions for making future systems more resilient and stable.

For the section on improvements since Hurricane Katrina, there are two categories: improved organizational capacity and improved collaborative partnerships. For improvements in organizational capacity, I created the concepts of human resource management, resource management, communication, planning, and funding as the five most important factors for an organization's capacity for adaptation. For the improved collaborative partnerships, I devised codes for building rapport, collaboration structures, and support from partners in the disaster management system. The section on identified problems is composed of three sub-categories: problems in operation, problems in collaboration, and problems in communication. Problems in operation include: failures in human resource management and resource management, the lack of professional management plan/procedures, and insufficient funding. Problems in collaboration include: rivalries among organizations, institutional barriers for collaboration, and a lack of collaborative attitudes and culture. Finally, problems in communication include the breakdown of the communication system.

The third section, factors to be considered for building future adaptive systems, is composed of two categories: better collaboration and better operation. Under the category of better operation, are included codes for: human resource management, resource management, consistent planning, and funding for future system. Under the category of better collaboration, there are included codes for: communication technology/equipment, and building rapport among partners through established constant working relationships among organizations in the system.

Tables 4-7 to 4-9 show the structure of codes. Each code has a separate column for frequency (number of times mentioned by interviewees) and number of organizations that mentioned it as an important factor. To give weight to the codes to help select important factors for the disaster response and mitigation, this study used both frequency and number of

organizations. To create the coding tree, this study used the qualitative analysis software known as MAXQDA (2008).

Table 3-7 Structured codes for the part of improvements since hurricane Katrina

Category	Concept	Code	Description
Improved organizational capacity	Improved Manpower	Training and Education	Increase in required training and training programs
		Improved personnel Welfare	More considerations for personnel's safety and working conditions
		Adaptive leadership	Improved leadership based on learning from previous disasters
		Increased expertise of personnel	Increased level of expertise through disaster management experiences
		Staffing	Increased number of personnel for the operation of disaster management
	Improved Resource Management	Private Vendor management	Pre-identified and pre-contracted vendors for stable supplies provision
		More regional resources for self sufficiency	Using available regional resources to fill the needs gap until state and federal assistance is provided
		More available resources	More resources for disaster response and mitigation in the system
		Pre-positioning of resources	Positioning resources before hurricane landfall
		Exact estimation of needs	Estimating the exact needs of resources in advance
	Improved communication for getting common operation picture	Reliability	Increased reliability for communication system
		Clear communication procedures	Clear contact point and procedures for communication
		Application of more advanced technology	Communication equipment or reporting procedures with more advanced technology
		More communication equipment	More communication equipment
		Redundancy of communication	More redundant communication facilities and equipments
		Reinforced public notification system	Reinforced information diffusion system for public awareness of the situation
		Utilizing LNOs for on-site information	Deployment of liaison officers in partners' emergency operation center
		Frequent communication with partners	More communication with partners during disaster response
	Improved planning activities	New operation procedures	New procedures and plans for operations after hurricane Katrina
		Clear Role Definition	Clearly defined role of each organization and department
		Alignment of plan among organizations	Coordinated plan and timeline among organizations in the system
	More funding for system improvement		More funding for disaster management system improvement
Improved Collaboration Partnership	Building Rapport	Keeping constant working relationship	Constant interactions with partners for building rapport
		Improved collaboration through co-planning	Co-planning with other partner organizations
		Trust through co-exercise	Co-exercises with other partner organizations
	Improvement in Interaction Structure	Collaboration under unified system	Establish unified system for better coordination among organizations
		Fewer bureaucratic layers in decision making	High rank personnel involvement for the quicker decision making
		Building new units for coordination	Building new coordinating units in the system for better collaboration
	Improved Supports from partners	Supports from political leaders	Support from political leaders for better collaboration
		Supports from national network partners	Personnel and resources within national network partners
		Supports from local/regional partners	Personnel and resources from partners in the same region
		Supports from partners in civil sector	Personnel and resources from civil sector partners

Table 3-8 Structured codes identified for major problems in disaster management

Category	Concept	Code	Description
Problems in Operation	Failure in human resource management	Staffing	Lack of personnel for operation
		Deteriorated personnel working conditions	Insufficient facilities and resources that weaken personnel morale
		Inexperienced personnel	Inexperienced personnel with insufficient training
		Turnover in major positions	Replacement of personnel in major positions
	Failure in resource management	Delayed or partial delivery	Delayed or partial resource delivery
		Inaccurate estimation for needs	Lack of exact resource estimation system
		Failure in vendor management	Unreliable resource delivery by private vendors in a timely manner
		Lack of available resources	Lack of resource in the disaster management system
	Lack of proper management plan/procedures	Lack of clear disaster management plan	Lack of proper disaster management plan
		Lack of flexibility for adaptation	Inflexibility of plan for adaptation
		Lack of aligned plan	Incompatibility of plan among organizations
	Insufficient funding		Insufficient funding for operation
Difficulties in getting common operating picture	Lack of situational awareness	Failure in transmitting action knowledge	Problems in diffusing action knowledge
		Difficulty in processing and producing action knowledge	Organizational incompetency in processing and producing action knowledge for collaboration
	Problems in communication system	Communication system breakdown	Communication system breakdown
		Lack of communication equipment	Lack of extra communication facilities for redundancy
		Lack of communication channels	Lack of clear communication channels and partners
		Lack of proper technology for communication	Lack of proper communication technology
Problems in collaboration	Lack of collaborative attitudes	Rivalries among organizations	Territorialism or competing interests on authority
		Competition for resources	Competition among organizations for the same resources
		Ego (Personality)	Personal tendency refusing collaboration
	Institutional barriers	Lack of transparency in its operation	Hidden agenda preventing collaboration
		Bureaucratic incompetence	Lack of collaboration due to the bureaucratic incompetency
		Lack of coordinating structure	Lack of coordination institutional structure
		Unexpected intervention from political leaders	Unexpected intervention from political leaders which disrupt the entire operation
		Lack of collaboration experiences	Lack of collaboration experiences

Table 3-9 Structured codes for the suggestion of future disaster management

Code 1	Code 2	Code 3	Description
Factors for better collaboration	Communication	More communication with partners	More communication during disaster response and mitigation
		Application of more advanced technology	Application of more advanced technology
		More communication equipment	More equipment for better communication
	Building rapport with partners	Mutual understanding of other's role and limitation	Clear understanding of other's role and weakness
		Constant co-training, planning, operation	More co-planning, co-training, and co-operation
		Establish working relationship through interaction	Constant interactions with partners for constant working relationship
		Developing community partnership	Reinforcing partnership with community and education for publics
Factors for better operation	Resources Management	More available resources in the system	Securing more available resources in the system
		Exact resource assessment for demands and supplies	Developing resource management system for exact estimation
	Human Resource Management	More consideration for personnel welfare	Investment in personnel welfare during operations of disaster response and mitigation
		Staffing	More personnel for operation
		Experienced leadership for adaptation	Securing more experienced managers for adaptation
		More training and education	More required training programs for personnel
	Planning	Constant planning for adaptation	Frequent updates for appropriateness of the disaster management plan
		Aligned and shared timeline	Aligning each disaster plan with other partner organizations
	More Funding for system improvement		More funding for education, equipment, facilities, and planning

3.5 EXAMINING INTERACTION STRUCTURE AND IDENTIFYING GAPS BETWEEN TWO HURRICANE RESPONSE SYSTEMS

3.5.1 Analytic purpose of social network analysis

The complex adaptive system can be understood as a network that is comprised of a set of nodes and links. A node is the smallest unit in a network and a link is a relation between two nodes, or points of intersection, in a network. In case of a multi-level (Multi-jurisdictional and multi-sectoral) response system, nodes can include federal agencies, local governments, and other related organizations such as non-profit or private organizations. Those nodes are connected and interdependent with each other through links in the networked structure.

An organizational network does not simply mean relationships, but it is a 'network structure' (Keast et al. 2004). Keast and his colleagues argued that networking is a common term that refers to actors making connections with each other. The 'networking' can be formal and also informal, while the 'network' means the connections become formalized. It may involve simultaneous actions by independent actors. More specifically, 'network structure' is formed from the formalized networking when actors realize that working separately is not enough to solve a particular problem or issue. In this sense, formality and strategic interdependence distinguish organizational networks from simple networking. So, the organizational network is a collectivity in which each member shares broad missions with 'strategically interdependent' actors for the effective collective problem solving.

I examined the difference between 'network' and 'networking' in each hurricane response system and how innovative creation of collaborative links (networking) contributed to the effective adaptation of the hurricane response system to changing conditions of crisis. Also, I compared the two separate networks of disaster response to Hurricane Katrina and Hurricane Gustav. Through this network comparison of two hurricane response systems, this study checked the questions of: 1) what are the actual interaction patterns among organizations and how do they create vulnerability and opportunities for organizations in a complex adaptive system, 2) how can large complex adaptive systems be formed from smaller components and what factors influence it, 3) what organizations are structurally important and who takes the key role in collaboration. Eventually, this study identified whether there was any evidence of organizational learning in the three years since Hurricane Katrina tested the response system and how this organizational learning in changing interaction patterns and organizational capacities contributed to the effective organizational adaptation to changing conditions.

3.5.2 Measures of social network analysis for the examination of interaction structure

From the content analysis of newspaper articles and situation reports for Hurricanes Katrina and Gustav, this study acquired a structured data set that was used for the social network analysis. This structured data set from content analysis of newspaper articles and situation reports were verified by practicing managers of hurricane response systems. For the identification of evidences of organizational learning in managing collaborative relationships, this study uses Quadratic Assignment Procedure (QAP) analysis. QAP analysis starts from the following research question;

> *If there is a tie between two particular actors in one relation, is there likely to be a tie between them in another relation? If two actors have a strong tie of one type, are they also likely to have a strong tie of another?* (Hanneman, 2005)

According to Hanneman (2005), when we have information about multiple relations among the same sets of actors, it is often of considerable interest whether the probability (or strength) of a tie of one type is related to the probability (or strength) of another. An effort to answer to this question correlates to the identification of evidence of organizational learning. If organizations in the Hurricane Katrina response system created more effective collaborative links in the system, and if organizations in the Hurricane Gustav response system learned lessons from the experiences of the Hurricane Katrina, they needed to use the organizational learning to revise the new version of the emergency management plan.

To address the research question of how large complex adaptive systems can be formed from smaller components and what factors influence its formation, I used clique analysis and identified the sub-groups in the Hurricane Katrina and Hurricane Gustav response systems and compared the cliques or sub-groups of each system to see whether there are any changes since the landfall of Hurricane Katrina in 2005. As Hanneman argued (2005), many of the approaches

to understanding the structure of a network emphasize examining how dense connections are built-up from simpler dyads and triads to more extended dense clusters such as cliques. This view of social structure focuses attention on how solidarity and connection of large social structures can be built up out of small and tight components. Also, with this clique analysis, this study identified the embedded relationships of core organizations and the relationships between subgroups. The definition of clique or subgroup in social network analysis is that a clique is a sub-set of a network in which the actors are more closely and intensely tied to one another than they are to other members of the network (Hanneman, 2005). The smallest unit of relationship to form a clique is two, but at this level the number of cliques will be greatly increased rendering no analytic advantage for this study. So to control the number of cliques and make the network comparison manageable, this study will set a minimum size for organizations at three. One thing to clarify is that the directed links of the disaster management network were symmetrized because, by definition, ties must be reciprocated in order to count for cliques. So a tie or link between organizations only exists if x→ y and y→x are both present.

For the identification of core actors or organizations in the hurricane response systems, this study used centrality measures of social network analysis. The most common way to identify the core actors in a network would be the use of several measures of centrality with the combination of intuitive interpretation of a sociogram. Centrality can be considered as a primary criterion for choosing core actors in the disaster network. Considering the complex characteristics of the hurricane response networks for Hurricanes Katrina and Hurricane Gustav, I used various conceptual standards more than total degree of centrality. Traditionally, as Freeman (1979) suggested, there are three basic centralities; Degree, Closeness, and Betweeness for the identification of core actors in a network. The problem of using centrality measurement is

that there seems to be no dominant centrality measurement in defining core nodes. In other words, each centrality measurement is a partial one and has its own strengths and weaknesses in identifying core actors. For example, a particular organization can be central in the sense that it has the most number of ties with other nodes in Degree Centrality[19]. Others can be powerful because they display the closest geodesic distance from other actors in Closeness Centrality[20]. At the same time, the length of paths between nodes also can matter in Betweeness centrality[21]. These various types of centrality imply that any one measurement cannot capture the exact 'central' nodes, and the combination or multiple use of centrality needs to be suggested.

For example, it is intuitive to say that the organizations with a large number of links in the entire system can be considered a core organization in the system, but at the same time, as Burt (1992) argued, power can be originated from the ability of 'bridging' actors and activities. Facing severe damage to their communication systems, some organizations in Hurricane Katrina response system functioned as 'mediators' and these organizations contributed by making the response system more adaptive to changing conditions. While focusing on the concept of 'centrality' for the identification of core actors, I considered the concept of 'mediator' at the

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19 Degree Centrality is based on adjacency and the number of immediate ties, such as dyadic relations, a node has. The strength of Degree Centrality is that it is useful in finding dominant actors in the network. The assumption is that if any actor has a high Degree centrality, it can be considered as powerful or dominant in the network because the more ties the actor has, the more opportunities and alternatives it will have. And this will make it possible for the actor not to be too dependent on any specific actor. Because this study assumed that this network is a directed one, we can use this centrality more in detail by dividing it into in-degree and out-degree centrality. According to Hanneman (2001), in-degree centrality shows how influential the actor may be, and the out-degree actor indicates that how prestigious the actor may be.

20 The closeness centrality is a measurement which is based on geodesic distances. It emphasizes the distance of an actor to all others in the network. According to Hanneman (2001), this concept is useful in the sense that it considers the relationship with all other nodes in the network. The basic assumption is that if any node has a high closeness centrality, then it can be a central actor because this actor can reach other actors with shorter paths and it can be favored by other actors.

21Betweeness centrality shows an actor who is located between actors and within a network, other actors depend on exchanges such as information and resources. Hanneman (2001) said that the betweeness assumes that the actor who is located in important geodesic paths is considered significant under the assumption that if any node has a betweeness location in the path, it can increase its leverage in the exchange activities.

same time. Thus, for the identification of 'core' actors in the network, I used both the concept of 'centrality' that deals with the most frequent relationships and the concept of 'mediator' that deals with the most critical interactions for information and resource sharing at the same time. Using these various centrality measures, this study compared two hurricane response systems and checked whether there are any changes in interactions among organizations as an evidence of organizational learning.

Based on findings from social network analysis, I developed management strategies for effective adaptation and those strategies were applied to the creation of new collaboration patterns. One of the critical knowledge for the strategic intervention could be gained from the identification of critical collaboration links in the hurricane response systems. To identify the most critical collaboration links among organizations and weaknesses in collaboration, this study used fragmentation analysis and lambda set analysis. While the clique or subgroup analysis checked how the large system was composed of small subgroups and which group or organization played the key role in connecting the entire subgroup, lambda set analysis identified the vulnerabilities of the disaster response systems. Once those weak nodes or links were identified, I developed a computational simulation to strategically intervene at these weak points and conducted an experimental study on guiding more effective system evolution with stability and resilience.

The concept of fragmentation analysis basically asks if there are certain connections in the graph which, if removed, would result in a disconnected structure (Hanneman 2005). The Lambda set approach ranks each of the relationships in the network in terms of importance by evaluating how much of the flow among actors in the network goes through each link. It then identifies sets of relationships which, if disconnected, would most greatly disrupt collaborations

among all of the actors. So, to check for the weaknesses in relationships, this study conducted a lambda set analysis first. Then, with this lambda set analysis, this study checked 'network robustness' which measures the stability of the entire structure when any major nodes are removed. This is especially meaningful in a disaster dynamic network because there is a sufficient possibility that nodes might be eliminated from the network by the unexpected impact of disasters.

3.6 AGENT-BASED COMPUTATIONAL SIMULATION IN DESIGNING COMPLEX ADAPTIVE SYSTEM

3.6.1 Analytic purpose of agent-based computational simulation

From the content analysis and social network analysis, I accumulated and prepared the data set to analyze the multi-agent based computational simulation. With the social network analysis, I identified weak structural points requiring intervention. Also, with data from the semi-structured interviews, I was able to provide insights into how to intervene. Through the agent-based computational simulation, I addressed the research question of how the complex system evolves, changes, and adapts to changing conditions and how it responds to conditional impact from outside with and without intervention.

More specifically, I posed sub-questions including: what types of interventions would guide a successful network evolution? What factors can be used as parameters for guiding improved performance of disaster response system? What factors inhibit 'network collapse' or, from the opposite perspective, what factors support 'network stabilization' after a major disaster?

One issue to clarify for the agent-based computational simulation analysis is what is meant by the "strategic intervention" in guiding a resilient and stable evolution of system. Like other social systems, a complex adaptive system operates under limitations from environmental complexity. For example, as identified in the semi-structured interviews, organizations in a disaster response system experienced a communication meltdown or a lack of personnel and resources. In this situation, the task of effective information sharing and resource allocation is hard to achieve, and organizations in the system face difficulties in adapting to changing conditions.

To address this problem, I virtually increased the capacities of organizations to make them process information more effectively. Also, I restructured or recreated collaboration links between core organizations in the system. These strategic interventions were possible through the identification of strengths and weaknesses in their relationships and the core actors in the Hurricane Katrina and Hurricane Gustav response systems. The third way of strategic intervention is to check the effect of culture, such as trust or rapport among organizations in disaster response (Comfort, 2005) that can be established between organizations through joint training exercises and drills. For example, the collaboration involved in planning and executing practice exercises before crisis can develop rapport. And this may increase the amount and the accuracy of information that any organization transmits to others with whom they have already established a good working partnership.

3.6.2 Development of a performance measurement metric for network comparison

This study developed a performance evaluation tool that compares networks to determine which intervention strategies can be effective in improving performance of a complex adaptive system. Although limited research on the measurement of network performance has been done, some

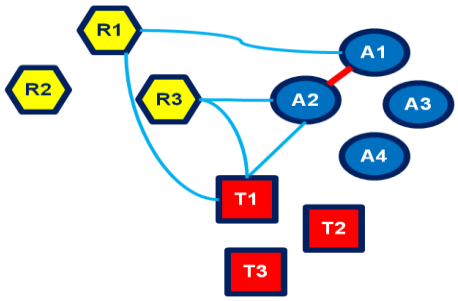
network researchers have started developing tools for this performance measurement in the network. For example, Moon and Carley (2007) developed the performance measures of knowledge diffusion (KD) and task completion (TC) in networks and suggested metrics for gauging knowledge and resource dispersion across organizations. According to this measurement, the ability to complete the system's mission depends on nodes receiving information. Therefore, information should be circulated and transmitted securely and rapidly for any system to adapt to a changing environment effectively. Using the ideas of knowledge diffusion (KD) and task completion (TC), this study developed a performance measurement formula: the rate of resource allocation in the disaster response system. The logic behind this formula is that, to complete its assigned mission, no organization can stand alone with its own resources. Complex and uncertain situations require timely and accurate resource allocation among organizations. If not, the lack of resources makes the collaboration fail and finally leads to the collapse of the disaster response system and eventually the failure of an organization to adapt to changing conditions.

The formula for resource allocation is defined as, $RA = \frac{\sum_{i=0}^{K} \sum_{j=0}^{A} ARij}{R*A}$ in which, A means agent and R means resources to be allocated to other organizations. The concept of network adaptation is already included in this formula. Instead of the comparison of static networks, it compares the degree of resource allocation after initial stage (i=0, j=0) and checks how organizations allocate resources over time. From semi-structured interviews, this study explored critical factors that influence the performance of the entire disaster response system, and by inserting these parameters into computational simulation models, this study explored the effects of single or combined parameters on the construction of adaptive system.

However, the metric of resource allocation is a proxy that does not directly measure the performance of the disaster response system. This metric is based on the assumption that the

effectiveness of the performance of a complex adaptive system depends on timely allocation of available resources to requesting organizations in the system. Especially when normal operating procedures fail and the communication system breaks down due to major crisis, the need for interdependency for resource allocation increases significantly. In this sense, resource alignment measures how well the collective activities of organizations distributed system-wide resources to other organizations. In developing this metric, this study considers two aspects. The first thing to consider is whether or not an organization has a resource that will be required by other organizations in the system. If an organization has specific resources - for example, generators for electricity, helicopters for search and rescue, or regular supplies for shelter management etc. - and if partnering organizations pursuing a related mission do not have enough equipment or resources for the completion of that mission, the partnering organizations will then make a request for the needed resource to the organization that has it.

The second aspect to consider is whether or not an organization is assigned to a task. If an organization has a resource but that resource cannot be used for the completion of any specific mission-related function, then the existence of that organization and the resources that organization has cannot contribute to the completion of any specific mission. For example: the Louisiana Department of Wildlife and Fisheries has a flat boat for its search and rescue functions but the American Red Cross does not need that resource for its sheltering function because they do not operate in the same functional domain. Therefore, whether any two organizations operate in the same emergency support function (ESF) domain is also important in building a performance measurement metric. The conceptual framework used to build the resource allocation (RA) metric is shown in Figure 4-5.



A: Agency (Organization)
R: Resources
T: Task (Emergency Support Function)

Figure 3-4 Framework of relationship between agency, resources, task

Figure 3-4 represents a simple example of relationship between agencies, its task, and its resources. The mission of Agency 2 (A2) is to do Task 1 (T1), and to do Task 1, Agency 2 needs Resource 1 (R1) and Resource 3 (R3). While Agency 2 has Resource 3 available, it does not have access to Resource 1, which is owned by Agency 1. For the completion of Task 1 and to get the necessary resource for the completion of Task 1, Agency 2 requires a resource to Agency 1. In this virtual situation, the major policy issue is how to facilitate the resource allocation between Agency 1 and Agency 2 in a timely manner. In other words, the strength, stability, and resilience of links between Agency 1 and Agency 2 are the most critical things to consider in building adaptive systems for disaster response and mitigation. After considering two aspects - the availability of resources and the assigned task of each organization, this study developed the metric for measuring the effectiveness of resource allocation between agencies more specifically as shown in formula 1.

Formula 1: *Resource Alignment*

$$= \frac{\sum_{i}^{(\text{num of org})} \left(\frac{\sum_{j}^{(\text{num of assigned tasks of org}_i)} (\text{num of required resouces for task}_j \text{ and acquired by org}_i)}{(\text{num of assigned tasks of org}_i)} \right)}{(\text{num of org})}$$

3.6.3 Logic of multi-agent based computational simulation

An organization initiating resource-allocation procedures with another organization must go through the following steps. First, in time N, when agent 1 needs resources for its task completion, it finds resource exchange candidates within two social links. The reason why agent 1 looks to its interaction partner within two social links is due to its embeddedness in the major disaster response plans. To acquire the necessary resources from other local, state and federal agencies, requests from local agencies must pass through the coordination system of the Parish EOC and the Governor's Office of Homeland Security and Emergency Preparedness (GOHSEP). So, the request for a resource allocation from the local agencies in the disaster response system should pass through at least two social links or nodes, the local Parish EOC or GOHSEP.

Second, agent 1 in the simulation model evaluates the probability of successful interaction between possible candidates and the organization itself. In evaluating the possibility of success, agent 1 considers whether the partnering organization has the necessary resources, and at the same time, it considers the disaster management plans and whether the interaction with the targeted organization is possible. It also considers whether it has a close working relationship with the partnering organization for the resource exchange.

Finally, based on this evaluation, agency 1 selects an interacting organization and sends a request for a resource allocation. In finding an interacting candidate in the disaster management system, agent 1 also has to consider two 'if' questions. First, when any organization tries to interact with other organizations within two social links, if that target organization does not have a required resource, then that organization should follow the previous three steps again. Second, after it succeeds in finding the organization which has a required resource, if that target organization does not have enough cognitive capacity required to process the necessary

information, then this trial for interaction will just result in numerous 'No Responses (NRs)' in the system.

A successful resource exchange depends on the level of available resources of partnering organizations, a pre-defined role set by the disaster management plan, the existence of a solid working relationship, and the cognitive capacity of coordinating organizations. Some clarity is necessary regarding the relationship between clear roles defined by the disaster management plan and the solid working relationship among organizations. When previously agreed upon interaction is not possible under the extreme conditions of a disaster or when an organization functionally does not exist after a severe hit by a major disaster, organizations in the complex adaptive system seek possible alternative interactions and the collaboration history or solid working relationship helps the organization find a possible partner for resource allocation more effectively. In this sense, the pre-defined partnership and historically reinforced partnerships are both important for any organization to find partners for resource exchange. Figure 3-5 shows the algorithm of agent-based simulation model of this study.

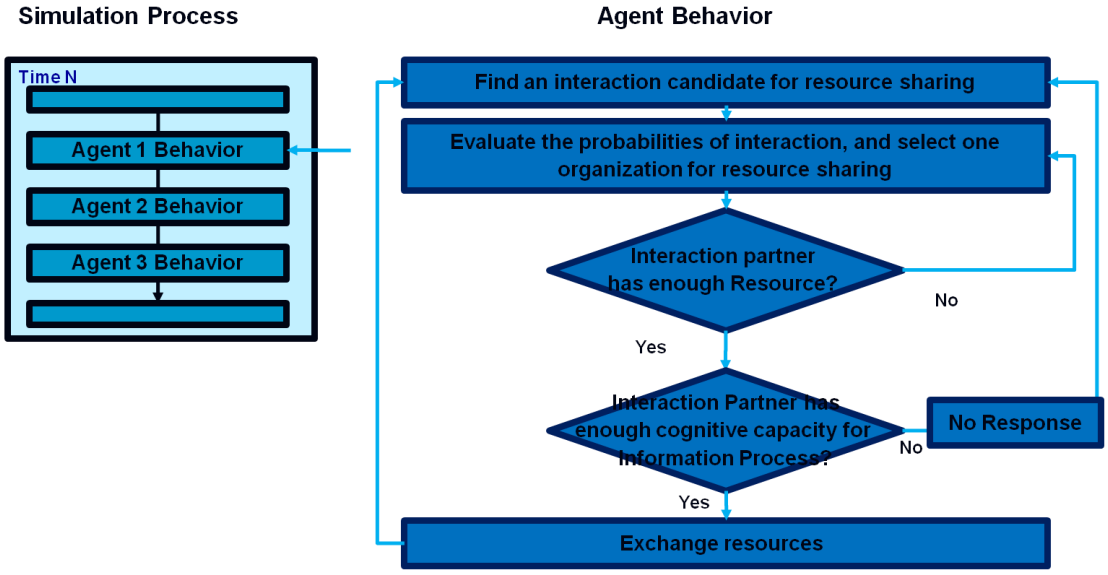


Figure 3-5 Algorithm of agent-based simulation Model

3.6.4 Steps of multi-agent based computational simulation

Based on the logic in the computational simulation, this study defines the steps of multi-agent based simulation in this section. First, the cycle of the computational simulation starts from the identification of key parameters. To improve the relevance of the computational simulation model, the identification of core parameters should be conducted by semi-structured interviews.

The second step of the computational simulation is the exploration of the parameter space. One must identify how to operationalize the core parameters in the computational simulation model and define what values each parameter can have. By varying the value of core parameters in the system, this study will check how changes in the parameter values affect the overall performance of a complex adaptive system in resource allocation.

The third part of the computational simulation is the execution of the computational simulation. This study will run the simulation 20,000 times and observe the evolution patterns of the complex adaptive system. Using a computational simulation allows the model to be run through a high volume of cycles. This will be a great advantage because, under normal situations, this many experiments are impossible with actual cases of response systems to major crisis. Comparative analysis of several hurricanes that hit different regions at different times is possible in a very limited way, but the lack of real-time data for disaster management requires use of a simulation method. The fourth step of computational simulation is the validation and recalibration process. Through calibrating and fitting the model of computational simulation, this study will adjust the value of parameters and explore the parameter space more in detail.

The final step of this computational simulation is to form several hypotheses or possible policy recommendations based on the result of the computational simulation. If any parameter proves to contribute significantly to the improved performance of the modeled complex adaptive

system, this study will suggest that that parameter be carefully considered when designing future interaction structures and developing policy alternatives for more effective system adaptation to changing conditions. These five steps of the computational simulation are shown in Figure 3-6.

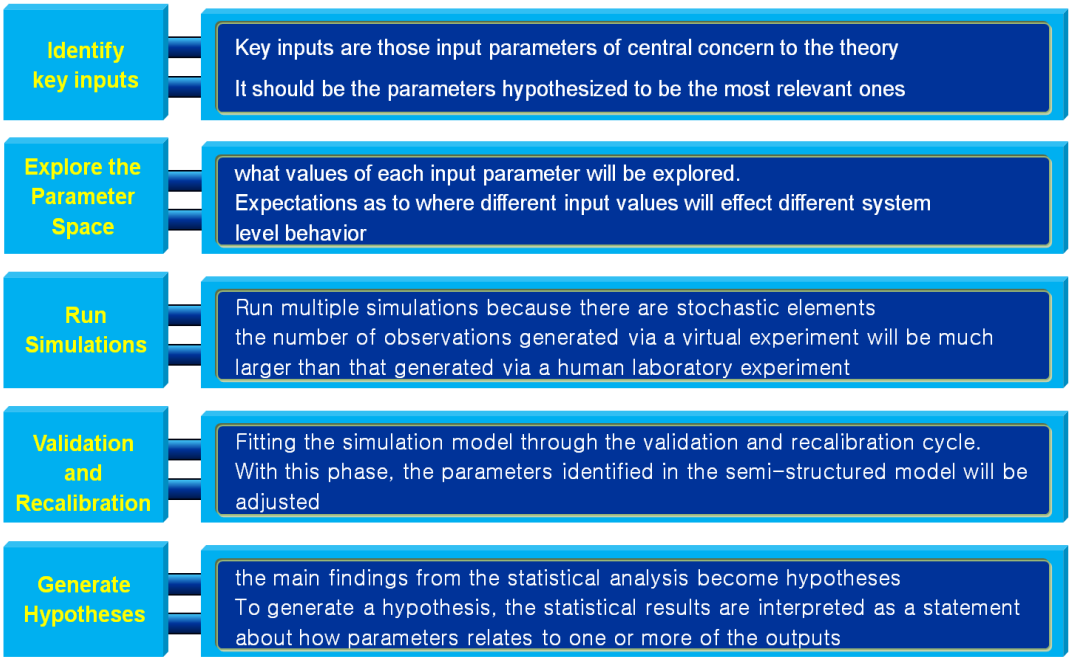


Figure 3-6 Steps of multi-agent based computational simulation

3.6.5 Expected outputs of computational simulation

With a static data set, this study can only compare a limited phase of the network adaptation and evolution. But, networks change and evolve over time, and the prediction of this evolution is very important in designing a more resilient and stable adaptive system. Adaptation, as is necessary for system survival, is not a one-time influence but an ongoing process that is continuously constructed and reconstructed during interaction with the environment. A study of this nature can expect any pattern of evolution over time, but this natural evolution cannot guarantee that it is moving in a desirable direction under conditions of complexity and

uncertainty. Therefore, I will develop possible policy alternatives and check how can strategic intervention alternatives can make the network perform better, and eventually to adapt to changing conditions.

The concept of strategic intervention requires finding successful strategies (Carley, 2004) to make the complex adaptive system recover and adapt successfully in a changing environment. A strategic intervention in a network means to arbitrate between the entities or links of a network. For instance, a node can be added or removed, so as to form a link (Borgatti et al, 2006; Albert et al, 2000) to increase information and resource sharing among organizations in the network. Also, by adding links, we can increase the capacity of an organization in processing information and delivering required resources to other organizations in a timely manner.

The idea of network evolution and strategic intervention inherently include the concept that there is a starting point of organizational relationship (every network evolution has its initial point t=0). These interventions can increase performance, but they can also disrupt existing relationships and lead to the deterioration of network performance. Roughly, there are three possible types of system evolution: "Improvement", "Resilience", and "Dysfunction". In the case of "Improvement", the diffusion rate goes above the baseline after the intervention. This instant performance improvement is the ideal type of system evolution. When "Resilience" occurs, the diffusion rate goes down immediately after the intervention but can recover within several periods of time. This case has some policy implications because there is sufficient possibility that any core organization may be rendered functionally dead for a comparatively long period of time. During response operations for Hurricane Katrina, many critical organizations were isolated due to the collapse of the communication system, which led to the malfunction of those organizations. Designing a system to recover from this situation is a critical policy issue. This case of

"Resilience" can identify some policy implications to assist organizations recover from outer impacts. In the case of "Dysfunction" the diffusion rate goes down and the damage will be sustained for multiple time points. This is the pattern for any complex adaptive system to avoid in its path of evolution. The three possible evolution patterns are shown in figure 3-7. This study will pursue "Improvement" and "Resilience" as desirable evolution patterns and seek strategies of how to avoid the "Dysfunction" condition.

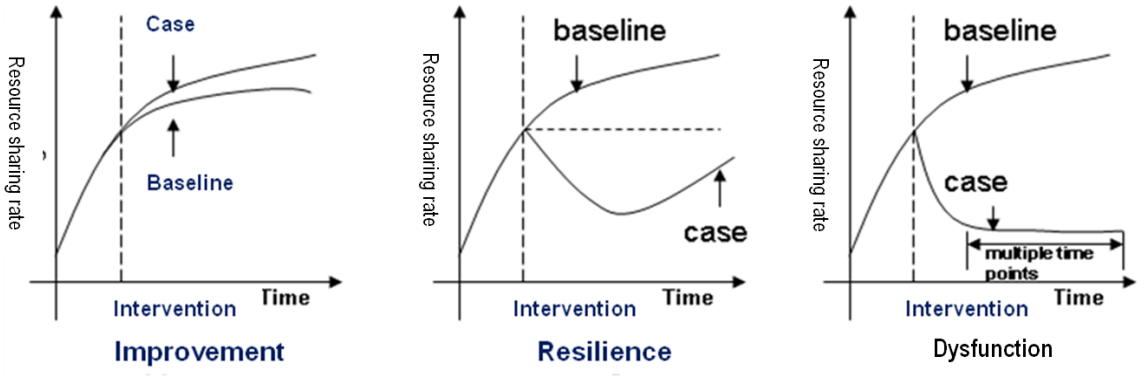


Figure 3-7 Three possible evolution patterns after strategic intervention

4.0 THE CONTEXT FOR ADAPTATION: THE ASSESSMENT OF EXTERNAL ENVIRONMENT OF THE 2005 AND 2008 GULF COAST HURRICANES

This chapter introduces two cases of comparative study of organizational adaptation to changing conditions; the response systems to Hurricane Katrina and Hurricane Gustav. It provides contextual information gained from an assessment of external environments. Environmental factors, combined with internal organizational capacities, affect the overall performance of system. From these environmental assessments, I identified opportunities and threats (Bryson, 1988) that organizations in the system faced during their response to Hurricane Katrina and Hurricane Gustav. Basically, the external factors are those that organizations cannot control, while the inside factors are those mostly controlled by the organizations in the system (Pfeffer & Salancik, 1978). As Bryson (1988) argued, the identification of opportunities and threats can be discovered through monitoring a variety of political, economic, legal, and technological forces and the organizations in the system can cleverly use these assessments in improving their capacities for effective adaptation to changing conditions.

As the major contextual information, this study discusses legal, technical, and social/political factors that directly or indirectly affected the performance of the system's responses to Hurricane Katrina and Hurricane Gustav. For the legal factors, I investigated the fundamental disaster management plans at the local, state, and federal level and how disaster management plans in each level were integrated or failed to be integrated into a consistent plan

in response to Hurricane Katrina. I also identified how weaknesses in laws and plans for the response to Hurricane Katrina could be revised based on learning from failures. For the technical assessment that affected the operation of hurricane response systems, I focused on issues in management of the levees' system, technical and management issues in the communications system breakdown, and the blackout of electricity, especially for the Hurricane Gustav response system. For the categorization of political and social factors, I examined the failure of exerting responsible leadership, inequality in economic and social status, and racial issues that prevent organizations from collaborating effectively in response to crises.

4.1 THE CONTEXT OF THE HURRICANE KATRINA AND HURRICANE GUSTAV RESPONSE SYSTEMS

4.1.1 Hurricane Katrina (August-September 2005)

Hurricane Katrina formed over the Bahamas on August 23, 2005, and crossed southern Florida as a moderate Category 1 hurricane, causing flooding before strengthening rapidly in the Gulf of Mexico. Katrina made its second landfall at 6:10 a.m. CDT[22] on Monday, August 29 as a Category 3 hurricane with sustained winds of 125 mph near Buras-Triumph, Louisiana. At landfall, hurricane-force winds extended outward 120 miles from the center and the storm's central pressure was 920 mbar. After moving over southeastern Louisiana and Breton Sound, it made its third landfall near the Louisiana/Mississippi border with 120 mph sustained winds, still at Category 3 intensity (See figure 4-1 below).

[22] Central Daylight Time

Facing this large scale disaster, the National Hurricane Center (NHC) issued a hurricane watch for southeastern Louisiana, including the New Orleans area at 10 a.m. CDT Saturday, August 27. That afternoon, the National Hurricane Center extended the watch to cover the Mississippi and Alabama coastlines as well as the Louisiana coast to Intracoastal City. Also, the United States Coast Guard began pre-positioning resources beyond the expected impact zone starting on August 26, and activated more than 400 reservists. Also, the President of the United States declared a state of emergency in selected regions of Louisiana, Alabama, and Mississippi on Saturday, the 27th, two days before the hurricane made landfall. That same evening, the National Hurricane Center upgraded the storm alert status from hurricane watch to hurricane warning over the stretch of coastline between Morgan City, Louisiana to the Alabama-Florida border. During video conferences involving the president on August 28 and 29, the director of the National Hurricane Center, Max Mayfield, expressed concern that Katrina might push its storm surge over the city's levees and flood walls. On Sunday, August 28, President Bush spoke with Governor Blanco to encourage her to order a mandatory evacuation of New Orleans (United States Senate, Committee on Homeland Security and Governmental Affairs 2006).

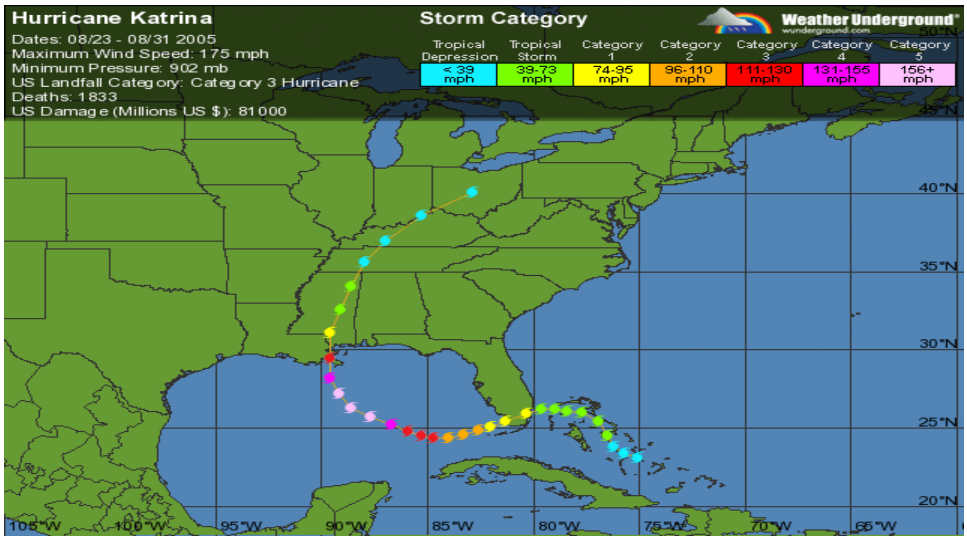
But, in spite of those various preparation and response activities, the response system at all levels of government did not work properly. As delineated in the National Response Plan (2004), disaster response and planning was first and foremost a local government responsibility. When local government exhausts its resources, it then requests specific additional resources from the parish level. The request process proceeds similarly from the parish to the state to the federal government as additional resource needs are identified. Many of the problems in disaster response to Hurricane Katrina arose from inadequate planning and breakdown of back-up communications systems at various levels (refer 4-2 for more detailed discussion). Also, even

though some disaster recovery responses to Katrina began before the storm, the level of preparedness was lower than expectations and the voluntary activities from faith-based organizations and residents from communities could not be coordinated and guided in an effective manner.

In responding to these chaotic situations of official system breakdown, the activities of military agencies were highly regarded. Of the 60,000 people stranded in New Orleans, the Coast Guard rescued more than 33,500 (GAO, 2006). The United States Northern Command established Joint Task Force Katrina based out of Camp Shelby, Mississippi, to act as the military's on-scene command on Sunday, August 28 (Bowman et al, 2005; GAO-06-643). Approximately 58,000 National Guard personnel were activated to deal with the storm's aftermath with troops coming from all 50 states; the Department of Defense also activated volunteer members of the Civil Air Patrol (CNN, 2006). But the Department of Homeland Security's late decision to take over the federal, state, and local operations officially on 12:00 CDT August 30, 2005 was doomed to fail. This decision was rejected by Governor Blanco who indicated that her National Guard could manage the situation, an analysis that was already proven false (GAO-06-643). FEMA provided housing assistance to more than 700,000 applicants, but only one-fifth of the trailers requested in Orleans Parish had been supplied, resulting in an enormous housing shortage in the city of New Orleans.

At least 1,464 people lost their lives in the actual hurricane and in the subsequent floods, making it the deadliest U.S. hurricane since the 1928 Okeechobee Hurricane (Department of Health and Hospitals, 2006). The economic effects of the storm were far-reaching and by April 2006, the Bush Administration had sought $105 billion for repairs and reconstruction in the region (Boston Globe, 2006). Also, Katrina redistributed over one million people from the

central Gulf Coast elsewhere across the United States; this became the largest diaspora in the history of the United States. By July, 2006, when new population estimates were calculated by the U.S. Census Bureau, the state of Louisiana showed a population decline of 219,563, or 4.87% (U.S. Census Bureau, Population Estimate, 2006).



Source: Weather Underground (http://www.wunderground.com)

Figure 4-1 Trace and change of strength of hurricane Katrina

The criticisms of the government's response to Hurricane Katrina primarily consisted of condemnations of the mismanagement of the communication system and the lack of leadership in the relief efforts in response to the storm and its aftermath. More specifically, criticism focused on the delayed response to the flooding of New Orleans, and the subsequent state of chaos in the southern part of Louisiana (Thevenot and Gordon, 2006). Within days of Katrina's August 29, 2005 landfall, public debate arose about the local, state and federal governments' role in the preparations for and response to the hurricane. Criticism was initially prompted by televised images of visibly shaken and frustrated political leaders, and of residents who remained stranded by flood waters without potable water, food or shelter. In accordance with federal law, then-President George W. Bush directed the Secretary of the Department of Homeland Security,

Michael Chertoff, to coordinate the Federal response. Chertoff designated Michael D. Brown, head of the Federal Emergency Management Agency, as the Principal Federal Official to lead the deployment and coordination of all federal response resources and forces in the Gulf Coast region. However, the President and Secretary Chertoff initially came under harsh criticism for what some perceived as a lack of planning and coordination, even Governor Blanco had challenged their efforts. Eight days later, Brown was recalled to Washington and Coast Guard Vice Admiral Thad W. Allen replaced him as chief of hurricane relief operations (Failure of Initiative, 2006).

Additionally, there was strong criticism of the local and state government headed by Mayor Ray Nagin of New Orleans and Louisiana Governor Kathleen Blanco respectively. Nagin and Blanco were criticized for failing to implement New Orleans' evacuation plan and for ordering residents to a shelter of last resort without any provisions for food, water, security, or sanitation. Perhaps the most important criticism of Nagin was that he delayed his emergency evacuation order until 19 hours before landfall, which led to hundreds of deaths of people who, by that time, could not find any way out of the city. The destruction wrought by Hurricane Katrina raised other, more general public policy issues about emergency management, environmental policy, poverty, and unemployment. The storm's devastation also prompted a Congressional investigation, which found that FEMA and the Red Cross did not have a logistics capacity sophisticated enough to fully support the massive number of Gulf coast victims (Failure of Initiative, 2006).

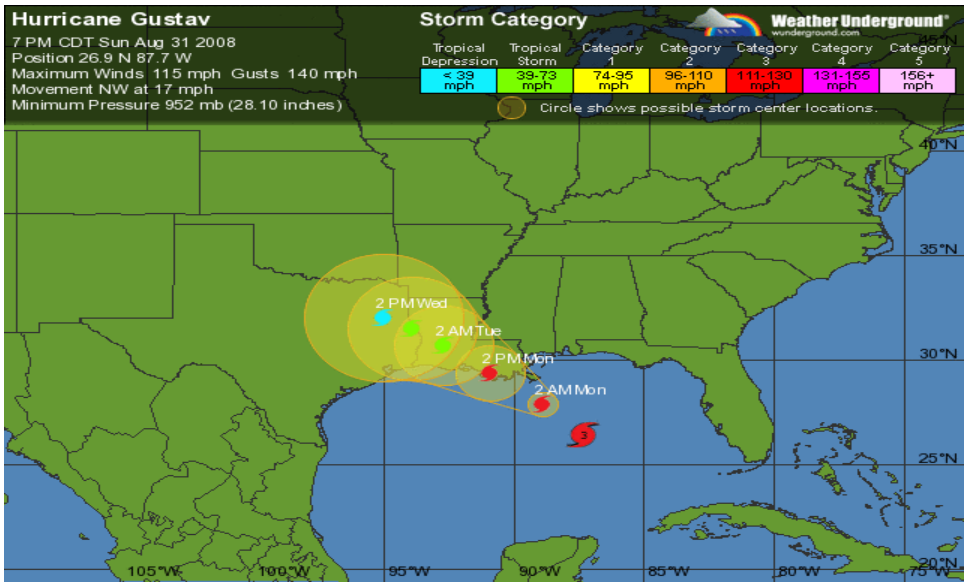
The disaster response system for Hurricane Katrina was a significant failure in terms of securing citizen’s lives and welfare. These conditions resulted from the lack of a coordination structure, the breakdown of the communication system, the inappropriate leadership in creative

adaptation, and the lack of resources for an effective operation. Since the failure of Hurricane Katrina, the United States government committed significant resources, attention, and time to establish a more effective disaster response framework and to improve performance of system. According to a Congressional report on policy changes since Hurricane Katrina (CRS report, RL33729), the United States government changed the structure of disaster management system, recalibrated FEMA's mission and responsibility, reinforced retention program for the better leadership, adopted strategic human capital plan for the training and education, and revised its procurement procedures. Three years after Hurricane Katrina's landfall, Hurricane Gustav made its landfall in almost the same region geographically and tested the integrity of the newly revised disaster response system.

4.1.2 Hurricane Gustav (August-September 2008)

Hurricane Gustav formed on the morning of August 25, 2008, about 260 miles southeast of Haiti and rapidly strengthened into a tropical storm that afternoon, and into a hurricane early on August 26. Later that day, it made landfall on the island of Hispaniola near Haiti, inundated Jamaica, ravaged Western Cuba and then steadily moved across the Gulf of Mexico. Once into the Gulf, Gustav gradually weakened due to increased wind shear and dry air. It weakened to a Category 2 hurricane late on August 31, and remained at that intensity until landfall on the morning of September 1 near Cocodrie, Louisiana. By 10 PM CDT, Gustav had been downgraded to a Tropical Storm with winds of 60 mph about 20 miles southwest of Alexandria, Louisiana and by 4 AM CDT on September 2 Gustav had diminished to a Tropical Depression with a threat of severe flooding in the lower Mississippi Valley and eastern Texas (National Hurricane Center, 2008).

After the severe criticism regarding the lack of preparation for Hurricane Katrina, all emergency management agencies were on alert before the landfall of Hurricane Gustav. On August 31, the National Hurricane Center predicted with 45% probability that Gustav would remain at Category 3 or above on September 1. This influenced preparations, although in fact Gustav had dropped just below the Category 3 threshold to Category 2 by landfall, and Category 1 shortly afterwards. On the morning of August 26, with Gustav still over Haiti, Louisiana emergency preparedness officials met several times to discuss predictions that Gustav would reach the state as a major hurricane in three to five days (Times Picayune, 2008).



Source: Weather Underground (http://www.wunderground.com)

Figure 4-2 Trace and the change of strength of Hurricane Gustav

Several areas of Louisiana planned for evacuations and parishes in the New Orleans area announced plans for voluntary evacuations beginning Saturday, August 30. New Orleans Mayor Ray Nagin said that it was possible that thousands of people who needed city help could start leaving on Saturday as the first wave of a full-scale evacuation. Later, he ordered the mandatory evacuation of the whole of New Orleans commencing on the morning of August 31, calling Gustav "the storm of the century ... the mother of all storms." on August 31 (MSNBC, 2008).

Nagin also declared a dusk-to-dawn curfew and the cessation of city assistance in evacuations by the afternoon (Times Picayune, 2008). By that afternoon, 1.9 million people had evacuated southern Louisiana, with 200,000 of them being residents of New Orleans alone, making it the largest evacuation in the history of Louisiana. Officials had finalized evacuation plans which proposed assisted evacuations as early as August 29, consisting of contraflow lane reversal on all major highways and 700 buses to help move evacuees. Wary of repeating the mistakes of Hurricane Katrina, authorities chose not to use the Louisiana Superdome and New Orleans Convention Center as emergency shelters (Times Picayune, 2008). The following day, Louisiana governor Bobby Jindal declared a state of emergency, activating between 3,000 and 8,000 members of the Louisiana National Guard.

In spite of a more advanced level of preparedness and coordination for disaster response activities, communities in Louisiana suffered severely from Hurricane Gustav mainly due to the strong wind and heavy rainfall resulting in a wide-range blackout of electrical services. Wind damage was severe enough to shut the city down for several days. Most businesses remained closed through September 5th, five days after landfall. Power lines along Baton Rouge's tree-lined streets were easily brought down as thousands of trees were uprooted and snapped in half by Gustav's fierce winds. Entire sections of the city were cut off by the mountains of debris. It would be two weeks before power was restored to all residents. Around 1.5 million people were without power in Louisiana on September 1 (Courier, 2008).

The responses to Hurricane Gustav were better prepared and coordinated than those of Hurricane Katrina. In this context, the comparison of Hurricane Katrina and Hurricane Gustav created an unprecedented chance for comparative analysis, rare in social science. As discussed in the chapter 3, the storms affected almost the same region and mobilized the entire disaster

management system. With this comparative study, it is possible to assess whether there is any sign of organizational/systemic learning from the earlier experiences of Hurricane Katrina. Estimating the effectiveness of disaster response and mitigation for two hurricanes, I extracted the critical factors and applied them to the design of a more resilient disaster management system. Table 3-1 summarizes and compares the two hurricanes response systems.

Table 4-1 Comparison between hurricane Katrina and hurricane Gustav

	Hurricane Katrina	Hurricane Gustav
Landfall	August 29th, 2005, near Buras about 55 miles south of New Orleans	September 1st, 2008, near Cocodrie, about 70 miles Southwest of New Orleans.
Strength (Saffir-Simpson Hurricane Scale)	Category 3	Category 2 & category 1 shortly afterwards
Damage	Over $100 billion (2005 USD)	Over $6.61 billion (2008 USD)
Fatalities	1,464	112 direct, 41 indirect
Strom surge	Estimated at 27 feet high.	Reported at 12 feet high.
Evacuation	No assisted evacuation before the storm.	Assisted evacuation as early as August 29.
Emergency declaration	Declared 2 days before the storm.	Declared 6 days before landfall.
Leadership change	FEMA headed by Michael Brown.	FEMA headed by David Paulison.
	New Orleans Mayor: Ray Nagin	New Orleans Mayor: Ray Nagin
	Louisiana Governor: Kathleen Blanco	Louisiana Governor: Bobby Jindal
Level of law enforcement	Law enforcement weak	Twice law enforcement than Katrina.
Levee status	Levees broke	Levees did not break

4.2 ASSESSMENT OF OPPORTUNITIES AND THREATS OF HURRICANE RESPONSE SYSTEMS

4.2.1 Assessment of legal factors: disaster management laws and plans

The operations and collaborations of organizations in the Hurricane Katrina response system were guided and regulated by National Response Plan (2004) that was the national plan to respond to emergencies such as natural disasters or terrorist attacks. It came into effect in December 2004, and was superseded by the National Response Framework on March 22, 2008

after the several revisions since the failure of Hurricane Katrina. The federal government first actively engaged in emergency management by passing the Congressional Act of 1803, which provided relief after a devastating fire in Portsmouth, New Hampshire. For the about the next 150 years, the federal government took a reactive role in emergency response until passing the Federal Civil Defense Act of 1950. But the problem of the previous disaster management plans was that there was no comprehensive plan for federal emergency response until 1979, when President Carter signed an executive order creating the Federal Emergency Management Agency (FEMA).

FEMA was first charged to take emergency response duties from multiple agencies in disjointed plans. In 1988 the Stafford Disaster Relief and Emergency Assistance Act (Stafford Act 1988) was enacted. The Stafford Act established a system of federal assistance to state and local governments and required all states to prepare individual Emergency Operations Plans. Under the Stafford Act, the initial response efforts to disasters are the major responsibility of local agencies. The problem, especially for the response to Hurricane Katrina, was that the strict application of Stafford Act prevented organizations from collaborating in the initial stage of preparation and response to Hurricane Katrina. This interpretation of the Act caused a severe lack of resources and limited joint collaboration for the first responders such as Parish governments and American Red Cross. The Stafford Act authorized the Director of FEMA to prepare a Federal Response Plan (FRP, 1999). Initially, the FRP brought multiple federal organizations together to assist states with disaster preparedness and response; it was augmented by the National Contingency Plan (NCP, 1990) through the Environmental Protection Agency (EPA).

Since that time, the United States government started to build nation wide and extensive disaster management plans by combining separate plans into united and synthesized ones. The NCP, in existence since 1968, was initially a blueprint for responding to oil spills, but was expanded to include hazardous materials in 1972 with the passing of the Clean Water Act. In 1980, the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), more commonly known as "Superfund," further expanded the scope of the NCP to include emergency removal actions at hazardous waste sites and required regulated facilities to submit contingency plans. The federal government helped state and local officials protect public health and the environment in the event of a hazardous material release or emergency through the NCP. In 1992, FEMA took an all-hazards approach and integrated various disaster management plans to emergency planning. In 1994, the Stafford Act was amended to incorporate most of the former Civil Defense Act of 1950. Also, in 1996 the Federal Radiological Emergency Response Plan (FRERP) was signed into law. The Nuclear Regulatory Commission (NRC) and FEMA prepared a plan outlining the federal government's response for peacetime radiological emergencies within the U.S. or its territories. Accordingly, by 1996, FEMA developed a guide for individual states to develop individual Emergency Operation Plans known as the Guide for All Hazards Emergency Operations Planning (1996).

Another critical change in disaster management plans is the establishment of the Department of Homeland Security (DHS), which was formed following the September 11 terrorist attacks and the Department of Homeland Security (DHS) put FEMA under its authority when it was established in 2003. The DHS administered the National Response Plan (NRP) when it came into effect in December 2004 just several months before the landfall of Hurricane Katrina. But as many official reports and research papers pointed out (FEMA, 2006; White

House, 2006; House of Representatives, 2006), the National Response Plan did not function well in preparing, coordinating, and mitigating the adversarial impacts from Hurricane Katrina. Due to the lack of proper cognition of the magnitude of situation, the pro-activation of National Response Plan was not possible.

According to Failure of Initiative (2006), including the office of President, top public officers in federal governments did not recognize the situation immediately and accordingly failed in timely activation of National Response Plan. More critical issue was the plan itself. With the creation of the Department of Homeland Security (DHS) since September 11 terrorist attack and the development of the National Response Plan (NRP), an additional layer of management and response authority was placed between the President and FEMA, and additional response coordinating structures were established which, in the case of Hurricane Katrina, blocked the effective information flow and resulted failure in coordinating activities. According to the Failure of Initiative (2006), the Secretary of Homeland Security became the President's principal disaster advisor responsible for enabling the President to use his authority under the Stafford Act to direct all federal agencies, particularly the Department of Defense (DOD), to respond in a coordinated and expeditious fashion. But, the Secretary of Homeland Security did not function appropriately as critical response decision point mainly due to his lack of disaster management experiences. Even though there were plenty of advance warning from the National Hurricane Center (NHC) and simulated analysis for the breakdown of levees system prior to that, the Homeland Security Operations Center failed to provide valuable situational information to the White House and key operational officials during the disaster.

Since the failure of getting proper situation awareness, it has become clear to agencies that the response to Hurricane Katrina was not unified and the coordination among local, state,

and federal authorities failed in several areas. The National Response Plan and National Incident Management System were supposed to serve as a pre-established unified command structure for response to such a catastrophic disaster. For the seamless execution of the NRP, each agency needed to develop effective operating procedures essential to satisfying that agency's roles and responsibilities under the NRP and NIMS. Some agencies such as The U.S. Army Corps of Engineers and the Department of Transportation had well developed standard operating procedures and made it aligned with each other (U.S. Army Corps of Engineers, ESF #3 Field Guide, 2001). The efforts for the alignment of disaster management plans between federal and state agencies and between state and local agencies were not effective due to the lack of coordinated plans. Many Parish governments had no disaster management plans at all (Ascension Parish 2006) and this situation caused the failure in coordination in the initial stage of response and mitigation.

Due to the lack of sufficient operating procedures for their responsibilities under the NRP, many local agencies referred to related sections of the NRP when asked for operating procedures. But since the NRP was not developed to the level of an operational plan itself, this led to problems with execution of Emergency Support Function (ESF) responsibilities of local agencies. With this lack of coordinated plans and the failure of FEMA in coordinating response activities, the Department of Defense took the unified command function by taking requests from the State of Louisiana directly (Senate Comm. Hearing at 70-72, 2005). These ad-hoc activities of core coordinating organizations sometimes successfully complement the lack of disaster management plans, but in many cases, resulted in a duplication of efforts and a delay in the responses to Hurricane Katrina. Unplanned and unreported interactions between agencies created many difficulties in managing well-logged inventories of available resources. An additional notable

problem of the National Response Plan was the lack of clear communication procedures between core organizations, a condition that disrupted the overall information flow and situational awareness. In summary, Hurricane Katrina exposed numerous deficiencies in the National Response Plan, and various failures delayed appropriate federal, state, and local responses to Hurricane Katrina. Organizations were ill prepared and they did not understand their required roles and responsibilities as prescribed by the NRP. As a result, the expected coordination by FEMA was not sufficient to integrate the efforts of each agency into an effective response system.

Since the failure and criticisms on National Response Plan, it was updated on May 25, 2006 following the lessons from the experience of responding to Hurricanes Katrina, Wilma, and Rita in 2005. On March 2008, DHS replaced the National Response Plan with the National Response Framework (2008). The National Response Framework as a part of the National Strategy for Homeland Security presented the guiding principles enabling all levels of domestic response partners to prepare for and provide a unified national response to disasters and emergencies. Building on the existing National Incident Management System (NIMS) as well as Incident Command System (ICS), the NRF's coordinating structures aimed to provide an effective implementation at any level for local, state, and national emergency or disaster response. In developing a new disaster management plan, the DHS focused on the following five principles to make their new disaster management system more operable under stress. First, DHS emphasized an "*Engaged partnership"* which means leaders at all levels of organizations collaborate to develop shared goals and align capabilities. This change is designed to prevent any level of agencies from being overwhelmed in times of crisis. Second, under the National Response Framework, the responsibilities of first response are still in local agencies. The

National Response Framework presents the principle of "*Tiered response"* which focused on the efficient management of incidents, so that such incidents are handled at the lowest possible jurisdictional level and supported by additional capabilities only when needed. But the National Response Framework also focused on "*Scalable, flexible, and adaptable operational capabilities"* for implementation according to changes in size, scope, and complexity of incidents, so that the responses to disasters adapt and meet the requirements under ICS/NIMS management by objectives. Third, the NRF suggested "*Unity of effort through unified command."* Unity of effort in NRF refers to the state of harmonizing efforts among multiple organizations working towards a similar objective (Lawrence, 1995). This prevents organizations from working at cross purposes and it reduces duplication of effort. Instead of revising the main feature of Stafford Act, organizations in charge of Incident Command System or National Incident Management System are supposed to respect for each participating organization's chain of command with an emphasis on seamless coordination across jurisdictions in support of common objectives. This seamless coordination is guided by the effective and interoperable communication protocol between organizations in ICS/NIMS command structures and assigned resources to coordinate response operations among multiple jurisdictions that may be joined at an incident complex.

With these principles, organizations still were required to collaborate under the command system of Incident Management System, but the National Response Framework applied learning from the failure of National Response Plan and emphasized the dynamic transparent fashion of collaboration and also the ability for adaptation. Like the National Response Plan for the response to Hurricane Katrina, the National Response Framework was activated several months before the landfall of Hurricane Gustav. Due to its clarity in mission, communication protocol,

and the pro-activation of proper part of the plan, the National Response Framework was effective in response to Hurricane Gustav.

4.2.2 Assessment of technical factors: levees system, wetland use policy, and communication system

As many Hurricane Katrina related reports pointed out, the levee system breakdown was a second, but the most critical blow to the Hurricane Katrina response system. Since Hurricane Katrina hit New Orleans and its neighboring region in August 29, 2005, there were over 50 failures of the levees and flood walls during Hurricane Katrina. The levee and flood wall failures caused flooding in 85% of New Orleans and also severely damaged the communication equipment of organizations in the response system. As a result, millions of gallons of water spilled into vast areas of New Orleans, flooding thousands of homes and businesses with 10 feet or more of water (IPET, 2006). More specifically, the storm surge caused breaches in 20 places on the Mississippi River-Gulf Outlet Canal (MR-GO)[23] and caused flooding of the entire Saint Bernard Parish and the East Bank of Plaquemines Parish. Also, three major breaches occurred on the Industrial Canal; one on the northeast side near the junction with Gulf Intracoastal Waterway and two on the southeast side along the Lower Ninth Ward, between Florida Avenue and Claiborne Avenue (IPET 2006). On the east side of New Orleans, the 17th Street Canal levee breached 4 feet (1.2 m) below design specs on the New Orleans side near the Old Hammond

[23] Mississippi River-Gulf Outlet Canal is the 76 mi (122 km) channel constructed by the United States Army Corps of Engineers in the mid-20th century that provided a shorter route between the Gulf of Mexico and New Orleans's inner harbor Industrial Canal via the Intracoastal Waterway. In 2005, the MR-GO channeled Hurricane Katrina's storm surge into the heart of Greater New Orleans, contributing significantly to the subsequent multiple engineering failures experienced by the region's hurricane protection network.

Highway Bridge. The London Avenue Canal breached in two places, near Robert E. Lee Boulevard, and near the Mirabeau Avenue Bridge.

These multiple failures of the levee system caused widespread inundation and significant damage, hampering rescue and recovery efforts. The problem from a disaster management perspective is that the storm surge over the levees was much anticipated from the various technical reports and simulated analysis before the landfall of Hurricane Katrina. This well-known threat was the motivation for FEMA to sponsor the "Hurricane Pam" exercise in 2005. In this previous exercise, flooding as the result of overtopping of levees and the breaches in floodwalls was predicted for a storm stronger than a fast-moving Category 3 hurricane. That is, it was expected that some water would flow over the levees and floodwalls based on Katrina's forecasted strength. Although the city did not receive Katrina's strongest force head-on, the levee and floodwall infrastructure's capability to protect the city was exceeded (CRS Report for Congress, 2005).

Before the landfall of Hurricane Katrina, New Orleans already faced frequent flooding threats from the Mississippi River, coastal storms, and intense precipitation; the system of levees and floodwalls around the city was designed to provide a certain level of protection from those threats (*Times-Picayune*, 2005). Also, the complementary system of pumps and canals is designed to remove water trapped in the city, but the historical experience of successful response to flooding with the existing pumping system prevented more investment on extensive restructuring of the levee system. The storm damage reduction infrastructure around New Orleans consists of levees and floodwalls, and represents a combination of federal and local investments and responsibilities. Most of the nation's flood and storm damage reduction infrastructure was supposed to be maintained by local governments and local levee districts;

some of the infrastructure was locally built, while other projects were built by the federal government. And this heterogeneity in building and managing the levee system limited an integrated response to the failure of levees and water walls.

The principal federal agency responsible for constructing flood, storm, and shore protection infrastructure was the U.S. Army Corps of Engineers. In August 2002, the Corps completed a reconnaissance study of whether to strengthen coastal Louisiana's hurricane damage reduction projects, including the New Orleans projects, to protect against Category 4 and 5 storms (CRS Report RS20866). If implemented, coastal Louisiana would have the only Category 5 protection system in the country (CRS Report RL32064). But, Hurricane Katrina has resulted in some questioning why a Category 4 or 5 hurricane storm damage system was not already in place for New Orleans. Partially, the levee system had not be maintained with full funding over decades.

For example, with the completion of MR-GO in 1965, the Port of New Orleans advanced a plan to largely abandon its wharfs along the Mississippi River and relocate its activities to the inner harbor created by the Industrial Canal, the Intracoastal Waterway, and the MR-GO. This vast project, termed "Centroport U.S.A." never secured sufficient funding and was quietly jettisoned by the port in the mid-1980s. The France Road Container Terminal and the Jourdan Road Wharf were the only two elements realized according to the Centroport plan (U.S. Army Corps of Engineers, New Orleans District, 1997). Also, once construction of the levees was completed by USACE, the responsibilities for operating and maintaining the levees were split among many local and state organizations, which prevented the standard cooperation agreement for carrying out flood control projects statewide. The costs of constructing these projects were shared, with operation and maintenance being a 100 percent local responsibility. These included

levee boards in each parish, as well as separate water and sewer boards. The number of organizations involved, and disagreements among them, made accountability diffuse and created potential gaps and weaknesses in parts of the flood protection system (Failure of Initiative 2006). Also, local sponsors did not have control over all factors that could affect their parts of the levee system.

Despite the well-known importance of the levees, and the consequences of failure, the local levee boards responsible for maintaining and operating the levees did not have any warning system in place. While federal regulations required that they monitor levees during periods of potential flooding, the requirement was impractical to implement during the response to hurricane Katrina. In addition to no warning system, the loss and breakdown of communications worsened the situation. Although there were some sporadic reports of flooding from a variety of information sources, the poor and broken communication system made it difficult for coordinating agencies such as LOHSEP and FEMA to confirm that there were actual breaches in the levees. These factors, combined with the physical difficulties of getting to the breach sites, delayed repair of the levee breaches.

Since the failure of levee system, there have been some significant improvements to the levees of New Orleans. The Army Corps of Engineers reinforced the structures of the levee system in New Orleans area and increased the height of the levees to make them to withstand overtopping without catastrophic failures. When Hurricane Katrina hit the Gulf area, levees were susceptible to erosion by overtopping, by edified flow, and by undercutting. Once flood waters overtopped an embankment they quickly scoured the land-side toe of the embankment, and scoured deep holes that develop on either side of the "hydraulic jump." So, the Army Corps of Engineers adopted geogrid-wrapped hay bales or gravel filled HDPE baskets that can be used as

facing elements for mechanically-stabilized embankments. Also, when the levee system was exposed to storm surge, the new levee system made them to be more efficient energy dissipation systems, not just simple barriers. With structural changes, the holes have been fixed and strengthened, the walls have been built up an additional three feet, and new pumps have been installed for better drainage (CNN, 2008). Another step to protect levees system from disasters was to improve communication protocols between local governments who were in charge of management and the Army Corps of Engineers. For example, the levee officials and the corps met every two weeks to discuss and inspect flood-control projects designed to guard against a 100-year storm before then landfall of Hurricane Gustav. The revised communication protocol was to ensure a smooth transition as the Corps designs and builds $4 billion worth of levees, floodwalls, floodgates and pumping stations that operated and maintained by the levee district, formally known as the Southeast Louisiana Flood Protection Authority. The inspection teams include representatives from the Corps and the levee district as well as the state Department of Transportation and Development and the Office of Coastal Protection and Restoration. These efforts for the coordinated preparation and response to disasters and strengthened structure of levees were not tested by Hurricane Gustav.

In the immediate aftermath of a catastrophic disruption of Hurricane Katrina, communication channels broke down and could not be reestablished as rapidly so that individual efforts for emergency response could not be fully coordinated. More significantly, as Comfort mentioned (2007), the common operating picture that was critical to joint operations was not available to core organizations in the response system. Accordingly, due to the lack of advanced technology in managing resources and the breakdown of the communication system, effective collaboration and coordination was not possible. First, organizations in the hurricane Katrina

response system were suffered from the lack of available communication equipment. For example, cell towers were typically not equipped with sufficient emergency power backup capacities, and backup generators with long-distance switches did not tolerate flooding caused by the levee system breakdown. As a result, both mobile phone and long-distance phone terrestrial communication suffered an almost complete disruption in Katrina's wake. In comparison, satellite communications remained quantitatively operational and were utilized within minutes of the disaster by FEMA, the National Guard and the Red Cross, as well as by state and local first responders, utility workers, and people in search of relatives (Wireless IQ, 2005). More than 20,000 Global-star, Iridium and Mobile Satellite Ventures satellite phones and terminals were deployed in the affected region within 2 days after the event. Within the first 72 hours the Iridium network traffic surged by 3000% and the subscriber base rose by 500%. The provider Globalstar was activating 1400 devices/day, as compared with a typical rate of about 80 devices per day. Mobile Satellite Ventures reported an increase in traffic in the affected region of more than 400% (Leitl, 2005), and supplied satellite terminals to a number of emergency responders (e.g. FEMA's Urban Search and Rescue teams).

Like this, Hurricane Katrina devastated an infrastructure such as cell phone towers and radio antennas, that depends on aboveground structures. A 400-foot antenna built to withstand 150 mile-per-hour winds fell during the storm, crippling communications for the sheriff’s office in Jefferson Parish. A majority of the public-safety systems serving police and fire departments in the Gulf Coast region ceased functioning, severely hampering the coordination of rescue efforts. The New Orleans Police Department’s system was largely inoperative for 3 days following the hurricane. These failures left many key emergency response personnel with no way of communicating with one another during a time when coordination of rescue efforts was most

important. In New Orleans, hundreds of police officers were left trying to communicate on two radio channels using a back-up system, which resulted in delays before their messages could get through (Piper & Ramos, 2006).

Many of these failures of communication occurred because of poor planning processes, with key generators placed on ground floors vulnerable to flooding. However, at least one transmission site operated by the New Orleans police flooded despite being 10 feet off the ground. Other communications systems that stopped functioning due to loss of power resulting from damaged generators couldn't be repaired for days because technicians were not allowed past state police roadblocks. Also, backup systems became overwhelmed due to high volume and phone lines proved vulnerable to Katrina, with almost 2 million phone lines and cell phones experiencing interruptions or being out of service along the Gulf Coast. New Orleans residents trapped in their homes by floodwaters couldn't call for help and family members couldn't call to find out if they had escaped. This combination of failed backup generators (either flooded or out of fuel), downed telephone lines, flooding in the switch offices that route calls, and overwhelmed phone lines resulted in a defunct phone system.

While emergency services radio towers in the area, built to resist sustained winds within the 200 MPH range, largely remained functional, cell phone services broke down due to tower, antennae, and equipment damage. A mobile cell service was not fully deployed. Text messaging on cell phones however, worked remarkably well. Radio and TV stations, for the most part, successfully stayed on the air, often employing satellites. The major BellSouth Internet hub in New Orleans went remarkably unscathed, but there were serious problems at the user-connect end. In areas that sustained power outages, DSL likewise went down. BellSouth had not installed a battery backup, knowing that batteries would be insufficient to power a system of such

magnitude. In summary, Hurricane Katrina tested all modes of communication technology during and after the Hurricane Katrina. Immediately following the storm, there was severe chaos in information sharing. Some of this can be attributed to poorly mapped channels of communication flow at local, state, regional, and particularly federal levels, and some of it was due to equipment damage and malfunction. As a result, the information that was critical to collaboration among organizations was not available to managers of core organizations. Combined with the lack of proper technology for resource management, the level of technology was not sufficient to meet the impending needs from organizations in the Hurricane Katrina response system.

4.2.3 Assessment of political and social factors

As delineated in the National Response Plan (2004), disaster response and planning is first and foremost a local government responsibility. When local government exhausts its resources, it then requests specific additional resources from the parish level. The request process proceeds similarly from the parish to the state and from state to the federal level as additional resource needs are identified. Many official reports and research papers show that the political leadership necessary for the effective coordination of individual activities was not exerted in responding to Hurricane Katrina (The Federal response: Lessons learned, 2006). For example, Michael Chertoff, Secretary of the Department of Homeland Security, decided to take over the federal, state, and local operations officially on August 30, 2005, citing the National Response Plan (California Chronicle, 2006). But this attempt was refused by Governor Blanco who indicated that her National Guard could manage the situation. Also, FEMA provided housing assistance to more than 700,000 applicants—families and individuals. However, only one-fifth of the trailers

requested in Orleans Parish have been supplied, resulting in an enormous housing shortage in the city of New Orleans (Times Picayune, 2005), the shortage resulted partially because many local areas voted to not allow the trailers, and many areas had no utilities, a requirement prior to placing the trailers.

From previous examples of coordination failure, there were strong criticisms, especially for the failure in coordinating multi-jurisdictional and multi-sectoral activities in response to Hurricane Katrina. The criticisms primarily consisted of cases of mismanagement and lack of leadership in the relief efforts in response to the storm and its aftermath. For example, the severely delayed responses to the flooding of New Orleans, and the subsequent state of chaos in the Superdome were the most critical failure of coordination and collaboration. Within days of Katrina's landfall, public debate arose about the local, state and federal governments' role in the preparations for and response to the hurricane.

Many critics have noted that while Mayor Nagin gave a mandatory evacuation order on August 28, before the storm hit, they did not make sufficient prevention and provisions to evacuate the homeless, the poor, the elderly, the infirm, or the carless households (Statement on Federal Emergency Assistance for Louisiana, 2005). Prior to the landfall of Hurricane Katrina, on August 27, the White House issued a statement, effective August 26, authorizing federal emergency assistance for Louisiana. The statement authorized the Department of Homeland Security (DHS) and the Federal Emergency Management Agency (FEMA) to coordinate disaster relief and required emergency measures, authorized under Title V of the Stafford Act, to save lives, protect property and public health and safety in the 39 parishes in the State of Louisiana. But, the President had not yet authorized FEMA to enter the coastal areas despite the governor's request including parishes in the southern coastal areas (Office of the Governor, Press release

2005). Facing this situation, the Governor's efforts activated the National Guard at August 26, State of Emergency Declaration and Red Cross relief in New Orleans but those activities were not well coordinated with the federal efforts.

According to the Louisiana Evacuation plan (Louisiana State Emergency Management Plane 2005), evacuation was mainly left up to individual citizens to find their own way out of the city. It was known that many residents of New Orleans lacked cars, especially for the poor residents. It is also believed that many citizens, having survived previous hurricanes, did not anticipate the impending catastrophe and chose not to ride out the storm. Even so, a 2000 census revealed that 27% of New Orleans households, amounting to approximately 120,000 people, were without privately owned transportation. Additionally, at 38%, New Orleans has one of the highest poverty rates in the United States (U.S. Census Bureau, 2004). These factors may have prevented many people from being able to evacuate on their own. State and city evacuation plans (New Orleans Emergency Operation Plan, 2004, Part 1 Section C and part II-2) mentioned the emergent use of school buses for evacuation, but as Mayor Nagin admitted, it was not clear whether these buses were owned by the city or by a private contractor to which the city had outsourced school bus services and city of New Orleans had no control over them.

The most important criticism of Nagin was that he delayed his emergency evacuation order until 19 hours before landfall, which led to hundreds of deaths of people who (by that time) could not find any way out of the city (A Failure of Initiative, 2006). Related with this, many residents of New Orleans region blamed state and local governments (75%) more than at the Federal government (67%), with 44% blaming Bush's leadership directly (ABC Poll, 2005). This problem of the lack of political leadership and resulting inadequate preparedness caused the failure of the flood protection system in 53 different places in metro New Orleans that were

designed and built by the US Army Corps of Engineers (IPET 2006). When Hurricane Katrina passed east of New Orleans, it was a weakening Category 4 storm and the levee system was not prepared for large size hurricanes. Questions have been raised about sufficient funding for the Corps of Engineers, which was in charge of many hurricane-protection programs across the United States. Due to the budget cut by Bush Administration, the Corps had performed only last-minute and substandard reinforcement of levees, some of which subsequently failed. For example, In 2005, President Bush proposed cutting the Corps' budget by 7%, and in 2004 proposed a 13% cut (*Washington Post*, 2005; *Times Picayune*, 2005). This lack of adequate funding to construct and manage levees systems caused severe second impact to the response system to Hurricane Katrina.

Many local emergency managers defended FEMA against the charge of lack of political leadership and federal agencies' unpreparedness pointing out that the Bush Administration has since 9/11 reduced the agency's budget, mission, and status. FEMA, which was elevated to cabinet-level status under President Bill Clinton's administration and later, incorporated into the Department of Homeland Security, placed high priority on counter-terrorism and disaster preparation (Comfort, 2006) rather than natural disasters. Before Hurricane Katrina's landfall, the International Association of Emergency Managers (2007) had predicted that FEMA could not adequately respond to a catastrophe due to the integration and staffing overlaps. Also, President Bush was criticized for appointing Michael D. Brown as FEMA director who had no experience in disaster relief prior to joining FEMA. The entire disaster response system before the landfall of Hurricane Katrina was not activated or sufficiently resilient to such a large scale crisis.

Besides the effect of political factors on the performance of hurricane Katrina response system, also social factors such as race, social class, and culture affected severely the

organizational response to crisis. As Elliott and Pais argued (2006), although residents of the Gulf South share a common region, their responses to Hurricane Katrina varied in non-random ways reflective of racial and class divisions that have taken root and grown in the area over time (Fothergill et al., 1999). Since media images showed that nearly all those left behind to suffer and die were African Americans (CNN, 2005), the social effects of race and social class ignited the debates on the effect of race and economic class on evacuation. Some alleged that race, class, and other factors contributed to delays in government response. The percentage of black victims among storm-related deaths was 49%, below their proportion in the area's population (approx. 60%, Louisiana Department of Health and Hospitals, 2005). Also, some researchers argued that poor residents were not able to afford homes in safer flood-protected areas and did not have the resources to evacuate easily (Lavelle & Feagin, 2006).

Demographically, two-thirds of the residents of New Orleans are African Americans, and New Orleans is one of America's poorest cities with more than 25% of residents and 40% of children living at or below the poverty line (GAO, 2006). More critically, within the city of New Orleans, the poorest tended to live in the lowest parts that are most vulnerable to flooding. Also, 98% of residents in the Lower Ninth Ward, which was flooded by a catastrophic breach in the nearby Industrial Canal, were poor and African-American. Many of the poor depend on welfare, Social Security, or other public assistance checks, which they receive on the first of each month, meaning that Hurricane Katrina made landfall just when many of the poor had exhausted their resources. Thus, many of the city's poor simply couldn't afford to flee the city before the hurricane struck. Also, social and economic class affected the performance of the response system because those families most able to afford homes in safer flood-protected areas had the resources to evacuate more easily than poorer families. Elliott and Pais argued that race and class

are inextricably intertwined primarily because of a long history of well-institutionalized poverty combined with race in the city of New Orleans. Due to the long rooted history of slavery and poverty, economic and political power has been held primarily by the white elite (Elliott, 2006). With respect to race, there are two broad areas where racial differences seem to have mattered. The first involves timing of evacuation and sources of emotional support, that is, behavior more or less under the control of individuals themselves. Related with pure race issue, some researcher argued that education and their economic status need to be considered together. Forman (2006) argues that African-American in the City of New Orleans were less inclined than whites to evacuate before the storm, mostly because they did not believe that the hurricane would be as devastating as it eventually was. Or culturally, Elliott found that African-Americans were more likely to report "leaning on the lord" while whites were more likely to report relying on friends and family. Like this, the issue of race needs to be interpreted with their economic and cultural factors together. In summary, the differences in race, economic class, and culture affected the performance of Hurricane Katrina response system while there are hot debates regarding the extent of effects.

4.3 SUMMARY OF ASSESSMENT OF CONTEXT SURROUNDING TWO HURRICANE RESPONSE SYSTEMS

Since 9/11/2001, the United States Government has committed significant resources, attention, and time to establish a Department of Homeland Security (DHS) to improve security for the nation. But DHS's ineffectiveness in responding to the 2005 hurricanes on the Gulf Coast led to wide public criticism of its performance, and further concerns whether the United States disaster

response system actually learns from the previous crises and effectively adapts to rapidly changing conditions. The newly established disaster response system since 9/11 terrorist attack was seriously tested by the adversarial impacts from Hurricane Katrina in various ways.

For the disaster management laws and plans, the National Response Plan (NRP 2004) was not fully reliable for effective organizational responses to Hurricane Katrina. It was not fully developed to define coordination procedures among multi-sectoral and multi-jurisdictional organizations. Also, the disaster response personnel were not well educated and trained to apply core features of the National Response Plan to their actual responding efforts. The lack of cognition of the magnitude of situation by DHS worsened the situation and caused severe delay in the activation of national level disaster response system. Facing the National Response Plan's ineffectiveness, it was superseded by the National Response Framework (2008) after the several revisions since the failure of Hurricane Katrina. The National Response Framework was the national level disaster response plan and, as many suggested, it was well developed using lessons from Hurricane Katrina and effectively implemented for the response to Hurricane Gustav in 2008. The deficiencies of the National Response Plan were not overcome by experienced leadership. Even though there was plenty of advance warning from the National Hurricane Center (NHC) and simulated analysis for the breakdown of the levee system, including the office of President, top public officers in federal and State governments did not recognize the risk and accordingly failed in timely activation of the National Response Plan.

Due to the lack of clear communication procedures in the NRP and physical damage from the flood and levee collapses, the failure of the communication system for the Hurricane Katrina triggered failure in the response system. Failures in communication between core organizations disrupted the overall information flow, the common situational awareness and hindered in

coordinating activities. In comparison, many pieces of communication equipment remained operational and were utilized within minutes of the disaster in response to the Hurricane Gustav due to the organizations' investments on the advanced communication system. Combined with the failures of communication system, the levee system breakdown was the second, but the most critical damage to the Hurricane Katrina response system. Despite the well-known importance of the levees, and the consequences of failure, the local levee boards did not have any warning system in place and the responsibilities of maintenance were scattered. This heterogeneity in building and managing the levee system caused the lack of integrated response to the failure of the levees and water walls. Since the failure of the Hurricane Katrina, the boards and the Army Corps of Engineers developed a new levee system to be more efficient energy dissipation systems, not just simple barriers. Also, they revised communication protocols to ensure smooth coordination and collaboration. These efforts for coordinated preparation and response to disasters and strengthened structure of levees were not tested by Hurricane Gustav.

What made the effective coordination more difficult were the social factors that were specific to the State of Louisiana. The NRP and the Stafford Act delineated that disaster response and planning was first and foremost a local government responsibility. But the high poverty level of the State of Louisiana proved that it could not stand alone in the case of such a large disaster. The racial and class divisions that have grown in the area over time made an integrated response, especially for the implementation of evacuation, hard to achieve. Consideration for social and racial factors needs more time to be reflected in the disaster response systems.

5.0 THE HURRICANE RESPONSE SYSTEMS AND THE IDENTIFICATION OF MAJOR PROBLEMS

This chapter examines how organizations in the hurricane response system operated individually and jointly to address the problems from complex conditions. With descriptions for Hurricane Katrina and Hurricane Gustav response systems, I identified the major problems that the system faced during its response to the hurricanes. This chapter uses two data sources from content analysis and semi-structured interviews. The newspaper reports on response operations in the *Times-Picayune*, and the situation reports recorded by the LOHSEP (and GOHSEP for the Hurricane Gustav) were used as the data sources for content analysis. These sources provide empirical data to identify the patterns of actual interactions on a daily basis and the dynamic changes of the disaster response systems for both hurricanes. From content analysis, this chapter documents how many organizations joined the disaster response systems by date, what kinds of information and resources were exchanged, and how this interaction pattern evolved within the timeline of this analysis. Also, the content analysis reveals critical problems to be addressed for future disaster response systems. The findings from semi-structured interviews verify and complement the problems identified from the content analysis and examine critical points more closely in which the Hurricane Katrina disaster response system failed. It provides complementary descriptions of the kinds of challenges that organizations needed to address and how those problems affected the entire performance of disaster response systems.

5.1 THE HURRICANE KATRINA AND HURRICANE GUSTAV RESPONSE SYSTEMS

5.1.1 The descriptions of Hurricane Katrina and Hurricane Gustav response systems

Hurricane Katrina, a more severe storm that triggered secondary devastation from flooding caused by the collapsed levees, generated a larger response system with 533 organizational actors, than did Hurricane Gustav with 332 organizational actors identified from newspaper reports. There are small differences in the number of organizations in the system by level of jurisdiction: Public 57% (Katrina) vs. 57.5% (Gustav), Private 15.9% (Katrina) vs. 22% (Gustav), and non-profit 26.5% (Katrina) vs. 20.5 (Gustav). The changes in the total number of private and non-profit organizations reflect the difference in size and severity of damage caused by the two hurricanes. Due to its comparatively small size that resulted in less damage to the region, the Hurricane Gustav response system includes a smaller number of non-profit organizations. But due to changes in procedures for securing resources in preparation phase, there are more private organizations in the Hurricane Gustav response system.

Table 5-1 Frequency Distribution of Organizations Identified in the Hurricane Katrina Response System*

Level of Jurisdiction	Source of Funding									
	Public		Private		Non-Profit		Special-Interest		Totals	
	N	%	N	%	N	%	N	%	N	%
International	11	2.1	3	0.6	5	0.9	0	0	19	3.6
National	0	0	24	4.5	75	14.1	1	0.2	100	18.8
Federal	67	12.6	0	0	0	0	0	0	67	12.6
Regional	1	0.2	7	1.3	26	4.9	0	0	34	6.4
State	79	14.8	7	1.3	4	0.8	2	0.4	92	17.3
Sub-Regional	11	2.1	12	2.3	9	1.7	0	0	32	6.0
Parish/County	55	10.3	3	0.6	1	0.2	0	0	59	11.1
District	27	5.1	2	0.4	0	0	0	0	29	5.4
City	53	9.9	27	5.1	21	3.9	0	0	101	18.9
Totals	304	57	85	15.9	141	26.5	3	0.6	533	100.0

Source: *Times Picayune*, New Orleans, LA. August 27 – September 19, 2005. (Comfort & Haase, 2006)

Table 5-2 Frequency Distribution of Organizations Identified in the Hurricane Gustav Response System

Level of Jurisdiction	Source of Funding									
	Public		Private		Nonprofit		Special Interest		Totals	
	N	%	N	%	N	%	N	%	N	%
International	1	0.3	1	0.3	1	0.3	0	0	3	0.9
National	0	0.0	39	11.8	13	3.9	0	0	52	15.7
Federal	25	7.5	0	0	0	0	0	0	25	7.5
Regional	3	0.9	8	2.4	4	1.2	0	0	15	4.5
State	39	11.8	5	1.5	17	5.1	0	0	61	18.4
Subregional	3	0.9	1	0.3	4	1.2	0	0	8	2.4
Parish/County	77	23.2	2	0.6	7	2.1	0	0	86	25.9
District	13	3.9	0	0	0	0	0	0	13	3.9
City	30	9.0	17	5.1	22	6.6	0	0	69	20.8
Totals	191	57.5	73	22.0	68	20.5	0	0	332	100.00

Source: *Times-Picayune*, New Orleans, LA. August 26 – September 21, 2008.

As table 5-1 and 5-2 shows, Hurricane Katrina was a more severe disaster that generated more difficult conditions to challenge the response system. Moreover, the secondary impact of the levee collapse led to the mobilization of the entire nation's disaster response system which led many organizations to participate spontaneously in the response system. The other difference between the two hurricane response systems is that, recognizing that the first response to any disaster event is necessarily local, it reveals that the proportion of organizational actors from the local jurisdictions – city, district, and parish – was 35.4% in the Katrina response system, in contrast to being over half (50.6%) of the actors in the Gustav response system. Similarly, the proportion of national and federal organizations participating in the Katrina response system was markedly higher at 31.4% in contrast to 23.2% for the Gustav response system. This also indicates that the relatively small size of Hurricane Gustav did not activate the entire federal and national agencies to the same extent to the Hurricane Katrina, although the number of activated state level organizations in the system was nearly equal.

5.1.2 The changing pattern of Hurricane Katrina and Hurricane Gustav response systems

This section shows the changing pattern of interactions among organizations in the Hurricane Katrina and Hurricane Gustav response systems. While much of the data was consistent between the two systems, more detailed situation reports that show actual resource exchange patterns by date were not made available by GOHSEP for Hurricane Gustav. The available situation reports for Hurricane Gustav mainly recorded the major actions taken by state and federal governments in a style akin to a newspaper article. For this reason, the depth of content analysis is not compatible with that of Hurricane Katrina, and due to this limitation in data for the Hurricane Gustav content analysis, I combined the two separate data sources together for the response to Hurricane Gustav before conducting the content analysis.

Table 5-3 shows the distribution of organizations sorted by source of funding and by dates for Hurricane Katrina. And based on this table, Figure 5-1 presents the changing pattern of the Hurricane Katrina response system. Similarly, Table 5-4 and Figure 5-2 show the distribution of organizations sorted by source of funding and by date for Hurricane Gustav and its changing pattern over time. The noticeable difference in their changing pattern is that a higher percentage of organizations had already activated and participated before the landfall of Hurricane Gustav while the highest peak of the Hurricane Katrina response system is one day after the hurricane landfall. This pattern shows that the level of preparedness for the Hurricane Gustav disaster response system was higher than that for Hurricane Katrina. The pattern for the Hurricane Gustav response system also shows that organizational action was much more concentrated in the initial stage of response when compared to that of Hurricane Katrina. This concentrated effort in the initial stage of response means that it minimized the dispersion of energy within the

hurricane response system and thus contributed to the improvements in performance of organizations.

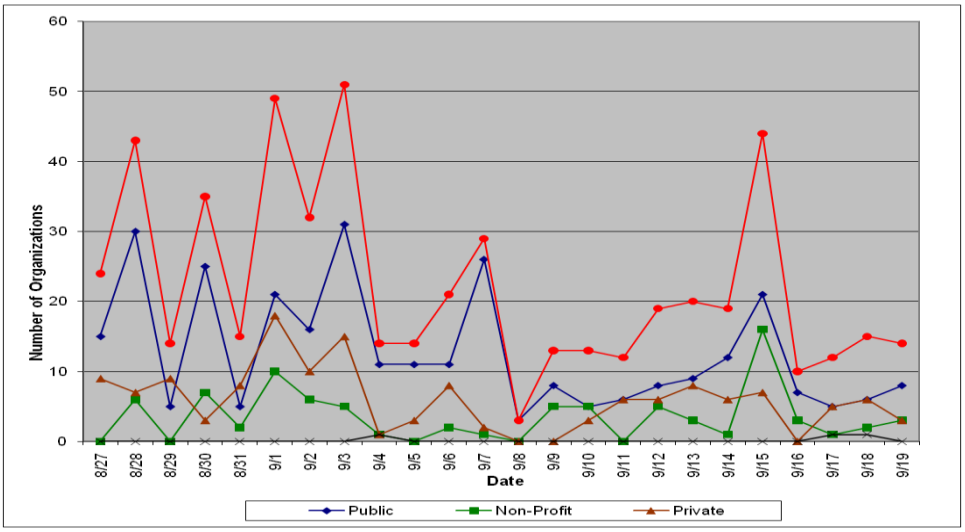
Another difference in the changing patterns by dates is the consistent entry of new organizations into the system for Hurricane Gustav. According to Figure 5-1, the total number of new organizations entering into the system dropped after the landfall of Hurricane Katrina with another peak at September 15th, roughly two weeks after landfall. But, Figure 5-2 reveals that the number of new organizations entering the system, unlike that for Hurricane Katrina, did not drop significantly after landfall. The second highest peak of the number of organizations was reported just one week after landfall for Hurricane Gustav. This pattern for Hurricane Gustav is favorable when compared to the second peak of the Hurricane Katrina response system which occurred in September 15, 2005, almost three weeks later of the landfall of Hurricane Katrina.

Also, the steady increase in the entry of new organizations means that the entire disaster response system has support from the outer environment of Hurricane Gustav response system. This support contributed to the increase of the available resources and support by the organizations in the larger disaster response system. Usually, for disaster response and mitigation, new organizations entering into the system bring new resources, and this helps existing organizations in the system survive and recover from the disaster more rapidly, resulting in a higher level of resilience of the disaster response system.

Table 5-3 Frequency Distribution of Organizations by source of funding, Hurricane Katrina

Date	Source of funding									
	Public		Non-Profit		Private		Special Interest		Total	
	N	%	N	%	N	%	N	%	N	%
8/27/2005	15	4.9	0	0.0	9	6.4	0	0.0	24	4.5
8/28/2005	30	9.9	6	7.1	7	5.0	0	0.0	43	8.1
8/29/2005	5	1.6	0	0.0	9	6.4	0	0.0	14	2.6
8/30/2005	25	8.2	7	8.2	3	2.1	0	0.0	35	6.6
8/31/2005	5	1.6	2	2.4	8	5.7	0	0.0	15	2.8
9/1/2005	21	6.9	10	11.8	18	12.8	0	0.0	49	9.2
9/2/2005	16	5.3	6	7.1	10	7.1	0	0.0	32	6.0
9/3/2005	31	10.2	5	5.9	15	10.6	0	0.0	51	9.6
9/4/2005	11	3.6	1	1.2	1	0.7	1	33.3	14	2.6
9/5/2005	11	3.6	0	0.0	3	2.1	0	0.0	14	2.6
9/6/2005	11	3.6	2	2.4	8	5.7	0	0.0	21	3.9
9/7/2005	26	8.6	1	1.2	2	1.4	0	0.0	29	5.4
9/8/2005	3	1.0	0	0.0	0	0.0	0	0.0	3	0.6
9/9/2005	8	2.6	7	8.2	0	0.0	0	0.0	15	2.8
9/10/2005	5	1.6	4	4.7	2	1.4	0	0.0	11	2.1
9/11/2005	6	2.0	0	0.0	6	4.3	0	0.0	12	2.3
9/12/2005	8	2.6	5	5.9	6	4.3	0	0.0	19	3.6
9/13/2005	9	3.0	3	3.5	8	5.7	0	0.0	20	3.8
9/14/2005	12	3.9	1	1.2	6	4.3	0	0.0	19	3.6
9/15/2005	21	6.9	15	17.6	7	5.0	0	0.0	43	8.1
9/16/2005	7	2.3	3	3.5	0	0.0	0	0.0	10	1.9
9/17/2005	5	1.6	1	1.2	5	3.5	1	33.3	12	2.3
9/18/2005	5	1.6	3	3.5	5	3.5	1	33.3	14	2.6
9/19/2005	8	2.6	3	3.5	3	2.1	0	0.0	14	2.6
Total	304	57.0	85	15.9	141	26.5	3	0.6	533	100.0

Source: Times-Picayune, New Orleans, LA. August 27 – September 19, 2005.



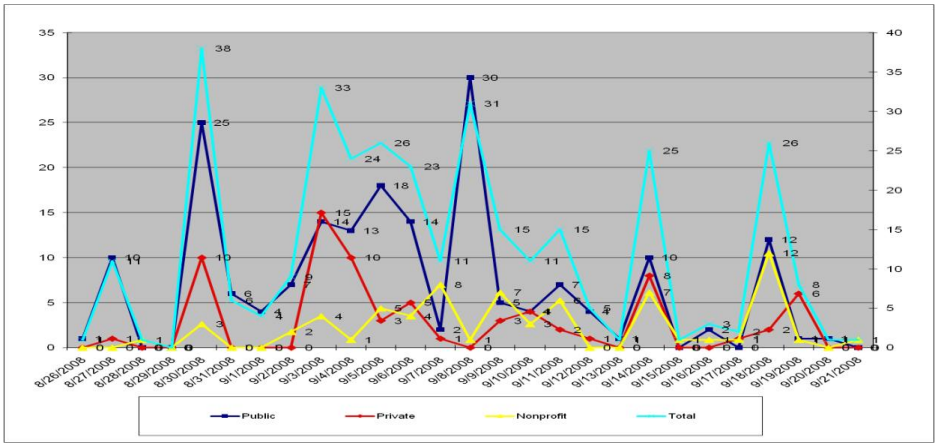
Source: "The Dynamics of Disaster Recovery: Resilience and Entropy in Hurricane Response Systems" Louise K. Comfort, Namkyung Oh, Gunes Ertan, September 2009, Public Organization Review, volume 9: pp309-323, Springer, USA.

Figure 5-1 Number of organizations activated by date and source of funding, hurricane Katrina

Table 5-4 Frequency Distribution of Organizations by source of funding, Hurricane Gustav

Date	Source of Funding							
	Public		Private		Nonprofit		Total	
	N	%	N	%	N	%	N	%
8/26/2008	1	0.5	0	0.0	0	0.0	1	0.3
8/27/2008	10	5.2	1	1.4	0	0.0	11	3.3
8/28/2008	0	0.0	0	0.0	1	1.4	1	0.3
8/29/2008	0	0.0	0	0.0	0	0.0	0	0.0
8/30/2008	25	13.1	10	13.9	3	4.3	38	11.4
8/31/2008	6	3.1	0	0.0	0	0.0	6	1.8
9/1/2008	4	2.1	0	0.0	0	0.0	4	1.2
9/2/2008	7	3.7	0	0.0	2	2.9	9	2.7
9/3/2008	14	7.3	15	20.8	4	5.8	33	9.9
9/4/2008	13	6.8	10	13.9	1	1.4	24	7.2
9/5/2008	18	9.4	3	4.2	5	7.2	26	7.8
9/6/2008	14	7.3	5	6.9	4	5.8	23	6.9
9/7/2008	2	1.0	1	1.4	8	11.6	11	3.3
9/8/2008	30	15.7	0	0.0	1	1.4	31	9.3
9/9/2008	5	2.6	3	4.2	7	10.1	15	4.5
9/10/2008	4	2.1	4	5.6	3	4.3	11	3.3
9/11/2008	7	3.7	2	2.8	6	8.7	15	4.5
9/12/2008	4	2.1	1	1.4	0	0.0	5	1.5
9/13/2008	1	0.5	0	0.0	0	0.0	1	0.3
9/14/2008	10	5.2	8	11.1	7	10.1	25	7.5
9/15/2008	0	0.0	0	0.0	1	1.4	1	0.3
9/16/2008	2	1.0	0	0.0	1	1.4	3	0.9
9/17/2008	0	0.0	1	1.4	1	1.4	2	0.6
9/18/2008	12	6.3	2	2.8	12	17.4	26	7.8
9/19/2008	1	0.5	6	8.3	1	1.4	8	2.4
9/20/2008	1	0.5	0	0.0	0	0.0	1	0.3
9/21/2008	0	0.0	0	0.0	1	1.4	1	0.3
Total	191	57.5	72	21.7	69	20.8	332	100.0

Source: Times Picayune, New Orleans, LA. August 26 – September 21, 2008.



Source: "The Dynamics of Disaster Recovery: Resilience and Entropy in Hurricane Response Systems" Louise K. Comfort, Namkyung Oh, Gunes Ertan, September 2009, Public Organization Review, volume 9: pp309-323, Springer, USA.

Figure 5-2 Number of organizations activated by date and source of funding, hurricane Gustav

5.2 PERFORMANCE PROBLEMS IDENTIFIED FROM THE CONTENT ANALYSIS OF SITUATION REPORTS FOR HURRICANE KATRINA

5.2.1 Lack of preparedness for the response to Hurricane Katrina

This study uses two types of situation reports recorded by the Louisiana Office of Homeland Security and Emergency Preparedness (LOHSEP). The first one is the daily situation report that was recorded, updated and released to the public briefly through the website of LOHSEP. This brief situation report provided the information on the initiating organizations and responding organizations and the content of their interaction likely to newspaper articles. At the same time, LOHSEP recorded the more detailed data that includes the transaction time, the types of resources to be allocated, and the status of resource allocation for its internal use. Using this second type of situation reports, I coded interactions between agencies within the state of Louisiana.

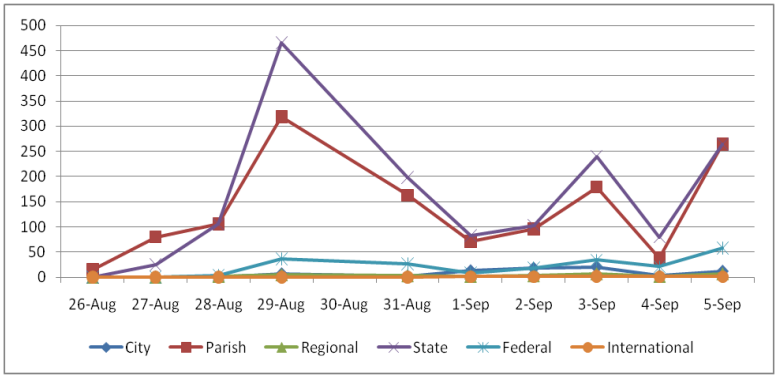
Table 5-5 shows the total number of interactions listed in the situation reports for Hurricane Katrina by date and by level of jurisdiction. Based on this table, Figure 5-3 shows the pattern of fluctuations in the number of interactions in the Hurricane Katrina response system. Only 15 requests for assistance from parishes were registered on August 27, 2005, two days before landfall. That number increased to 80 requests on August 28, 2005, with 25 requests from state agencies. Only on August 30, 2005, the day after Katrina made landfall, was there a significant increase in requests for assistance initiated by parish, state, and regional jurisdictions, with a modest number, 36 requests, initiated by agencies at the federal level. This small number of interactions shows that the overall collaboration level for the preparation of Hurricane Katrina was significantly low. As discussed in the chaos theory (Prigogine & Stengers, 1984), the initial

condition of any system is crucial for its later evolution and adaptation, and the low level of preparedness for Louisiana and the City of New Orleans indicates potential problems for its response operations during Hurricane Katrina. The official report, "*The Failure of Initiative"* verifies the low level of preparedness of Hurricane Katrina response system by pointing out that the Department of Homeland Security (DHS) and the state agencies were not well prepared: "…despite extensive preparedness initiatives, Department of Homeland Security (DHS) was not prepared to respond to the catastrophic effects of Hurricane Katrina…." The main reason for this low level of preparedness, it can be assumed, is that the response system for Hurricane Katrina had never experienced such a large scale disaster, and so they had neither a relevant disaster management plan nor personnel in the system with sufficient experiences.

Table 5-5 Number of requests for assistance registered in Situation Reports by date and level of jurisdiction

Level of Jurisdiction	City		Parish		Regional		State		Federal		International		Total	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
26-Aug	0	0.0	15	1.13	0	0.0	0	0.0	0	0.0	0	0.0	15	0.47
27-Aug	0	0.0	80	6.01	0	0.0	25	1.6	0	0.0	0	0.0	105	3.27
28-Aug	0	0.0	106	7.96	2	6.5	105	6.7	4	2.0	0	0.0	217	6.75
29-Aug	7	9.3	319	23.97	5	16.1	466	29.8	36	17.6	0	0.0	833	25.92
31-Aug	2	2.7	163	12.25	3	9.7	198	12.7	26	12.7	0	0.0	392	12.20
1-Sep	13	17.3	71	5.33	2	6.5	83	5.3	8	3.9	1	16.7	178	5.54
2-Sep	18	24.0	96	7.21	3	9.7	103	6.6	18	8.8	1	16.7	239	7.44
3-Sep	20	26.7	179	13.45	7	22.6	240	15.3	34	16.6	2	33.3	482	15.00
4-Sep	3	4.0	38	2.85	2	6.5	80	5.1	21	10.2	1	16.7	145	4.51
5-Sep	12	16.0	264	19.83	7	22.6	264	16.9	58	28.3	1	16.7	606	18.86
Total	**75**	**100**	**1331**	**100**	**31**	**100**	**1564**	**100**	**205**	**100**	**6**	**100**	**3212**	**100**

Source: Situation Reports, Louisiana Office of Homeland Security and Emergency Preparedness, August 27 – September 6, 2005



Source: Situation Reports, Louisiana Office of Homeland Security and Emergency Preparedness, August 27 – September 6, 2005. Situation Reports were not available for August 31, 2005. (APPAM 2008 Conference Paper "Designing adaptive system for disaster mitigation and response" by Louise K. Comfort, Namkyung Oh, Gunes Ertan, and Steve Scheinert)

Figure 5-3 Number of requests for assistance registered in Situation Reports by date and level of jurisdiction

This low level of preparedness could have been anticipated by the outcome of the simulated operations exercise, Hurricane PAM. In the summer of 2004, FEMA ran a disaster simulation exercise in which a fictional hurricane named Pam hit the New Orleans area. The purpose of the Pam simulation was to help FEMA and local authorities in hurricane-prone areas prepare for future disasters. The result of FEMA's Hurricane Pam simulation could have provided a plan of action to prepare for real disasters like Hurricane Katrina. But there is very little evidence of organizational learning after this exercise. It predicted an almost accurate level of damage by suggesting possible scenarios, but the disaster response entities in the system did not change their standard operating procedures nor improve their operational and collaborative capacity. The lack of learning caused serious problems in collaboration during the actual response phase to Hurricane Katrina.

5.2.2 Problems identified in response to the request for resource allocation

The content analysis of the Hurricane Katrina situation reports further documents the system's ineffectiveness in allocating requested resources to other organizations. The data show that the available resources requested to support disaster operations after landfall were not identified, delivered, tracked, and stored effectively for the use of other organizations in the system. As a result, requests for resources were either delayed or failed to elicit timely responses. In fact, most organizations suffered either from late delivery or they got "no response (NR)" to their requests.

Table 5-6 shows the frequency distribution of requests for assistance by mission status reported to LOHSEP. All transactions were classified by their emergency support functions (ESFs) including: Search & Rescue, Damage Assessment, Supplies, Transportation, Evacuation, Shelter, Security, Emergency Response, Medical, Utility, Heavy Equipment, Light Equipment,

Personnel, and Communication & Coordination, based on the emergency support functions (ESFs) defined in the national response plan (2004). This analysis shows that during the period of August 27–September 6, 2005 there were 3,034 transactions that passed through the resources coordinating system of LOHSEP. The major role of LOHSEP for Hurricane Katrina was to coordinate and bridge the resource allocation between local and state/federal agencies. It also coordinated the resource allocation activities through the Emergency Management Assistance Compact (EMAC)[24]. Thus, LOHSEP allocated resource requests among organizations and maintained records of the logistics available in any specific time period.

Once there was a request for resource allocation from local governments, LOHSEP first assigned that request to the organization designated to perform that responsibility under the State Emergency Plan. If the designated organization cannot fulfill the request, LOHSEP sought an available organization that had the requested resources. If LOHSEP identified an organization with available resources, it assigned the request to that organization to provide resources. To complete this task successfully, LOHSEP had to be equipped with several critical capacities. First, it needed to communicate effectively with all local, state, and federal partners to check resource needs and process this information with accuracy and timeliness. Second, it needed to have the capacity of identifying and keeping track of available resources that are being used by other organizations in their operations. Third, it needed to be able to update requests and correct errors that are inevitable under the urgent, stressful context of disaster. These three tasks required LOHSEP to be equipped with a well designed supply chain management system, highly advanced resource management technology, and also a reliable communication system.

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24 EMAC, the Emergency Management Assistance Compact, is a congressionally ratified organization that provides form and structure to interstate mutual aid. Through EMAC, a disaster impacted state can request and receive assistance from other member states quickly and efficiently, resolving two key issues upfront: liability and reimbursement. (http://www.emacweb.org)

Tables 5-7 and 5-8 show how LOHSEP, as a primary coordinating organization, failed in managing the requests for resource allocation for the response to Hurricane Katrina. Among 3,034 requests for resources, only 4.6% (status of from 'requested' to 'Enroute', 'On-Scene', and 'Released') of total requests were actually delivered to the requesting organizations and the remaining 95.2% were not delivered in a timely manner. Of this set of requests, 56.1% remained at the stage of 'requested'. These requested resources were neither identified nor processed by LOHSEP and could not be delivered to the requesting organization. Also, the status of 'Pending' meant that requests for resources were submitted and assigned to a state organization or referred to a federal organization, but they were not accepted for action by that organization. While pending, many resource requests had been cancelled. This high pending and cancellation rate shows that the state-wide resource management system was significantly damaged and ineffective, and the large volume of duplicated and unnecessary requests caused congestion in the information processing channel of LOHSEP. Combined with the communication system breakdown, an overloaded LOHSEP could not process critical information in a timely manner and transmit it to the other organizations effectively.

Also, Table 5-8 shows the high ratio of 'no-response (NR)' to the requests by parish governments to LOHSEP. Again, this finding reveals that local parish governments did not receive timely support from state and federal agencies. If LOHSEP were equipped with an efficient communication system and advanced technology for resource management, it could have processed the requests more effectively. This capacity would have likely increased the resilience of the Hurricane Katrina response system significantly.

Table 5-6 Frequency Distribution of Requests for Assistance by Mission Status reported to Emergency Operation Center, State of Louisiana

	Search & Rescue		Damage Assessment		Supplies		Transportation		Evacuation		Shelter		Security		Emergency Response		Medical		Utility		Heavy Equipment		Light Equipment		Personnel		Communication & Coordination		Row Totals	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
No Response	27	14.8	3	37.5	166	25.0	40	21.5	8	57.1	45	19.0	104	20.6	21	25.0	63	35.4	58	25.7	130	28.3	16	19.8	28	20.9	20	26.7	729	24.0
Action Required	95	52.2	7	87.5	414	62.3	99	53.2	12	85.7	115	48.5	207	41.0	45	53.6	141	79.2	115	50.9	245	53.4	36	44.4	71	53.0	38	50.7	1640	54.1
Operation Pending	98	53.8	2	25.0	248	37.3	65	34.9	3	21.4	83	35.0	248	49.1	36	42.9	26	14.6	100	44.2	157	34.2	38	46.9	47	35.1	24	32.0	1175	38.7
Cancelled	15	8.2	1	12.5	37	5.6	26	14.0	1	7.1	28	11.8	36	7.1	4	4.8	21	11.8	35	15.5	60	13.1	5	6.2	27	20.1	4	5.3	300	9.9
On-Going	0	0.0	0	0.0	0	0.0	2	1.1	0	0.0	0	0.0	9	1.8	0	0.0	0	0.0	0	0.0	7	1.5	0	0.0	0	0.0	1	1.3	19	0.6
En Route	5	2.7	0	0.0	9	1.4	5	2.7	0	0.0	12	5.1	27	5.3	5	6.0	1	0.6	28	12.4	9	2.0	2	2.5	4	3.0	0	0.0	107	3.5
On Scene	0	0.0	0	0.0	0	0.0	7	3.8	0	0.0	36	15.2	51	10.1	2	2.4	3	1.7	1	0.4	24	5.2	7	8.6	0	0.0	10	13.3	141	4.6
Released	0	0.0	0	0.0	3	0.5	1	0.5	0	0.0	0	0.0	2	0.4	0	0.0	1	0.6	8	3.5	1	0.2	0	0.0	1	0.7	1	1.3	18	0.6
Total Transactions	182	6.0	8	0.3	665	21.9	186	6.1	14	0.5	237	7.8	505	16.6	84	2.8	178	5.9	226	7.4	459	15.1	81	2.7	134	4.4	75	2.5	3034	100

Source: Situation Reports, Louisiana Office of Homeland Security and Emergency Preparedness, August 27 – September 6, 2005 (APPAM 2008 Conference Paper "Designing adaptive system for disaster mitigation and response" by Louise K. Comfort, Namkyung Oh, Gunes Ertan, and Steve Scheinert)

Table 5-7 Change in Status of Requests for Assistance, Louisiana Office of Homeland Security and Emergency Preparedness

	Search & Rescue	Damage Assessment	Supplies	Trans-portation	Evacuation	Shelter	Security	Emergency Response	Medical	Utility	Heavy Equipment	Light Equipment	Personnel	Communication & Coordination	Row Totals
Number of Requests, Required to Pending	**26**	**1**	**30**	**6**	**1**	**9**	**30**	**3**	**2**	**20**	**6**	**4**	**5**	**N/A**	**143**
Total number of hours in Status	1254.0	107	5208.0	112.0	4	290.0	981.0	101.0	52.0	1740.0	128.0	156.0	256.0	N/A	
Mean Number of Hours in Status	48.2	107	173.6	22.4	4.00	32.2	32.7	33.7	26.0	87.0	21.3	39.0	51.2	N/A	
Median Number of Hours in Status	12.0	107	192.0	15.5	4.00	27.0	37.0	32.0	26.0	93.0	17.0	42.5	39.0	N/A	
Std. Deviation	122.8	N/A	48.6	15.1	N/A	32.9	14.1	20.6	5.7	33.2	14.6	29.5	53.1	N/A	
Range	627.0	N/A	179.0	38.0	N/A	105.0	72.0	41.0	8.0	124.0	35.0	67.0	130.0	N/A	
Minimum	0.0	N/A	67.0	6.0	N/A	2.0	0.0	14.0	22.0	20.0	4.0	2.0	14.0	N/A	
Maximum	627.0	N/A	246.0	44.0	N/A	107.0	72.0	55.0	30.0	144.0	39.0	69.0	144.0	N/A	
Number of Requests, Required to (Pending) to Cancelled	**7**	**1**	**12**	**8**	**1**	**10**	**19**	**2**	**12**	**15**	**28**	**2**	**11**	**2**	**130**
Total number of hours in Status	79.0	50	568.0	344.0	108	468.5	494.0	89.0	721.5	1004.0	2141.5	130.0	365.5	41.0	
Mean Number of Hours in Status	11.3	50	47.3	43.0	108.0	46.9	26.0	45.0	60.1	66.9	76.5	65.0	33.2	20.5	
Median Number of Hours in Status	4.0	50	39.5	21.0	108.0	40.8	26.0	44.5	8.5	46.0	61.0	65.0	29.0	20.5	
Std. Deviation	16.9	N/A	29.3	51.4	N/A	40.3	25.5	60.1	82.2	51.8	57.5	83.4	19.7	16.3	
Range	41.0	N/A	111.0	136.0	N/A	138.0	94.0	85.0	188.5	148.0	188.0	118.0	71.0	23.0	
Minimum	0.0	N/A	3.0	4.0	N/A	6.0	0.0	2.0	4.0	2.0	2.0	6.0	6.0	9.0	
Maximum	41.0	N/A	114.0	140.0	N/A	144.0	94.0	87.0	192.5	150.0	190.0	124.0	77.0	32.0	
Number of Requests, Required to Completed (Enroute+On Scene+Released)	**2**	**N/A**	**6**	**3**	**N/A**	**11**	**35**	**2**	**1**	**28**	**6**	**1**	**N/A**	**1**	**96**
Total number of hours in Status	2.00	N/A	112.0	8	N/A	370.0	762.0	56	37	1810.0	193.0	2.0	N/A	14.0	
Mean Number of Hours in Status	1.00	N/A	37.3	2.70	N/A	33.6	21.8	28.0	N/A	64.6	32.2	2.0	N/A	14.0	
Median Number of Hours in Status	N/A	N/A	25.0	2.00	N/A	19.0	19.0	28.0	N/A	39.0	24.5	2.0	N/A	14.0	
Std. Deviation	N/A	N/A	39.0	3.05	N/A	38.8	24.6	12.7	N/A	47.5	34.5	N/A	N/A	N/A	

Source: Situation Reports, Louisiana Office of Homeland Security and Emergency Preparedness, August 27 – September 6, 2005 (APPAM 2008 Conference Paper "Designing adaptive system for disaster mitigation and response" by Louise K. Comfort, Namkyung Oh, Gunes Ertan, and Steve Scheinert)

Table 5-8 Types of Ratio for Changes in Status, Requests for Assistance in Disaster Operations, Louisiana Office of Homeland Security and Emergency Preparedness

		Search & Rescue	Damage Assessment	Supplies	Transportation	Evacuation	Shelter	Security	Emergency Response	Medical	Utility	Heavy Equipment	Light Equipment	Personnel	Communication & Coordination	Total
No Response Ratio	Number of 'No Response'	27	3	166	40	8	45	104	21	63	58	130	16	28	20	729
	Number of Total Requests	182	8	665	186	14	237	505	84	178	226	459	81	134	75	3034
	Ratio of NR to Requests	14.84	37.50	24.96	21.51	57.14	18.99	20.59	25.00	35.39	25.66	28.32	19.75	20.90	26.67	24.03
Holding Ratio	Number of 'Action Required to Pending'	26	1	30	6	1	9	30	3	2	20	6	4	5	N/A	143
	Number of Total Requests - No Response	155	5	499	146	6	192	401	63	115	168	329	65	106	55	2305
	Ratio of Action Required to Pending	16.77	20.00	6.01	4.11	16.67	4.69	7.48	4.76	1.74	11.90	1.82	6.15	4.72	N/A	6.20
Cancellation Ratio	Number of 'Action Required to Cancelled'	7	1	12	8	1	10	19	2	12	15	28	2	11	2	130
	Number of Total Requests - No Response	155	5	499	146	6	192	401	63	115	168	329	65	106	55	2305
	Ratio of Action Required to Cancelled	4.52	20.00	2.40	5.48	16.67	5.21	4.74	3.17	10.43	8.93	8.51	3.08	10.38	3.64	5.64
Completion Ratio	Number of 'Action Required to Enroute, On Scene, and Released'	2	N/A	6	3	N/A	11	35	2	1	28	6	1	N/A	1	96
	Number of Total Requests - No Response	155	5	499	146	6	192	401	63	115	168	329	65	106	55	2305
	Ratio of Action Required to Enroute, On Scene, and Released	1.29	N/A	1.20	2.05	N/A	5.73	8.73	3.17	0.87	16.67	1.82	1.54	N/A	1.82	4.16

Legend: **No Response Ratio** = Number of 'No Response' / Number of Total Requests by Transaction Category; **Holding Ratio** = Number of 'Action Required to Pending' / (Number of Total Requests by Transaction Category - Number of No Response); **Cancellation Ratio** = Number of 'Action Required or Pending to Cancelled'/ (Number of Total Requests by Transaction Category – Number of No Response); **Completion Ratio** = Number of 'Action Required to Enroute, On-scene, and Released' / (Number of Total Requests by Transaction Category – Number of No Response.

Source: *Situation Reports*, Louisiana Office of Homeland Security and Emergency Preparedness, August 27 – September 6, 2005 (APPAM 2008 Conference Paper "Designing adaptive system for disaster mitigation and response" by Louise K. Comfort, Namkyung Oh, Gunes Ertan, and Steve Scheinert)

Findings from this analysis reveal where delays in resource delivery occurred, that is, where the bottlenecks are. A bottleneck is a critical point that causes delay in the interdependent process of emergency response, hindering the operations of the whole system. This inquiry seeks to identify points in the critical process of an evolving response system where delay by one organization triggers a cascade of delay throughout the set of organizations participating in response operations. The source of the delay could be technical, organizational or both. But if these bottlenecks can be identified in an actual response system, the response process can be redesigned to operate more efficiently in future disaster operations.

To identify the bottlenecks, this study focused on the responding organizations because they receive requests from the initiating organizations and are responsible for taking the next step of action and distributing the incoming information and resources to other organizations in the system. To identify the bottlenecks in this process, I counted the total number of hours that a request for assistance spent in one phase before it was shifted to the next phase in the response process. Table 5-7 shows the system's late response to requests for resources allocation through data on the processing of change in status categories, or the number of hours that requests were held in each action status category before moving to the next. These data provide a profile of the pace of disaster operations and the amount of delay involved in meeting requests for action. The data document the sizeable delay in assigning the requests to an agency for action - the change from "action required" to "pending" - for even the most urgent requests. For example, the delay for "search and rescue" (Mean = 48.2 hours) was more than two days and "emergency response" (Mean = 33.7 hours) was more than a day. For less immediate requests, such as "utilities", the time delay was 3.6 days, and for "supplies" the time delay was even longer, an average of 7.2 days.

According to this analysis, clearly, the EOC at LOHSEP was overwhelmed. The categories with the largest number of requests (security, search & rescue, and supplies) had significant delays, indicating disconnected linkages in the interdependent disaster response network. Two types of requests for assistance made to LOHSEP received a higher rate of completion than the others: security and utilities. While the requests detailed in the situation reports were initially intended for Louisiana state agencies, the cumulative delay in response indicates the inability of the state to meet these requests without federal assistance. This finding further indicates a low capacity of the state's emergency response system to absorb threatening information and communicate it effectively among its members.

The delay in transition from one status to the next status of resource allocation can be structured like Table 5-9 to place more focus on status transition time. As shown in Table 5-9, the total number of hours for the entire system to shift from "action required" to "pending" is 10,389 hours with the mean of 72.7 hours and standard deviation of 30 hours. Although there are no data for the status change from "on-scene" to "released", the recorded time delay was lengthy in shifts from "action required" to "pending" and from "pending" to "cancellation." After LOHSEP received the initial and unverified information from initiating organizations, agency staff needed to verify the incoming request and assign it to a response agency. This procedure was established to validate the request and ensure that scarce resources were allocated appropriately. During this period of verification, the request was classified as 'pending.' But, in an event the scale of Hurricane Katrina, the workload of LOHSEP staff in processing the incoming requests for assistance quickly increased to the point that the requests were stalled in the pending phase. As a result, quick and effective decision-making was severely limited. In this time-dependent process, the time lag increased dramatically in the subsequent status shifts.

Table 5-9 Total time delay in hours reported for each change of status

	Number of Transactions	Total Time Elapsed (Hours)	Mean	Median	Standard Deviation	Maximum	Minimum	Range
Action Required to Pending	143	10389	72.7	32.0	30.0	150.0	0.0	150.0
Pending to Enroute	23	938	40.8	39.0	47.0	150.0	0.0	150.0
Enroute to Onscene	21	353	16.8	19.0	7.6	43.0	8.0	35.0
Onscene to Released	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Action Required (Pending) to Released	13	893	68.7	44.0	54.3	150.0	2.0	148.0
Action Required to Cancellation	88	5031	57.2	39.0	51.2	192.5	0.0	192.5
Pending to Cancellation	42	1569	37.4	15.5	46.4	162.0	0.0	162.0

Source: *Situation Reports*, Louisiana Office of Homeland Security and Emergency Preparedness, August 27 – September 6, 2005 (APPAM 2008 Conference Paper "Designing adaptive system for disaster mitigation and response" by Louise K. Comfort, Namkyung Oh, Gunes Ertan, and Steve Scheinert)

To identify the organizations that created bottlenecks in resource allocation, this study counted the accumulated time period in hours for each responding organization to estimate the length of time it took for these organizations to shift to the next stage in response operations. For example, if it took 35 hours for FEMA to shift from "action required" to "pending" and 10 hours to shift from "pending" to "on scene", and again took 12 hours from "on scene" to "released", then the total accumulated number of hours in this case is 57 hours and the mean is 19 hours. One possible criticism for this approach is that if any one organization has a higher number of response requests than other organizations, then the accumulated time would increase accordingly. By dividing the accumulated number of hours over the response process by the number of interactions, this study calculated the mean time of the delay between an initial report of 'action required' and the shift to the next stage of action. The results are reported in the following Table 5-10. The organizations listed in Table 5-10 represent the set of organizations identified in the situation reports as the primary actors in the disaster response system that emerged following Hurricane Katrina. Each organization interacted with other organizations in the performance of the fourteen categories of response actions. These fourteen categories

represent subsets of actions taken within the entire disaster response system. Table 5-10 summarizes the accumulated time, total number of requests for assistance, and means of response time for each organization. None of the organizations reported rapid mean response records, but compared to one another, the Louisiana National Guard, Louisiana Office of Homeland Security and Emergency Preparedness, and the Louisiana State Police were more efficient in their roles. These findings document the lower time lag for the organizations responsible for security at the state level in comparison to the other categories. Other organizations that received a significant number of requests, such as the US Army Corps of Engineers, and FEMA, were much slower in their response.

Table 5-10 Total time lag for each responding organization

Name of Organization	Accumulated Total Delay, When Responding (Hours)	Number of Transactions	Mean (Hours)
Department of Health and Hospitals, Louisiana	730.5	5	146.1
American Red Cross: Louisiana Southeast Chapter	144	1	144.0
Department of Transportation and Development, Louisiana	152	2	76.0
Army Corps of Engineers	4571	64	71.4
Louisiana Emergency Operations Center	283	4	70.8
Federal Emergency Management Agency, United States	1477	25	59.1
Department of Agriculture and Forestry, Louisiana	955	18	53.1
Department of Wildlife and Fisheries, Louisiana	791.5	20	39.6
Parish of East Baton Rouge	39	1	39.0
Civil Air Patrol - Louisiana Wing	76	2	38.0
Emergency Management Assistance Compact	37	1	37.0
Louisiana State Police	145.4	4	36.4
Homeland Security Division of LOHSEP	64	2	32.0
Louisiana Office of Homeland Security and Emergency Preparedness	862	27	31.9
Louisiana Army National Guard	312.5	10	31.3
Louisiana National Guard	2915.5	105	27.8
Louisiana Air National Guard	183	10	18.3

Source: Situation Reports, Louisiana Office of Homeland Security and Emergency Preparedness, August 27 – September 6, 2005 (APPAM 2008 Conference Paper "Designing adaptive system for disaster mitigation and response" by Louise K. Comfort, Namkyung Oh, Gunes Ertan, and Steve Scheinert)

5.3 PERFORMANCE PROBLEMS VERIFIED AND IDENTIFIED FROM THE SEMI-STRUCTURED INTERVIEW

Using semi-structured interviews, this study verified the problems identified from the content analysis of situation reports and tried to examine critical points more closely in which the Hurricane Katrina response system failed. For this reason, findings from the semi-structured interviews were used to confirm the problems identified in the previous content analysis. This analysis revealed several more problems that organizations actually faced in their response to Hurricane Katrina. Table 5-11 identifies the frequencies that managers of different organizations mentioned the major problems in the organizations' operation and collaboration activities for Hurricanes Katrina.

Figure 5-3 shows the five most critical problems that managers faced in response to Hurricane Katrina. As identified by the content analysis of situation reports, the failure in maintaining a reliable communication system made it difficult for organization to develop situation awareness and this contributed to the ineffective performance of organizations in the disaster response system. With the collapse of the communication system, organizations could not manage their personnel and resources effectively, and this failure exacerbated the problems that interfered with their ability to operate and collaborate with their partners in the system. Finally, the lack of proper disaster response plan and also the insufficient resources for their operations were another critical problem they needed to address.

Table 5-11 Structured codes identified for major problems in disaster management

Category	Concept	Code	Description	Frequency	Number of Organization
Problems in Operation	Failure in human resource management	Staffing	Lack of enough personnel for operation	10	7
		Deteriorated personnel working conditions	Insufficient facilities and resources that weaken personnel morale	7	4
		Inexperienced personnel	Inexperienced personnel with insufficient training	19	14
		Turnover in major position	Replacement of personnel in major positions	6	5
		Total		42	
	Failure in resource management	Delayed or partial delivery	Delayed or partial resource delivery	21	15
		Inaccurate estimation of needs	Lack of exact resource estimation system	12	9
		Failure in vendor management	Unreliable resource delivery by private vendors in a timely manner	6	4
		Lack of available resources	Lack of resource in the disaster management system	20	13
		Total		59	
	Lack of proper management plan/procedures	Lack of clear disaster management plan	Lack of proper disaster management plan	24	15
		Lack of flexibility for adaptation	Inflexibility of plan for adaptation	3	3
		Lack of aligned plan	Incompatibility of plan among organizations	4	4
		Total		31	
	Insufficient funding		Insufficient funding for operation	5	3
Difficulties in getting big operation picture	Lack of situational awareness	Failure in transmitting action knowledge	Problems in diffusing action knowledge	7	13
		Difficulty in processing and producing action knowledge	Organizational incompetency in processing and producing action knowledge for collaboration	5	7
		Total		12	
	Problems in communication system	Communication system breakdown	Communication system breakdown	36	20
		Lack of communication equipment	Lack of extra communication facilities for redundancy	22	15
		Lack of communication channels	Lack of clear communication channels and partners	7	5
		Lack of proper technology for communication	Lack of proper communication technology	6	5
		Total		71	
Problems in collaboration	Lack of collaborative attitudes	Rivalries among organization	Territorialism or competing interests for authority	10	9
		Competition in resources	Competition among organizations for the same resources	6	5
		Ego (Personality)	Personal tendency to refuse collaboration	14	10
		Total		30	
	Institutional barriers	Lack of transparency in its operation	Hidden agenda preventing collaboration	5	5
		Bureaucratic incompetence	Lack of collaboration due to the bureaucratic incompetency	6	5
		Lack of coordinating structure	Lack of a coordinating institutional structure	6	4
		Unexpected intervention from political leaders	Unexpected intervention from political leaders which disrupt the entire operation	3	2
		Lack of collaboration experiences	Lack of collaboration experiences	11	5
		Total		31	

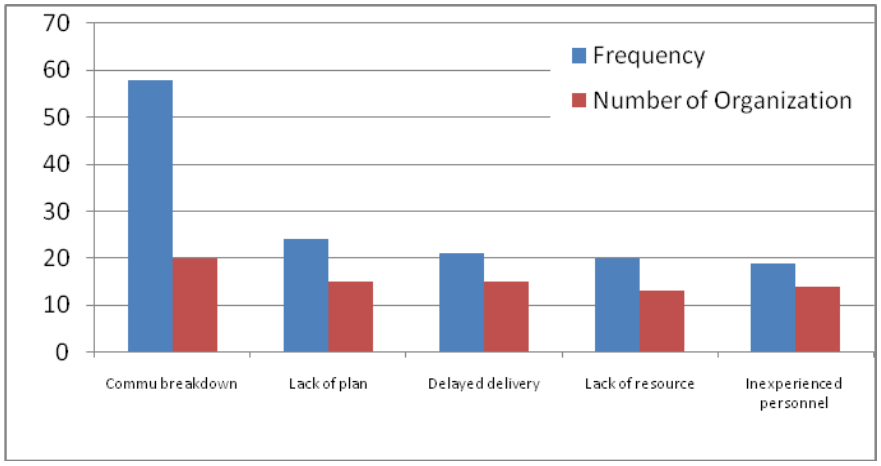


Figure 5-4 Top five identified problems by managers of core organizations

5.3.1 Communications system breakdown

As indicated in the frequency distribution, the most critical problem for the Hurricane Katrina response system was the collapse of the communications system. Many interviewees agreed that the breakdown of the communications system severely hampered their organization's operation and collaboration with partners in the system. Because of this breakdown, they could not understand the exact situation at the site and could not formulate the common operating picture that is necessary for effective coordination and collaboration. As a result, each organization in the system was isolated from others, could not transmit valid information to others, and was unable to operate in a coordinated manner.

Among the 36 organizations included in the sample, 27 (75%) respondents reported that their capacity to communicate with other organizations totally collapsed due to various reasons. These reasons ranged from lack of equipment and the lack of current technology to a lack of written, practiced procedures. As a result, the entire system for Hurricane Katrina could not develop the timely situational awareness that is necessary for a coordinated response to disasters. According to Table 5-11, 20 organizations that were positioned at critical points in the

collaboration structure could not adequately produce and transmit information necessary for coordination and collaboration. These factors prevented each organization from processing and producing actionable knowledge for other organizations in the system. Without accurate and timely information, the communications system for Hurricane Katrina was not stable and redundant. Rather, it was vulnerable to outside impacts from the disaster conditions.

5.3.2 Lack of experienced personnel in the Hurricane Katrina response system

In addition to the failures of the communication system, the disaster response system of Hurricane Katrina suffered from several problems in organizational operation. These problems included: lack of experienced personnel (failure in human resource management), lack of available resources (resource management), lack of appropriate disaster management plans and procedures (failure in planning), and funding for operations.

First, the response system for Hurricane Katrina had an inadequate level of personnel. Because of frequent turnover in major positions after the 9/11 terrorist attacks (Bergel, 2007 and Washington Post, 2007), the level of expertise and the morale of employees in the disaster management field had been severely downgraded. And these vacant core positions caused by frequent turnover were not filled by experienced personnel at the time of Hurricane Katrina. Thus, many organizations in the Hurricane Katrina disaster response system were exposed to a lack of leadership and experience.

> …we lost a lot of people, we'd lost a lot of experience, and we weren't as big as we were in the '90's. We weren't as big as we were, say, for 9/11. We didn't have as many full-time employees and that definitely caused problems during Katrina because we just didn't have enough people… (FEMA)

In this situation, the personnel in the system needed to operate with this limited number of inexperienced personnel. Moreover, the burden for each individual in the organization was

increased to an unmanageable level due to the overload of information processing requests. In extreme cases, some personnel deserted their positions in the response phase of Hurricane Katrina. As the superintendent of the New Orleans Police said, there was a severe under-staffing problem for the response to Hurricane Katrina and the personnel in active service were overloaded with work. This made all information processes and disaster response operations slow down significantly.

> More than 200 officers deserted during the storm and were fired or suspended. Many veteran officers retired, and some of the youngest officers quit and left town. As a result, the size of the force has dropped to about 1,400 officers on the street now, from nearly 1,700 before the hurricane. Recruiting replacements is difficult, partly because it is hard for candidates to find affordable housing, Mr. Riley said… (New York Times, June 2006)

> …We're understaffed. We take an approach of multitasking or multi-missioned approach. So we're always, we're never appropriately resourced either with infrastructure, with our assets, our capital assets, and not with people…. (U.S. Coast Guard, USCG)

But, at the same time, this lack of personnel and increased workload was used as a chance for breeding experienced personnel for future disasters. Especially, some managers in active service during Hurricane Katrina could develop its leadership, and creative ways of adaptation to changing conditions. But this improvised leadership was not enough for organizations to fill the gap created by the lack of experienced personnel at the time for the response to Hurricane Katrina.

> …it forces our people to be very innovative and to move forward with new ideas to be able to improve but sometimes the cost of that is that you lose some of the lessons learned… (U.S. Coast Guard, USCG)

Further, the situation for disaster response organizations was made more difficult by a lack of consideration for the welfare of personnel. Personnel working during the response to Hurricane Katrina had to operate in very poor working conditions. They had to operate without facilities for sleeping, bathing, or dining. Also, supplies, especially to first responders, were insufficient for normal operations.

> …welfare of everybody at this facility. In other words, let me give you a scenario. We allowed people to work 18 to 20 hours, exhausted, so now we implemented an internal management procedure for scheduling and hours worked… (St. Tammany Parish)

In summary, disaster management organizations suffered from a lack of personnel during the response to Hurricane Katrina. This lack of personnel and the low level of experience combined with the inferior working conditions exacerbated the harsh conditions caused by Hurricane Katrina. With this lack of personnel, the workload of core organizations in the system increased to levels so high as to cause the malfunction of those organizations.

5.3.3 Lack of available resources

With the failure of human resource management, physical resource management during Hurricane Katrina proved to be ineffective. In particular, the notorious delays and failures to respond to the requests for resource allocation were identified as one of the major problems for the Hurricane Katrina response system by the content analysis of situation reports. According to the coded segments of the semi-structured interviews, there were several different but related problems in resource management responding to Hurricane Katrina. First, physical resources were scarce throughout the entire disaster response system. According to the Stafford Act, the initial responsibility for the response to a disaster lies at the local level of government. If additional resources are needed, the federal and other state agencies are to be contacted to get available resources from outside the local and state disaster management system boundary. However, findings from the content analysis and semi-structured interview data show that resource allocation within local and state boundaries, with outside organizations at the federal level, and with other state agencies failed. And this caused difficulties in securing necessary resources for organizations in the system.

> …local and state government had no assets to provide support to anyone therefore they couldn't collaborate (Ochsner Hospital)

Because there were not enough resources available within the initial boundaries of the local and state response system for Hurricane Katrina, organizations needed to rely upon resources from outside of the system. Why resources were so scarce in the system was not clear from the content analysis of situation reports. According to the semi-structured interviews, agencies in the system could not estimate the need for resources accurately. This is mainly due to the lack of experience in coping with large disasters such as Hurricane Katrina. After Hurricane Andrew's landfall[25] in August 1992, the Gulf area had not been hit with such a large-scale hurricane in over 10 years, so the working memory and experience from that event were not retained by the disaster management system for the response to Hurricane Katrina. This failure in estimation of need reveals the absence of advanced technology for the resource management and the resource management activities could not be integrated into the operations of other organizations within the system. Accordingly, pre-positioning of available resources, a critical element of disaster management, was not possible for the Hurricane Katrina disaster response system.

> …Yeah, I think the biggest problem was that there was a perception of need as opposed to a true need. In other words, government can perceive that they need fuel and that they shouldn't be selling it to the public because we need it but if you're not really short on it, do you really need it? So it was more of a perception… (Washington Parish)

A second reason for the system's failure in securing sufficient resources for disaster response was a lack of vendor or supply chain management needed for maintaining a steady supply of resources. Without reliable and stable partners for supplies, the disaster response

25 Hurricane Andrew struck the northwestern Bahamas, southern Florida at Homestead (south of Miami), and southwest Louisiana around Morgan City in August. Andrew caused $26.5 billion in damage ($38.1 billion in 2006 US dollars), with most of that damage cost in south Florida, although other sources put damage between $27 billion to $34 billion in total costs. Its central pressure ranks as fourth-lowest in U.S. landfall records and Andrew was the costliest Atlantic hurricane in U.S. history until surpassed by Hurricane Katrina of the 2005 season.

system for Hurricane Katrina would not have sufficient resources. One example of the failure of vendor management is a bus company's failure to show up at the promised site and time that was preset for evacuation. For the evacuation of the southern parishes, each parish government and the Department of Social Services required hundreds of buses for residents' evacuation, but some buses did not show up as promised. Also, the local and state governments could not maintain a constant relationship with vending partners for the reliable supplies of resources.

> …Our problem came in the inability of pre-negotiated contracts of commercial buses to be executed in a timely manner. We knew that it could be a possibility so we had a back up to that with the utilization of school buses but that cost some confusion in there… (Governor's Office of Homeland Security and Emergency Preparedness, GOHSEP)

These failures in vendor management, the lack of available resources, and the inaccurate estimation for needs caused, as mentioned in the content analysis chapter, delayed or led to partial delivery of requested resources to the end-nodes of the disaster response system.

> …it was so confusing, working, the supplies didn't come because it took us two weeks to hold what we needed food and water and then when it would come they would send everything to one spot, drop the trailer off and leave with the truck and I'm sitting with three trucks of water up here, don't need the water in the northern end of the parish, need the water in the southern end of the parish but now it's in the northern. Made our job harder trying to move it from here to there… (Lafourche Parish)

5.3.4 Lack of disaster management plan/procedure

In addition to the mismanagement of the important resources of personnel and supplies, the disaster response system also suffered from the absence of clear disaster management plans and operating procedures. In many cases, organizations did not have clearly defined procedures in their disaster management plans. This was particularly true regarding resource allocation among organizations in the system, the contact points at the local, state and federal levels for resource and information sharing were not clear enough to interact quickly.

The problems could be attributed to the absence of plans for specific response activities, and sometimes, they the lack of exercise and education for existing plans and procedures. Many interviewees (15 organizations out of 36) complained that there was an entire absence of any kind of disaster response plans for Hurricane Katrina. Considering that the National Response Plan (NRP) was introduced to the system only in December of 2004, organizations were still not familiar with its details in time for Hurricane Katrina. This also contributed to the lack of exercises and training before Hurricane Katrina. Other interviewees pointed out that the existing disaster response plans were not clear enough to be used as a basis for the organizations' operations.

> …You hate to say it but it was again there was no planning. It was poor for Katrina… (Ascension Parish)…What we called our City Assistant Evacuation plan which we did not have for Katrina… (Orleans Parish)… Well because before then we really never had a plan for hurricane Katrina… (New Orleans Fire Department)

> …the National Response plan and NIMS had just come out in early 2005 so really by the time Katrina hit the organization, the state, the nation really hadn't had a chance to implement many of those systems and all… (Governor's Office of Homeland Security and Emergency Preparedness, GOHSEP)

In addition to the absence of effective disaster response plans, the existing plans were not flexible enough to allow managers to exert their creativity in efforts to adapt to the changing conditions. When the normal disaster management plan does not work, new working procedures for collaboration are required, and managers in major disaster management organizations need to demonstrate a competency in sense-making for adaptation (Weick 1995). But the rigidity in disaster management plans inhibited them from exerting that kind of leadership for the creative response to Hurricane Katrina.

> …The Stafford Act is not good for major emergencies whenever designed for the amount of disaster we had for Katrina. It needs to be improved. It needs to allow the freedom to a lot of different things but most of the Stafford Act is to repay after the damages… (Orleans Parish)

A third major problem was the lack of alignment among plans for disaster response and mitigation. Each plan's timeline, main partners, working procedures, and disaster fighting

equipment were not compatible with each other, and sometimes, there was competition among organizations for the procurement of resources instead of collaboration. For example, the timeline of evacuation of the southern parishes and the shelter preparation timeline of the state governments were not aligned with each other for response to Hurricane Katrina. As a result, many evacuees suffered due to unprepared or missing shelters over one week.

> …That was a state call, they sent them to Texas but Texas, their policy says they only hold them for two days. So in two days Texas said: "Get back on the bus, you're going home." And them people are ready to go home, so they got on the bus… (Lafourche Parish)

5.3.5 Lack of collaborative mind and culture

The problems identified in semi-structured interviews mirror those of identified by the content analysis of situation reports. This study sorted the findings from the content analysis and semi-structured interviews into two parts by their effects on the failure in collaboration. The first one is the lack of a collaborative mindset and personal attitude, and the second one is the institutionalized structural barriers that are basically stemming from the bureaucratic or hierarchical structure of the Hurricane Katrina response system.

The most critical problem was the lack of a collaborative mindset on the part of the managers taking the commanding positions in disaster response organizations. This lack of collaborative attitudes can be attributed to several reasons. First, a manager's ego or personality simply did not allow collaboration with other organizations. Why some managers in disaster response organizations refused to collaborate with others was uncertain and hard to determine from these semi-structured interviews, but many interviewees pointed out that a manager's ego/personality was the main reason for the failure of collaboration.

> …Policemen are a different mentality. They really are. They're trained to do it on their own. They're trained as a single body, you take care of yourself. Firemen are trained to work as teams. It's a little bit easier to do the unified thing because we from the get-go are trained to work as

> teams. Whereas the policeman are trained to work independently and you get into the swat teams and those type of teams on the police department… (New Orleans Fire Department)

In addition to this personality issue, rivalries among organizations were another source of problems. Someone described this problem as a 'turf battle' or 'territorialism', and others as 'politics' that can be defined as competition among organizations to increase their own power in the phases of disaster response and mitigation. With this turf battle or territorialism, effective coordination among organizations was not achieved in the response to Hurricane Katrina.

> …there is probably some internal turf battles within the various state agencies that are, turf battles and what I mean by that, you have them responsible for one area and you have another group that may have an overlap and there may be some controversy about who's in charge of what area… (Entergy)

This problem of personal ego and territorialism became explicit when each organization was isolated and suffered from a lack of resources during the initial stage of the response to Hurricane Katrina. Sometimes there were several organizations competing over setting priorities for the same resource allocation. In the extreme case, when resources passed through their authority, some local agencies intercepted them without coordinating those procedures with LOHSEP or other state and federal agencies.

> …I know the political, legislative branch was fighting, not fighting but jockeying to get those resources in those communities, the communities they represent. So yes, there was definitely some influence trying to get those resources where they need them until the state actually got enough people… (Assumption Parish)

Combined with personal factors, institutional barriers that prevented effective collaboration also played a critical role in the poor coordination and collaboration. The most part of institutional barriers is related to rigid bureaucratic principles in collaboration. Moreover, due to the lack of collaboration experiences, organizations did not make their operations clear and open to other organizations. And this lack of transparency hampered a development of a system-wide collaboration protocols.

> …Hidden agendas from other agencies. For instance there's GOHSEP, has enormous hidden agendas sometimes. Not sure why. Hidden agendas mean you know taking the planning effort

> down the road that only benefits them and puts the other agency in a poor light… (Department of Transportation and Development, LA)

Rather than collaborating, some organizations, or managers of those organizations, relied on the traditional command and control system and sometimes went far beyond the limits of legal authority for intervention in the command and control system. As a result, some political leaders stepped into the officially defined procedures for interaction and they, intentionally or unintentionally, distorted and caused confusion in collaboration.

> …people from higher levels of government or maybe local politicians and local leaders that aren't a part of that, when the planning and preparation is going on, then when the actual event happens, that's when they get interested in it and decide that "I've got to get involved in this and start calling the shots" and they come in and say "well do this, do this, do this" and you have to go "wait a minute sir, we've got a plan to do that, but that's not it. This is how we planned to do it, this is how we plan on doing this."… (Department of Wildlife and Fisheries, LA)

Combined with bureaucratic incompetency and irrelevant interaction structures that hampered collaboration among agencies, the collaboration links among agencies were weakened by the level of isolation. During the most critical period of the response, organizations in the system could not exchange necessary information and resources with other organizations.

6.0 EVIDENCE OF ORGANIZATIONAL LEARNING IN PERFORMANCE AND INTERACTION STRUCTURE

In chapter 5, I presented the findings from content analysis of situation reports and semi-structured interviews and identified the major problems that organizations faced during their adaptation to changing conditions. Organizations were not prepared for as large a disaster as Hurricane Katrina, and, accordingly, their capacity for communication and collaboration for information and resource allocation was severely damaged. This chapter checks the evidence of organizational learning between two hurricane response systems. To address the challenges from rapidly changing conditions and to improve their performance under complexity, organizations invested enormous resources and revised their interaction structure. The three year term between Hurricane Katrina and Hurricane Gustav tested the stability and resilience of this newly established system for disaster response and mitigation. But the problem is, as proven by the failure of Hurricane Katrina response system, various structural changes and investments do not always secure improvement in collaboration and effective operation in response to major disasters. Thus, I combined the organizational changes since Hurricane Katrina with the evidence of performance improvements and checked how intended changes could contribute to the entire system's response operations to Hurricane Gustav. I started from a comparison of each hurricane response systems' structure and their formation, and identified changes in core organizations and core collaboration links in the response systems.

6.1 EVIDENCE OF ORGANIZATIONAL LEARNING IN INTERACTION STRUCTURE AND FORMATION

This study uses comparative analysis of two hurricane response systems (Hurricanes Katrina and Gustav) to identify the difference in interaction structure among organizations in each response system. This comparison of the interaction structure of two response systems is possible with the structured data set prepared from content analysis of newspaper articles and situation reports. Using this structured data, this study creates network maps using UCINet (Borgatti et al, 2002). The network map of each response system provides a visualization tool that allows the direct and intuitive comparison of two network maps of response systems. But, at the same time, due to the number of organizations and complexity in their interactions, this network map does not work as an appropriate tool for comparative analysis. To identify the formation of the entire network and the core actors/collaboration links, this analysis complements the findings from network maps with measures of social network analysis.

6.1.1 Size of network of hurricane response systems

Table 6-1 provides the description of two hurricane response systems. It shows that the total number of non-isolated organizations is 329 for Hurricane Katrina and 222 for the Hurricane Gustav response system. The total number of links is 758 for Katrina and 302 for Gustav, with the average number of links at 2.35 for Hurricane Katrina and 1.36 for Hurricane Gustav respectively. Relationships are coded as interactions if any two organizations exchange information or resources or otherwise operate together during the preparation and response phase of either hurricane.

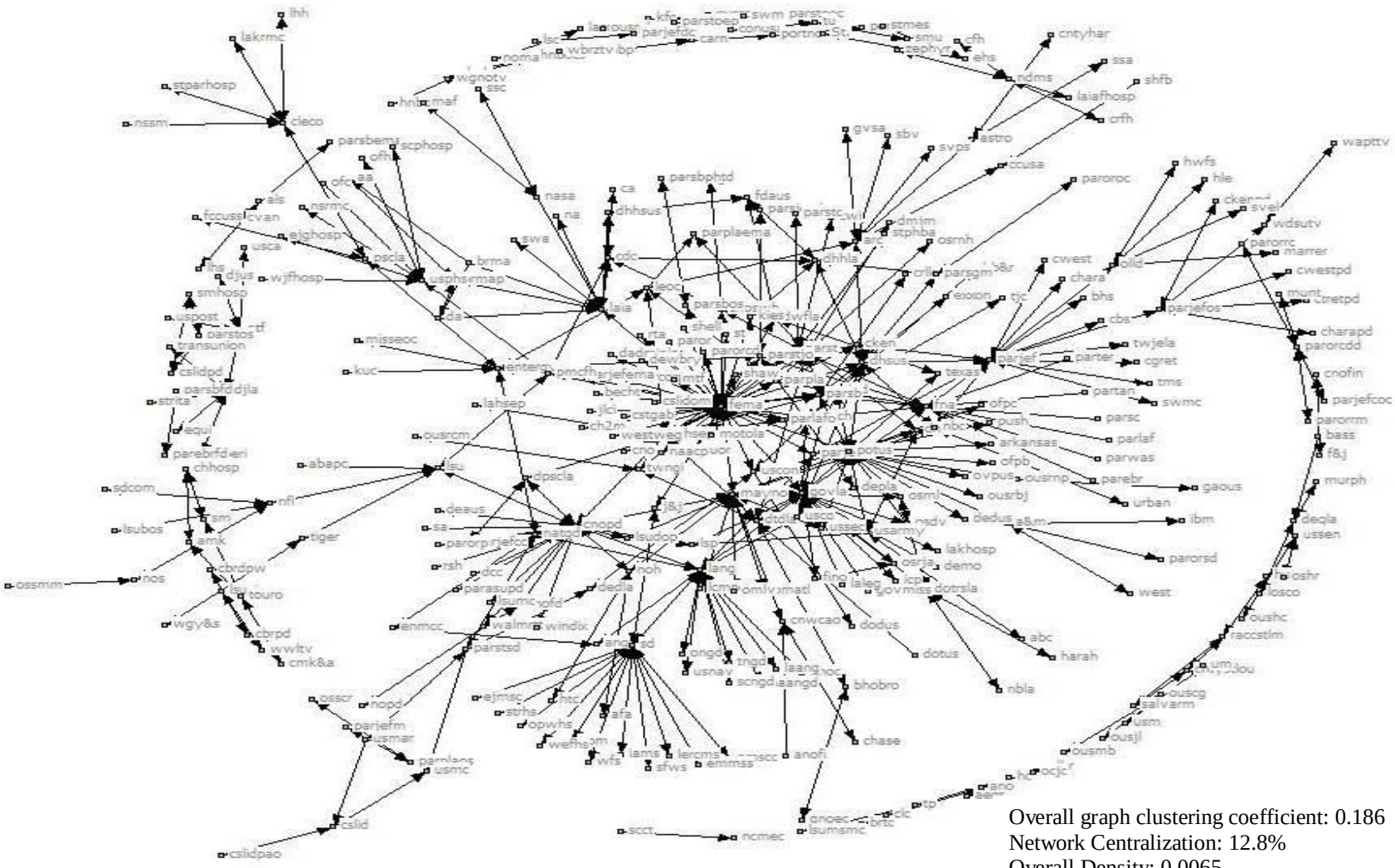
Table 6-1 Descriptive statistics of Hurricane Katrina and Hurricane Gustav management networks

	Number of Actors	Number of non-isolated actors	Network Size (Total Number of Ties)	Average Ties per Actor	Existence of Tie Direction
Hurricane Katrina	533	329*	758*	2.35*	Yes
Hurricane Gustav	332	222*	302*	1.36*	Yes

* After removing isolated nodes from the entire network

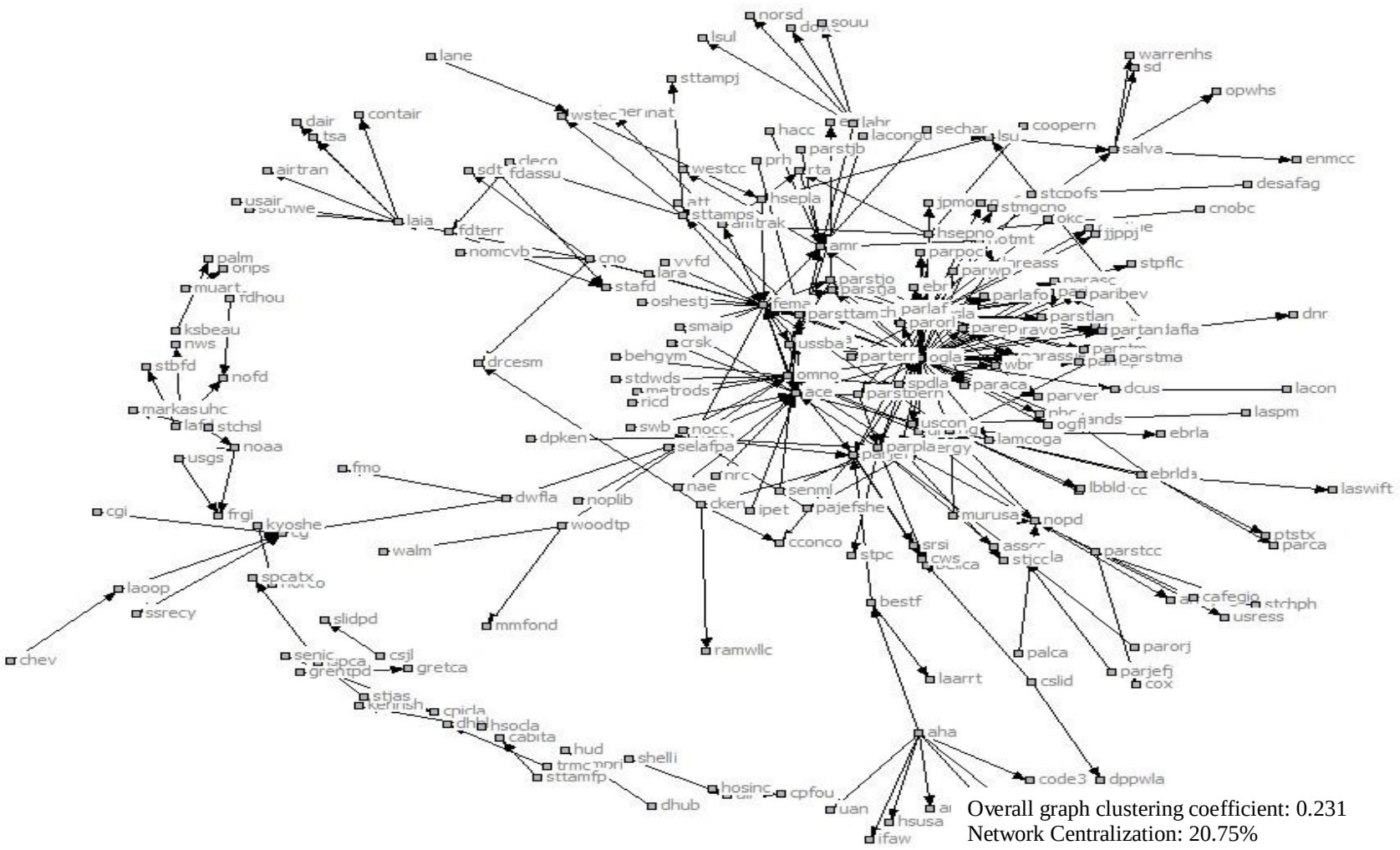
* Source: *Times Picayune*, New Orleans, LA. August 25 – September 19, 2005 for Hurricane Katrina, and *Times Picayune*, New Orleans, LA. August 26 – September 21, 2008 for Hurricane Gustav.

With this descriptive statistics of two hurricane response systems, a network map can give this study an intuitive interpretation for the identification of core actors and collaboration links. To determine and identify the features of both networks in more detail, this study removed isolated nodes (nodes with degree 0) to generate a new network map. This network maps in Figures 6-1 and 6-2 visualize the broad picture of interactions in both hurricane response systems. According to these figures, organizations in the Hurricane Katrina response system have a comparatively small number of brokering networks and accordingly, the peripheral organizations have formed links with other organizations relatively freely. However, the interaction structure of the Hurricane Gustav system shows the relationship of peripheral organizations in the system are quite strictly coordinated by parish, state, and federal brokering organizations. Also, the network map for Hurricane Katrina shows a larger system that is characterized by some critical or central nodes connecting other organizations. Contrary to that, the network map of the Hurricane Gustav response system shows that there were several core or central organizations that coordinated the overall response to Hurricane Gustav.



* Refer Appendix C for the list of acronym of organizations

Figure 6-1 Full Network Map for Hurricane Katrina Response System*



Overall graph clustering coefficient: 0.231
Network Centralization: 20.75%
Overall Density: 0.0062

* Refer Appendix C for the list of acronym of organizations

Figure 6-2 Full Network Map for Hurricane Gustav Response System*

As clearly shown in figure 6-1, the Federal Emergency Management Agency (FEMA), the Louisiana Office of Homeland Security and Emergency Preparedness (LOHSEP), the New Orleans Police Department (CNOPD), the Governor's Office of Louisiana (GOVLA), and the Office of the President of the United States (POTUS) played key roles coordinating activities of various other state and local organizations of Hurricane Katrina response system. Some parish governments such as Jefferson Parish (Parjef), some state departments such as the Louisiana Department of Social Services (DSSLA), some federal agencies such as the United States Public Health Service (USPHS), and other groups such as the Louisiana International Airport (LAIA), the Louisiana National Guard (LANG), and the Louisiana regional electricity company, Entergy (Entergy) played bridge roles connecting other local groups within Louisiana and other state agencies to the core organizations in the system.

Similarly, figure 6-2 shows the full network map for the Hurricane Gustav response system. The size of the entire disaster response system for Hurricane Gustav is smaller than that of Hurricane Katrina mainly due to the actual size of the hurricane. Organizations such as the Louisiana Department of Social Services (DSSLA), the Office of the Louisiana Governor (OGLA), and the Federal Emergency Management Agency (FEMA) took the core coordination roles in the Hurricane Gustav response system. As in the Hurricane Katrina management system, some organizations such as Jefferson Parish (PARJEF), the Salvation Army (SALVA), the American Humane Association (AHA), the American Red Cross (ARC), and government organizations such as the US Coast Guard (USCG), the Louisiana National Guard (LANG), and the Louisiana Department of Wildlife and Fisheries (DWFLA) took bridging roles for the Hurricane Gustav response system.

But the most noticeable difference is that the activities of organizations involved in the evacuation and sheltering missions played critical roles in the Hurricane Gustav response system. Considering the size of evacuation - 2 million residents in the southern parishes - it is not surprising that the southern parish governments, the Louisiana Department of Social Services, the Louisiana Department of Wildlife and Fisheries, and some nonprofit organizations such as the American Red Cross and the Salvation Army took central roles.

Also, figures 6-1 and 6-2 present some basic measures that were calculated to describe the two hurricanes' response systems respectively: density, total degree centrality, and clustering coefficient. The reported overall graph clustering coefficient is 0.186, network centralization is 12.8% and overall density is 0.0065 for the Hurricane Katrina response system. However, for the Hurricane Gustav response system, the overall graph clustering coefficient is slightly higher as 0.231, network centralization is much higher than that of Hurricane Katrina response system (20.75%), and there is small difference in the overall density (0.0062). The higher clustering coefficient and network centralization shows that the organizations in the Hurricane Gustav response system formed more cliques and depends more on the planned coordination procedures.

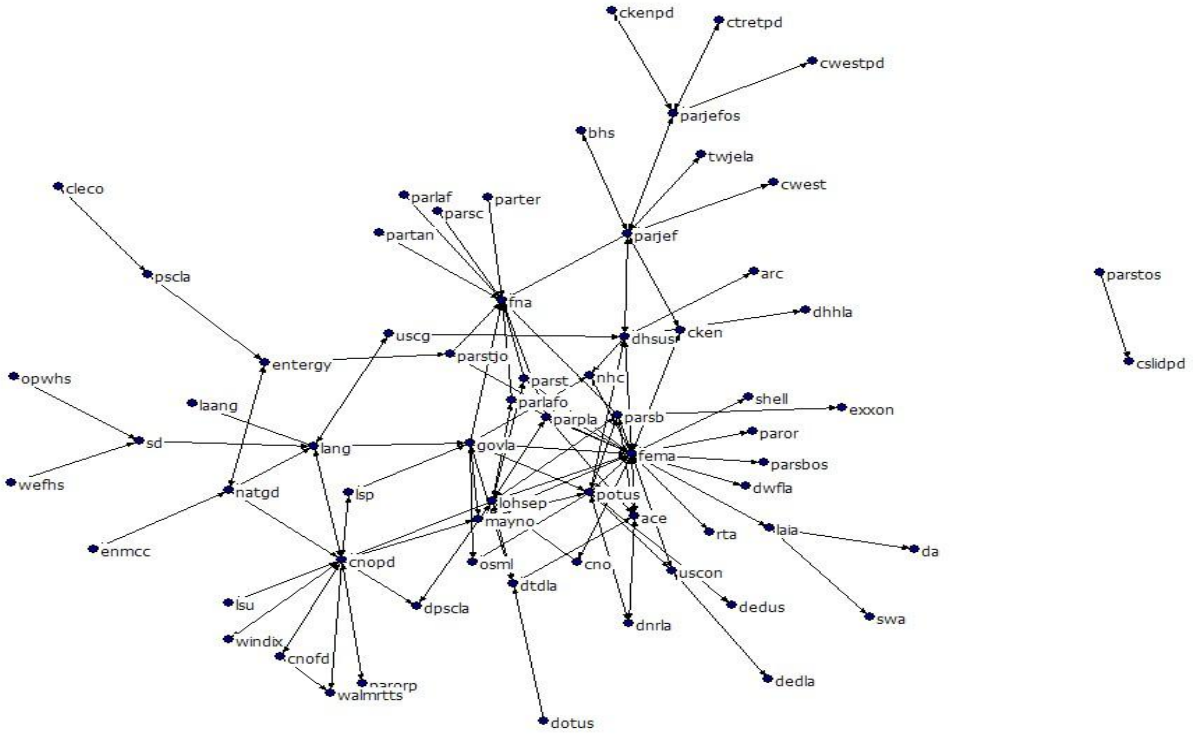
The higher density of the Hurricane Katrina response system is mainly due to the organizations' need to seek available collaboration partners for information and resources sharing. When they faced collapses of entire system and were isolation from the main body of coordination and collaboration system, they did not just follow the planned interaction procedures, rather, managers of each organization exerted leadership and actively created new collaborative partnership with any organizations that had necessary information and resources. It surely helped the entire Hurricane Katrina response system recover from the collapse of official

response system, but from the system management perspective, it reveals the system's weakness and vulnerability in response to crises.

The difference in the formation and shapes of clusters between hurricane response systems presents interesting implications. As discussed in the measurement of density, the clustered organizations in the Hurricane Gustav response system formed mostly in accordance to the disaster management plan. Contrary to that, the clustered organizations in the Hurricane Katrina response system did not follow the official disaster response procedures and showed irregular pattern of interactions. Accordingly, the network type in the Hurricane Gustav response system looks more like a 'cellular network' than the Hurricane Katrina response system.

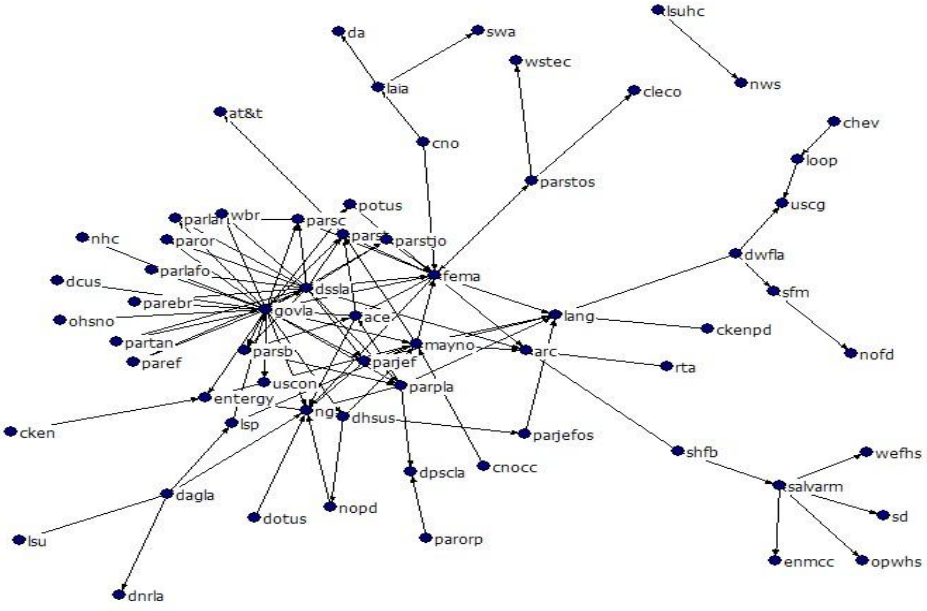
6.1.2 The comparison of interactions among organizations common to both response systems: Quadratic Assignment Procedure (QAP) analysis

Using measures of social network analysis provides very rough differences between the two hurricane response systems. More accurately, those measures of social network analysis: density, network centrality, and clustering coefficient are calculated to be network description tools, not designed for purposes of network comparison. Accordingly, there is no criterion, like the p-value in statistics, to determine the significance of different values of measurement. To overcome this problem, I selected common organizations from each hurricane response system and conducted a Quadratic Assignment Procedure (QAP) analysis, I then checked whether there is any significant difference in interacting structure of hurricane response systems.



* Refer Appendix C for the list of acronym of organizations

Figure 6-3 Interaction of Common Organizations, Hurricane Katrina (Louisiana, 2005)



* Refer Appendix C for the list of acronym of organizations

Figure 6-4 Interaction of Common Organizations, Hurricane Gustav (Louisiana, 2008)

Also, the network comparison with common organizations is to keep the same number of organizations for both hurricane response systems to ensure accurate QAP analysis. The QAP analysis is to measure the degree to which the structures of two networks are significantly correlated with each other. Like Pearson's Correlation in statistics, the QAP analysis checks whether the interaction structure of two separate networks has high correlation and accordingly identical interaction structure. If the interaction patterns of two response systems are statistically identical, this study can say that the p-value of QAP analysis is significant. Figure 6-3 and 6-4 present the network maps of organizations that participated in both Hurricanes Katrina (2005) and Hurricane Gustav (2008).

Table 6-2 Comparison of Network Statistics and Change among the Four Hurricane Response Systems

	Katrina	Gustav
Overall Density	0.0391	0.0292
Number of Ties	173	114
Total Degree Centrality	2.955	3.365
Clustering Coefficient	0.229	0.249
Number of Cliques (minimum size =3)	17	31
QAP correlation (p-value)	0.041 (p-value: 0.034)	

* P-values is significant when alpha is 0.05

Table 6-2 shows some descriptive statistics of Hurricane Katrina and Hurricane Gustav response systems with QAP correlation (p-value). The network measures such as overall density, total degree centrality, and clustering coefficient are not much different from those of the entire network of two hurricane response systems. Interestingly, the output of QAP analysis shows a significant difference in organizational interaction structure between the response systems that evolved following Katrina and Gustav (QAP correlation is 0.041 and its p-value is 0.034) and this means that the collaboration and coordination structure of Hurricane Gustav response system is statistically different from that of Hurricane response system. In the following sections, this

study compares the two systems with the identification of core organizations and the formation of entire hurricane response network.

6.1.3 Identification of changes in status of core organizations

The most common way to identify the core actors in a disaster response network would be the use of several measures of centrality with the combination of intuitive interpretation of a network map (sociogram). Traditionally, as Freeman (1979) suggested, there are three basic centralities: degree, closeness, and betweeness for the identification of core actors in a network. For example, it is quite intuitive to say that the organizations with the largest number of links in the entire system can be considered core organizations in the system. But as Burt (1992) argued, organizations that take the brokerage role and distribute important knowledge and resources in the system can be core organizations because power can be originated from the ability to bridge actors and activities. For measuring the centrality of an organization within a network, there seems to be no dominant centrality measurement. In other words, each centrality measurement is a partial one and has its own strengths and weaknesses in identifying core actors. A particular organization can be central in the sense that it has the most number of ties with other nodes in Degree Centrality[26]. Others can be powerful because they display the closest geodesic distance from other actors in Closeness Centrality[27]. At the same time, the length of paths between nodes also can matter in Betweeness centrality'[28].

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[26] Degree Centrality is based on adjacency and how many immediate ties, such as dyadic relations, a node has. The strength of Degree Centrality is that it is useful in finding dominant actors in the network.

[27] The Closeness Centrality is a measurement based on the geodesic distances. It emphasizes the distance of actor to all others in the network. According to Hanneman (2001), this concept is useful because it considers the relationship with all other nodes in the network.

[28] Betweeness Centrality shows an actor who is located between actors and on whom other actors depend for exchanges such as information and resources. Hanneman (2001) said that Between-ness Centrality assumes that the

Among these three centrality measures, total degree centrality can be considered as a primary criterion for choosing core actors, but considering the complex characteristics of the disaster response networks for Hurricanes Katrina and Hurricane Gustav; this analysis needs various conceptual standards more than the total degree of centrality. Facing a severe communication breakdown, some organizations took important coordinating roles in information diffusion and resources allocation and created many collaborative links with other organizations. At the same time, some organizations channeled important responding activities between local, state, and federal, or similarly between public, private, and non-profit organizations, and these organizations cannot be underestimated in identifying core organizations. So, while focusing on the concept of total degree centrality, I also consider the betweeness and closeness centrality at the same time. Table 6-3 shows the three most common measures of centrality of the top 13 organizations in the Hurricane Katrina and Hurricane Gustav response systems.

Due to the differences of network size, the value of each centrality measure differs by hurricanes, and thus, the core organizations identified by the three centrality measures are not consistent. In particular, the organizations that have a high closeness centrality are quite different from the organizations identified as core organizations by total degree centrality and betweeness centrality. The core organizations identified by cross-centrality measures are the Federal Emergency Management Agency (fema), the Office of the President of the United States (potus), the Louisiana Office of Governor (govla), the New Orleans Police Department (cnopd), the Office of New Orleans Mayor (mayno), and the Louisiana National Guard (lang) for both hurricane systems. One major difference is that, due to the focus on large-scale evacuation for Hurricane Gustav, the local governments, such as Jefferson Parish and Plaquemines Parish, are

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actor who is located in important geodesic paths is considered significant under the assumption that if any node has a Betweeness location in the path, it can increase its leverage in the exchange activities.

viewed as core actors in the Hurricane Gustav response system. This is in contrast to the Hurricane Katrina response system in which most of the identified core actors were federal and state agencies. However, some military agencies such as the Louisiana National Guard (Lang) are identified as core actors for both systems.

Table 6-3 Measures of centrality of Hurricane Katrina and Hurricane Gustav management network

Hurricane Katrina						Hurricane Gustav					
Degree Centrality[1]		Closeness Centrality[2]		Betweeness Centrality[3]		Degree Centrality[1]		Closeness Centrality[2]		Betweeness Centrality[3]	
fema	46.00	usmc	0.936	Fema	22.335	govla	23.077	stjcc	0.593	govla	3.908
potus	22.00	brmap	0.932	Govla	8.175	dssla	19.457	entergy	0.59	fema	2.825
govla	21.00	nhc	0.931	Parjef	7.752	fema	10.407	cws	0.586	mayno	1.087
cnopd	20.00	flourcorp	0.929	Potus	7.469	ng	7.24	cconco	0.586	dssla	1.073
parjef	15.00	fema	0.926	Cnopd	6.889	mayno	6.787	ebrla	0.583	ace	1.033
lang	14.00	laang	0.926	Lang	6.868	ace	6.335	srsi	0.583	hsepla	0.827
fna	13.00	parplaema	0.925	Dhsus	6.413	parpla	4.977	ng	0.581	ng	0.512
sd	13.00	govla	0.924	Mayno	5.693	amr	4.525	lang	0.58	parpla	0.505
mayno	12.00	potus	0.924	sd	4.382	parjef	4.072	parjef	0.58	parjef	0.422
lohsep	11.00	mayno	0.924	pmcfh	4.136	lang	4.072	pajefshe	0.58	spdla	0.362
dhsus	10.00	dodus	0.924	entergy	3.827	aha	3.62	lbbld	0.58	hotmt	0.35
laia	10.00	lang	0.923	lsu	3.483	laia	3.167	westcc	0.548	opusa	0.305
ace	10.00	dhsus	0.923	arc	3.132	parsttam	3.167	arc	0.546	salva	0.288
1 cutting point for degree centrality: 10.00 2 cutting point for closeness centrality: 0.923 3 Cutting point: 3.132						1 cutting point for degree centrality: 3.167 2 cutting point for degree centrality: 0.546 3cutting point for degree centrality: 0.288						

Source: *Times Picayune*, New Orleans, LA. August 25 – September 19, 2005 for Hurricane Katrina, and Times Picayune, New Orleans, LA. August 26 – September 21, 2008 for Hurricane Gustav.

Notably, the level of measures mentioned above is based on the individual actors. Another approach I consider is the identification of core actors from the entire network level perspective. Knoke's K-Core approach (1990) is relevant for this study. Knoke argues that an influence needs to be considered in a relational dimension and suggests the concept of coreness. For the identification of core organizations from the entire network level, I adopt the concept of 'network robustness' combined with the previous centrality measures. Table 6-4 shows the core organizations identified by K-coreness analysis. The cut point of both hurricane systems was set as 3, and organizations have higher K-core value than 3 were recognized as core organizations.

Table 6-4 K-Coreness values for each node

Hurricane Katrina		Hurricane Gustav	
Organization Name	**K-core Value**	**Organization Acronym**	**K-core Value**
Army Corps of Engineers	3	Army Corps of Engineers	4
Police Department, New Orleans	3	Department of Social Services, LA	4
Department of Homeland Security, US	3	Fema	4
Department of Natural Resources, LA	3	Louisiana National Guard	4
Department of Defense, US	3	National Guard	4
Department of Transportation and Development, LA	3	Office of Governor, LA	4
Entergy	3	Office of Mayor, New Orleans	4
Fema	3	Parish of Jefferson	4
Florida National Guard	3	Parish of Plaquemines	4
Office of Governor, LA	3	Parish of St. Bernard	4
Louisiana National Guard	3	Parish of St. John	4
Louisiana Emergency Operation Center	3	Parish of St. Tammany	4
Louisiana Office of Homeland Security and Emergency Preparedness	3	American Red Cross	3
Louisiana State Police	3	Amtrak	3
Office of Mayor, New Orleans	3	Department of Agriculture and Forestry, LA	3
National Guard	3	Department of Agriculture, US	3
Parish of Jefferson	3	Department of Homeland Security, US	3
Parish of Lafourche	3	Entergy	3
Parish of Plaquemines	3	Office of Homeland Security and Emergency Preparedness, New Orleans	3
Parish of St. Bernard	3	Parish of Lafourche	3
Parish of St. John	3	Parish of St. Charles	3
Office of President, US	3	Parish of East Baton Rouge	3
United States Army	3	Louisiana State Police	3
Cut Point, Hurricane Katrina	**3**	**Cut Point, Hurricane Gustav**	**3**

According to table 6-4, unlike the three centrality measures, the Army Corps of Engineers emerges as the actor with highest core value for both hurricane response systems. Also, there are several common organizations identified as core organizations using K-coreness measures, such as the Federal Emergency Management Agency (fema), the Office of President of the United States (potus), the Louisiana Office of Homeland Security and Emergency Preparedness (lohsep), and the Louisiana National Guard (Lang). Still, the most significant difference between the two hurricane systems is that the local parish governments such as Jefferson Parish, St. Bernard Parish, Plaquemines Parish, and St. Tammany Parish take core positions in the response system for Hurricane Gustav. This means that the local parish government successfully coordinated its subordinate organizations within its boundary with other

parish, state and federal agencies in the system. And again, this shows that, in the disaster response system for Hurricane Gustav, the local parish governments played a critical role in brokering resources and information for the large-scale evacuation.

This finding further supports the cellular feature of the Hurricane Gustav response system and that the Hurricane Gustav response system operated under predefined plans of disaster management more so than in Hurricane Katrina. The structure of interaction under major disaster management plans takes the form of a cellular network in which some brokering organizations connect the pedant organizations to the partnering organizations in the other cellular sub-structure. The organizations identified as power brokering organizations for the Hurricane Gustav response system are Jefferson Parish, National Hurricane Center, Lafourche Parish, Ochsner hospital, Office of President of the United States, and New Orleans Office of Mayor. This list of organizations is similar to those that were identified by pre-defined disaster management plans. Contrary to that, the power broker organizations in the Hurricane Katrina response system are quite different from organizations identified by centrality measures. This means that newly emerging organizations in the Hurricane Katrina response system took the role of coordination.

In summary, the results of the identification of core organizations using various measures and approaches are not consistent for analyzing the Hurricane Katrina response system. Specifically, the organizations identified by coreness value do not seem to be core organizations from the perspective of the centrality measures. Contrary to that, the organizations identified as core actors in the Hurricane Gustav response system by various measures are quite consistent across measures. This means that the collaboration and coordination structure of the Hurricane Gustav response system followed the disaster management plan more consistently. This finding

shows the stability of interaction structure of Hurricane Gustav response system. The organizations identified as core actors in the hurricane response systems can be used as the nodes for strategic intervention in the agent-based simulation of this study.

6.1.4 Differences in network formation between the hurricane response systems: Clique analysis

In this section, I conducted a clique analysis to identify the sub-groups in the Hurricane Katrina and Hurricane Gustav response systems. This analysis reveals how large hurricane response systems were formed from the small components (cliques) of organizational interactions. By comparing the formation of cliques or interaction patterns between cliques, this analysis checks whether there is any evidence of organizational learning in network formation since the landfall of Hurricane Katrina in 2005.

As Hanneman argues (2005), many approaches to understand the structure of a network emphasize examining how dense connections are built-up from simpler dyads and triads to more extended dense clusters such as "cliques." This view of network formation focuses on how solidarity and connection of large social structures can be built up out of small and tight components. Using this technique of clique analysis, I examined the embedded relationships of core organizations and the relationships between subgroups. With a minimum size set at 3, the number of cliques in the Hurricane Katrina response system is 34, and the number of cliques in the Hurricane Gustav response system is 60. There are a greater number of cliques in the Hurricane Gustav response system, again implying the cellular network of the system because, by definition, the organizations interact more frequently within the subgroup than other organizations outside of cliques. The comparatively small number of subgroups in the Katrina response system shows that each organization in the system quite freely interacted with other

organizations that were not in the same clique. Consequently, the coordination structure for the response to Hurricane Katrina broke down and organizations needed to find collaboration partners. Table 6-5 shows all cliques in the Hurricane Katrina response system.

According to table 6-5, there are several organizations that have co-membership with various subgroups of the system. Among them, FEMA has 15 co-memberships, the Louisiana Office of Homeland Security and Emergency Preparedness (LOHSEP) has 7 co-memberships, the Office of the President of the United States has six co-memberships, and the New Orleans Police Department also has six co-memberships in the Hurricane Katrina response system. This set of organizations with multiple memberships across the various subgroups conducted the brokerage role in the hurricane management system. FEMA coordinated and bridged actions between federal agencies and state/local agencies, similarly the Louisiana Office of Homeland Security and Emergency Preparedness (LOHSEP) brokered between federal/state and local organizations in the system. When each subgroup is sorted by the level of jurisdiction, there are four subgroups comprised of interactions among federal agencies, four subgroups of federal and local agencies, seven subgroups with federal and state agencies, 10 subgroups comprised of federal, state, and local agencies, six subgroups of state and local agencies, and three subgroups purely comprised of local agencies. In those subgroups comprised of organizations with multiple levels of jurisdiction. This analysis confirms that agencies with co-membership played a brokerage function.

Table 6-5 List of subgroups (cliques) of Hurricane Katrina response system

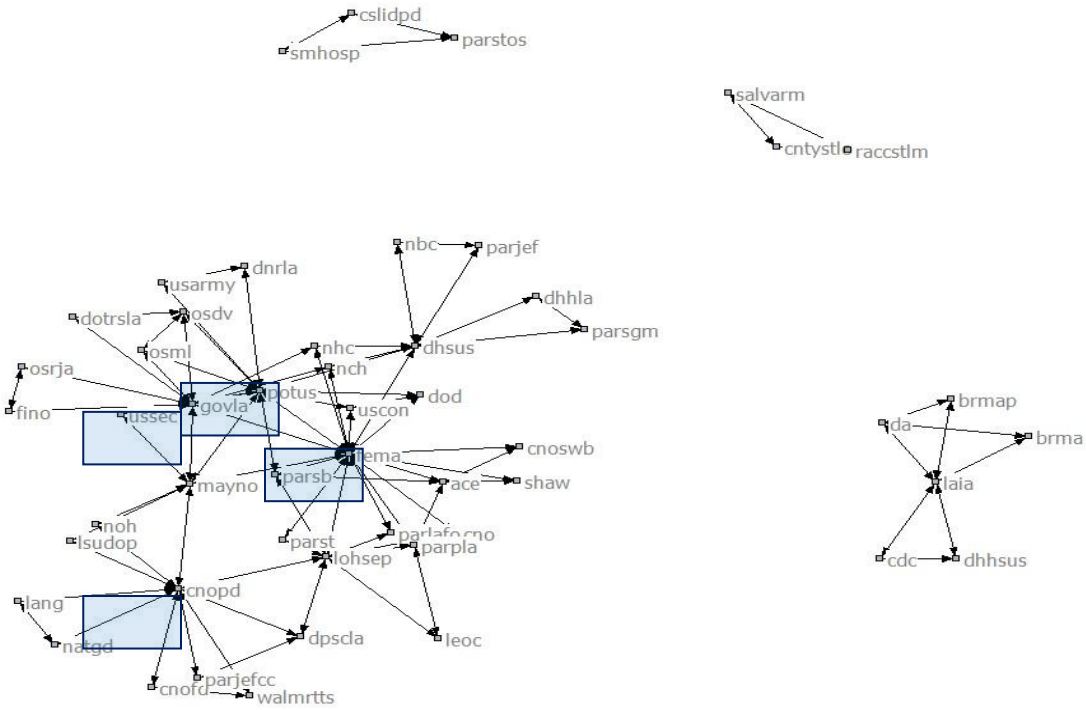
Group No.	Organization 1	Organization 2	Organization 3	Organization 4	Category
1	Department of Defense	fema	Office of President	US Congress	Federal
2	Department of Homeland Security, US	fema	Office of President		Federal
3	fema	Louisiana Office of Governor	Office of Mayor, New Orleans	Office of President	Federal+State+Local
4	fema	Parish of St.Bernard	Office of President		Federal+Local
5	City of New Orleans	fema	Louisiana Office of Homeland Security and Emergency Preparedness		Federal+State+Local
6	Army Corps of Engineers	City of New Orleans	fema		Federal+State+Local
7	fema	Louisiana Office of Homeland Security and Emergency Preparedness	Parish of Lafourche		Federal+State+Local
8	fema	Louisiana Office of Homeland Security and Emergency Preparedness	Parish of Plaquemines		Federal+State+Local
9	fema	Louisiana Office of Homeland Security and Emergency Preparedness	Parish of St.Bernard		Federal+State+Local
10	fema	Louisiana Office of Homeland Security and Emergency Preparedness	Parish of St. Tammany		Federal+State+Local
11	fema	Louisiana Office of Governor	National Hurricane Center		Federal+State
12	Department of Homeland Security, US	fema	National Hurricane Center		Federal
13	fema	Louisiana Office of Governor	National Hurricane Center		Federal+State
14	Army Corps of Engineers	fema	Parish of Plaquemines		Federal+Local
15	Army Corps of Engineers	fema	Parish of St.Bernard		Federal+Local
16	Army Corps of Engineers	fema	The Shaw Group, Inc		Federal (Private)
17	Baton Rouge Metropolitan Airport	Delta Airlines	Louis Armstrong International Airport		National+State (Private)
18	Centers of Disease Control and Prevention	Department of Health and Human Services, US	Louis Armstrong International Airport		Federal+State
19	City of New Orleans Fire Department	City of New Orleans, Police Department	Wal-marts		Local (Private)
20	City of New Orleans, Police Department	Department of Public Safety and Corrections, Louisiana	Louisiana Office of Homeland Security and Emergency Preparedness		State+Local
21	City of New Orleans, Police Department	Department of Public Safety and Corrections, Louisiana	Parish of Jefferson		State+Local
22	City of New Orleans, Police Department	Louisiana National Guard	National Guard		Federal+State+Local
23	City of New Orleans, Police Department	Louisiana State University Department of Psychiatry	Office of Mayor, New Orleans		State+Local
24	City of New Orleans, Police Department	Office of Mayor, New Orleans	New Orleans Hornets		Local
25	County of St. Louis, Missouri	Regional Assistance Center for the County of St. Louis, Missiouri	Salvation Army		State+Local
26	City of Slidell Police Department	Parish of St. Tammany	Slidell Memorial Hospital		Local
27	Department of Health and Hospitals, Louisiana	Department of Homeland Security, US	Parish of St. Gabriel, Morgue		Federal+State+Local
28	Department Natural Resources, LA	Office of President	US Army		Federal+State
29	Department of the Treasury, Louisiana	Louisiana Office of Governor	Office of Senator David Vitter		Federal+State
30	Fertility Institute of New Orleans	Louisiana Office of Governor	Office of State Representative John Alario		State+Local
31	Louisiana Emergency Operation Center	Louisiana Office of Homeland Security and Emergency Preparedness	Parish of Plaquemines		State+Local
32	Department of Homeland Security, US	National Broadcasting Corporation	Parish of Jefferson		Federal+Local
33	Louisiana Office of Governor	Office of Senator David Vitter	Office of Senator Mary Landrieu	Office of President	Federal+State
34	Louisiana Office of Governor	Office of Mayor, New Orleans	Office of President	United States Secret Service	Federal+State+Local

Based on clique analysis, I drafted a network map of interactions among subgroups. Figure 6-5 shows one main group and three small groups that are isolated from the main group in the Hurricane Katrina response system. Among these three isolated groups, the organizations in the first group performed medical functions with local hospitals and the Salvation Army, and the organizations in the third group worked for the air transportation of special medical needs evacuees (the function of the second groups is not clear). Except those separated sub-groups, the other organizations form a big cluster of subgroups together.

To determine which organizations act as nodes that connect the graph and which are isolated from groups, the analysis reported in figure 6-6 shows that Office of President of the United States, Office of Mayor of New Orleans, FEMA, New Orleans Police Department, Louisiana Office of Homeland Security and Emergency Preparedness (LOHSEP), and Governor's Office of Louisiana played core roles in connecting subgroups together. Figure 6-6 further shows how the large disaster response system for Hurricane Katrina was comprised of small components including federal, state, and local organizations. This formation is primarily set by the master plan for disaster response and mitigation. In those plans, local agencies cannot interact directly with other state and federal agencies for resource allocation. Similarly, almost no state agencies can directly contact other state and federal agencies for resource exchange without coordination by LOHSEP, so their coreness comes from the structure of disaster management plans.

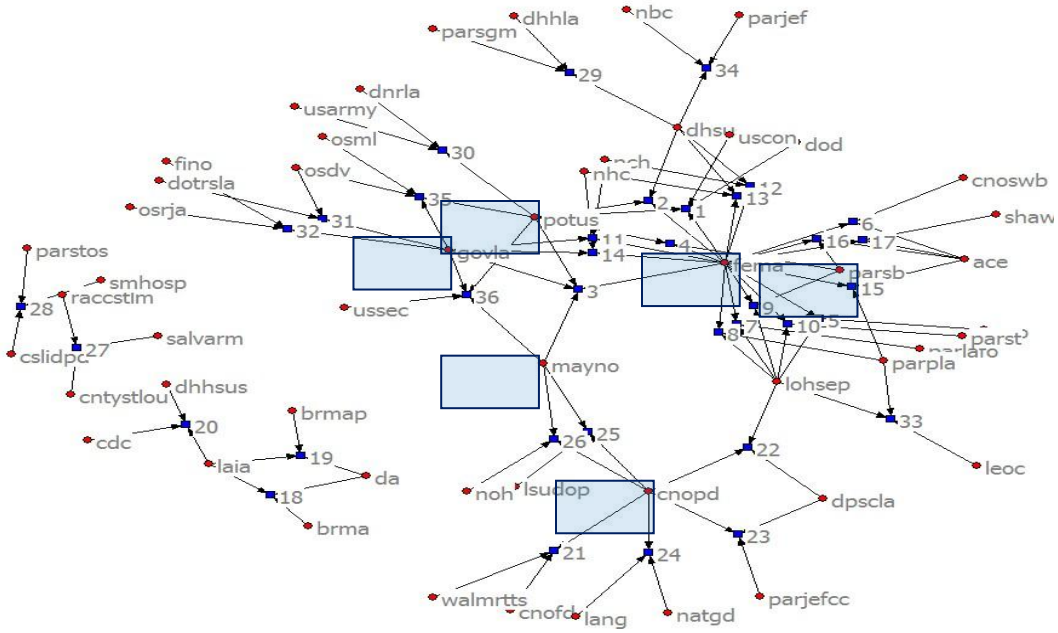
This structure constrains the entire system for the Hurricane Katrina response system. One organization, which is not considered as a core organization by the plan but is identified as a broker by this clique analysis is the New Orleans Police Department. According to figures 6-5 and 6-6, the New Orleans Police Department has links with federal and state military authorities

and emergency management agencies and connects them for the security functions of the Hurricane Katrina response system.



* Refer Appendix C for the list of acronym of organizations

Figure 6-5 Clique diagram of Hurricane Katrina management system (Using Cliqueoverlap.##D)



* Refer Appendix C for the list of acronym of organizations

Figure 6-6 Clique diagram of Hurricane Katrina management system (Using Cliqueset.##D)

This study conducts the same clique analysis for Hurricane Gustav response system, and also, based on clique analysis, it creates network map to examine the collaboration patterns between cliques or subgroups. The total number of subgroups identified by clique analysis for Hurricane Gustav response system is 59 when the minimum size of the organizations set as four. The list of subgroups of the Hurricane Gustav response system is shown in table 6-6. According to table 6-6, there are several organizations that have core membership with various subgroups of the system. Among them, the Department of Social Services has co-membership with 31 out of 59 subgroups. Also, the Office of Governor, Louisiana (specifically the Governor's Office Homeland Security and Emergency Preparedness, GOHSEP, which replaced LOHSEP after Hurricane Katrina) has co-membership with 47 cliques out of 59. FEMA has co-membership with 15 cliques, and the New Orleans Office of Mayor has eight co-memberships with various subgroups.

The high number of co-membership between LOHSEP and the Department of Social Services reveals that they had a very close working relationship to support the operation of parish governments, especially for their large scale evacuation of two million residents from southern parishes before the landfall of Hurricane Gustav. As reported, an unprecedented total evacuation and sheltering of residents was the most important mission of organizations in Hurricane Gustav response system. A total of 47 subgroups were formed from the firm collaboration links between Department of Social Services, Governor's Office Homeland Security and Emergency Preparedness, and individual parish EOCs (DSSLA-GOHSEP-parish). FEMA occasionally joined this close working relationship for the provision of federal level support to the evacuation and sheltering functions. Also, non-profit organizations such as the American Red Cross and local faith-based organizations often joined these subgroups to support

them. The clique analysis of the Hurricane Gustav response system showed three subgroups worked with Entergy, regional electricity company, because the long lasting blackout was one of the critical issues and problems of the Hurricane Gustav response system.

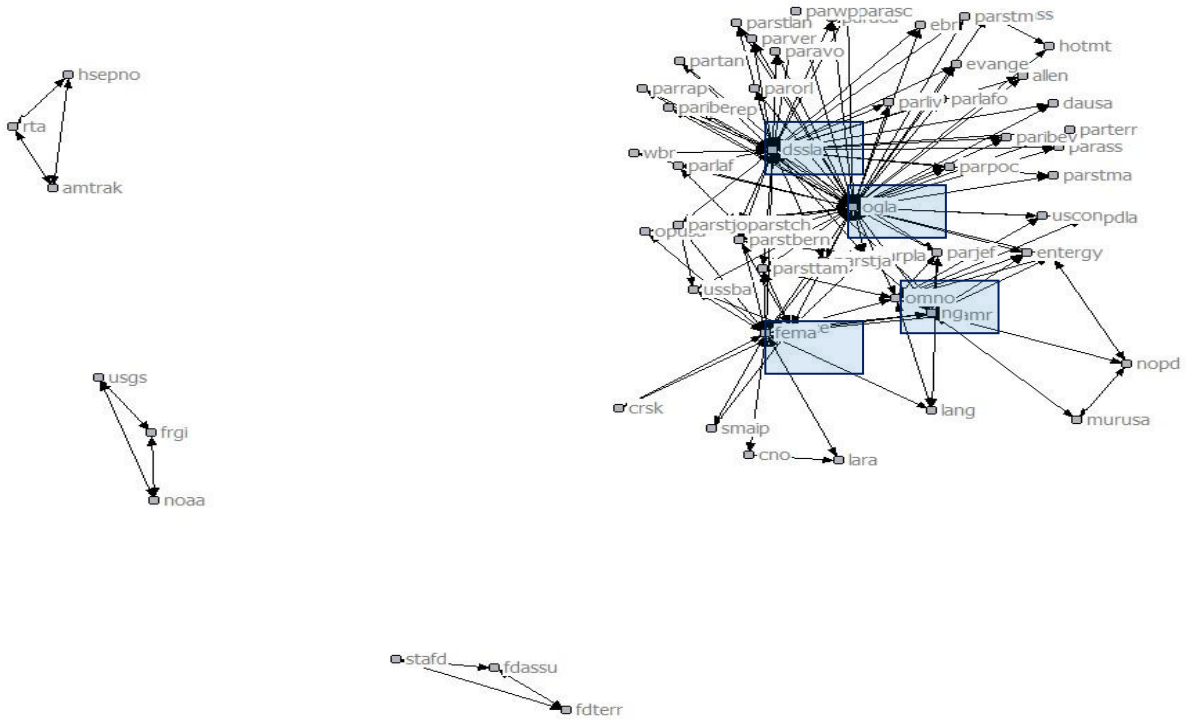
When the subgroups are sorted by level of jurisdiction, again in table 6-6, 21 subgroups were comprised of federal, state, and local agencies and 29 subgroups were comprised of state and local agencies. Most notably, there was no subgroup solely composed of federal agencies, unlike the Hurricane Katrina response system (4 subgroups were comprised of federal agencies only). This means that the response system for Hurricane Gustav was highly managed and operated by state and local organizations. Three subgroups were composed of federal and local agencies, and five subgroups are composed of federal and state agencies. There is just one subgroup composed solely of local agencies in the system.

To examine how the large network of Hurricane Gustav response system was composed of sub-groups, figures 6-8 and 6-9 show that, similar to the Hurricane Katrina response system, there is one big group and three small groups that are isolated from the main group. The first one is composed of organizations that took the transportation function for the evacuation of residents out of state of Louisiana; the organizations in the second clique collaborated for the security function that was composed of three local fire departments. The third cannot be clearly defined by function. To determine which particular actors connect the graph, figures 6-8 and 6-9 show that FEMA, the Governor's Office of Homeland Security and Emergency Preparedness (GOHSEP), the Department of Social Services, and the New Orleans Office of Mayor play the roles of core organizations that connect various subgroups together.

Table 6-6 List of subgroups (cliques) of Hurricane Gustav response system

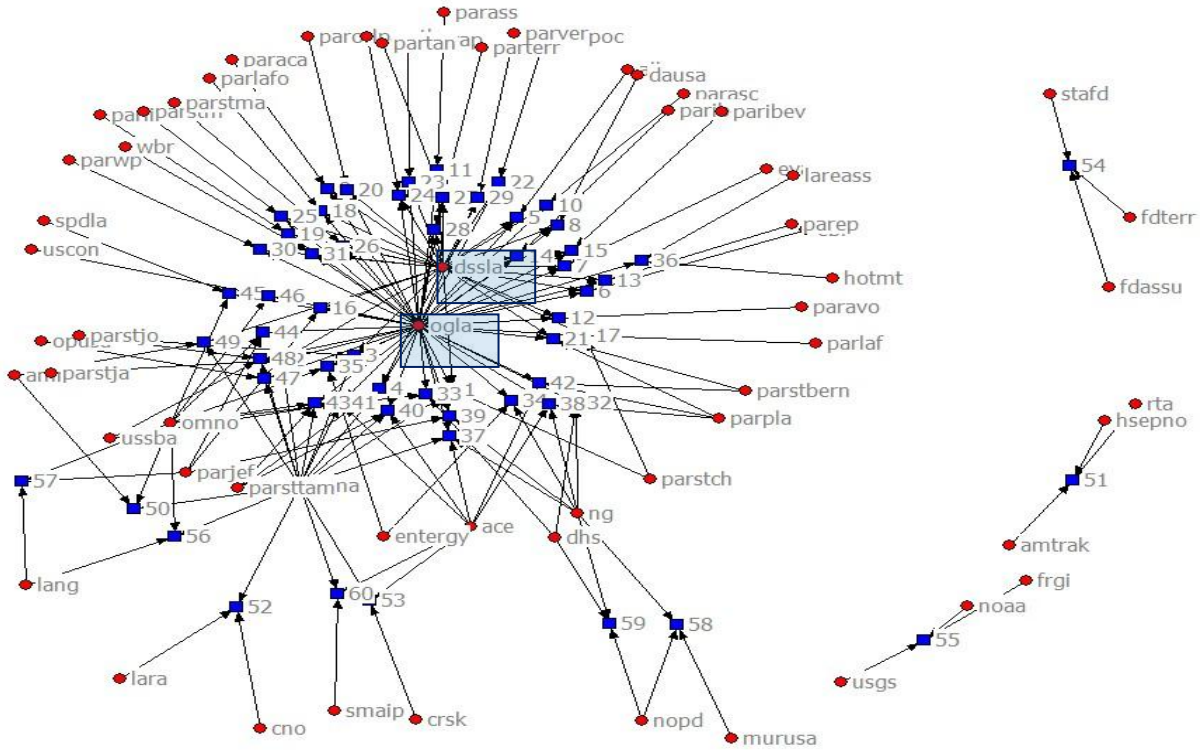
Group No.	Organization 1	Organization 2	Organization 3	Organization 4	Category
1	Dept of Social Services, LA	fema	Office of Governor, LA	Parish of St. James	Federal+State+Local
2	Dept of Social Services, LA	fema	Office of Governor, LA	Parish of St. John the Baptist	Federal+State+Local
3	Dept of Social Services, LA	fema	Office of Governor, LA	Parish of St. Tammany	Federal+State+Local
4	Parish of Allen	Dept of Social Services, LA	Office of Governor, LA		Federal+State+Local
5	Dept of Social Services, LA	Parish of East Baton Rouge	Office of Governor, LA		Federal+State+Local
6	Dept of Social Services, LA	City of Evangeline	Office of Governor, LA		Federal+State+Local
7	Department of Agriculture	Dept of Social Services, LA	Office of Governor, LA		Federal+State
8	Dept of Social Services, LA	Office of Governor, LA	Parish of Acadia		State+Local
9	Dept of Social Services, LA	Office of Governor, LA	Parish of Ascension		State+Local
10	Dept of Social Services, LA	Office of Governor, LA	Parish of Assumption		State+Local
11	Dept of Social Services, LA	Office of Governor, LA	Parish of Avoyelles		State+Local
12	Dept of Social Services, LA	Office of Governor, LA	Parish of East Feliciana		State+Local
13	Dept of Social Services, LA	Office of Governor, LA	Parish of East Iberia		State+Local
14	Dept of Social Services, LA	Office of Governor, LA	Parish of East Iberia		State+Local
15	Dept of Social Services, LA	Office of Governor, LA	Parish of Jefforson		State+Local
16	Dept of Social Services, LA	Office of Governor, LA	Parish of Lafourche	Parish of St. Charles	State+Local
17	Dept of Social Services, LA	Office of Governor, LA	Parish of Lafourcheo		State+Local
18	Dept of Social Services, LA	Office of Governor, LA	Parish of Livingston		State+Local
19	Dept of Social Services, LA	Office of Governor, LA	Jail, Parish of Orleans		State+Local
20	Dept of Social Services, LA	Office of Governor, LA	Parish of Plaquemines	Parish of St. Bernard	State+Local
21	Dept of Social Services, LA	Office of Governor, LA	Parish of Pointe Coupee		State+Local
22	Dept of Social Services, LA	Office of Governor, LA	Parish of Rapides		State+Local
23	Dept of Social Services, LA	Office of Governor, LA	Parish of St. Landry		State+Local
24	Dept of Social Services, LA	Office of Governor, LA	Parish of St. Martin		State+Local
25	Dept of Social Services, LA	Office of Governor, LA	Parish of St. Martina		State+Local
26	Dept of Social Services, LA	Office of Governor, LA	Parish of Tangipahoa		State+Local
27	Dept of Social Services, LA	Office of Governor, LA	Parish of Terrebonne		State+Local
28	Dept of Social Services, LA	Office of Governor, LA	Parish of Vermillion		State+Local
29	Dept of Social Services, LA	Office of Governor, LA	Parish of West Feliciana		State+Local
30	Dept of Social Services, LA	Office of Governor, LA	Parish of West Baton Rouge		State+Local
31	Department of Homeland Security, US	National Guard	Office of Governor, LA		Federal+State
32	Department of Homeland Security, US	Office of Governor, LA	Office of Mayor, New Orleans		Federal+State+Local
33	Entergy	National Guard	Office of Governor, LA		Federal+State+Local
34	Entergy	Office of Governor, LA	Office of Mayor, New Orleans		Federal+State+Local

35	Hot Meals Task Force	Louisiana Restaurant Association	Office of Governor, LA		State+Local
36	Army Corps of Engineers	fema	National Guard	Office of Governor, LA	Federal+State+Local
37	Army Corps of Engineers	National Guard	Office of Governor, LA	Parish of Plaquemines	Federal+State+Local
38	National Guard	Office of Governor, LA	Parish of Jefferson		Federal+State+Local
39	Army Corps of Engineers	fema	Office of Governor, LA	Parish of St. Tammany	Federal+State+Local
40	Army Corps of Engineers	fema	Office of Governor, LA	U.S. Small Business Administration-Disaster Planning Office	Federal+State
41	Army Corps of Engineers	Office of Governor, LA	Parish of Plaquemines	Parish of St. Bernard	Federal+State+Local
42	fema	Office of Governor, LA	Office of Mayor, New Orleans	Parish of St. Tammany	Federal+State+Local
43	Office of Governor, LA	Office of Mayor, New Orleans	Parish of Jefferson		State+Local
44	Office of Governor, LA	Office of Mayor, New Orleans	State Police Department, LA		State+Local
45	Office of Governor, LA	Office of Mayor, New Orleans	US Congress		Federal+State+Local
46	fema	Office of Governor, LA	Office of President, US		Federal+State
47	fema	Office of Governor, LA	Parish of St. John the Baptist	U.S. Small Business Administration-Disaster Planning Office	Federal+State+Local
48	American Red Cross	Dept of Social Services, LA	fema		Federal+State+Local
49	American Red Cross	fema	Office of Mayor, New Orleans		Federal+State+Local
50	amtrak	Department of homeland security and emergency preparedness, New Orleans	Regional Transit Authority		Federal+State
51	City of New Orleans	fema	Louisiana Recovery Authority		Federal+State+Local
52	Army Corps of Engineers	Crown Roofing Services Inc. Kenner	fema		Federal+local
53	Fire Department, Assumption Parish	Fire Department, Terrebone Parish	Fire Department, St. Tammany		Local
54	Friends of the Grand Isle	NOAA	U.S. Geological Survey		Federal+Local
55	fema	Louisiana National Guard	Office of Mayor, New Orleans		Federal+State+Local
56	Louisiana National Guard	Office of Mayor, New Orleans	Parish of Jefferson		State+Local
57	MuttShack Disaster Response Animal Rescue	Louisiana National Guard	New Orleans Police Department		State+Local
58	Department of Homeland Security, US	Louisiana National Guard	New Orleans Police Department		State+Local
59	Army Corps of Engineers	fema	S&M and Associates Inc. of Pascagoula		Federal+Local



* Refer Appendix C for the list of acronym of organizations

Figure 6-7 Clique diagram of Hurricane Gustav management system (Using Cliqueoverlap.##D)\



* Refer Appendix C for the list of acronym of organizations

Figure 6-8 Clique diagram of Hurricane Gustav management system (Using Cliqueset.##D)

6.1.5 Network robustness of hurricane response systems: Lambda set analysis

With clique analysis, I examined how the large disaster response system is composed of small subgroups and which groups of organizations played key roles in connecting entire subgroups for the achievement of the shared goal of disaster response and mitigation. Related with that, I conducted the following Lambda set analysis to identify weaknesses or vulnerabilities of the disaster response systems for Hurricanes Katrina and Gustav. If this analysis can identify those weak links, it will show how policy makers can strategically intervene at these weak points and strengthen the Hurricane Gustav response system to guide it toward more stability and resilience.

The concept of fragmentation in network analysis asks if certain connections in the graph were removed, how this removal affect the structure of the network (Hanneman 2005). The Lambda set analysis ranks each relationship in the network in terms of importance by evaluating how much of the flow among actors in the network goes through each link. It then identifies sets of relationships which, if disconnected, would most greatly disrupt the flow among all of the actors. This lambda set analysis[29] measures the robustness of a network structure when any major nodes are removed. This test of structural robustness can be meaningful for this study because, in dynamic changes of disaster response system, there is a sufficient possibility that nodes might be eliminated from the network by the unexpected impact of disasters.

The output of lambda set analysis is shown in figure 6-9. Within the Hurricane Katrina response system, the first relationship with the highest lambda set value is the working relationship among Governor's Office of Louisiana, Office of President, and FEMA (Lambda

[29] A lambda set is a maximal subset of vertices with the property that the edge connectivity of any pair of vertices within the subset is strictly greater than the edge connectivity of any pair of vertices, one of which is in the subset and one of which is outside (Borgatti et al, 1999).

value=13). If the links among these three organizations were removed, the impact of the removal of this relationship would be the most significant one. The next set of organizations with high Lambda value is the relationship among the Governor's Office of Louisiana, the Office of the President of the United States, FEMA, the Department of Homeland Security, and the Louisiana Office of Homeland Security and Emergency Preparedness with a score of 10. Similarly, those organizations such as the New Orleans Police Department, the New Orleans Office of Mayor, the Army Corps of Engineers, and the Louisiana National Guard can be added to the list of major organizations that maintained critical relationships and that if those links are removed, the collaboration operation of Hurricane Katrina response system would be significantly disturbed.

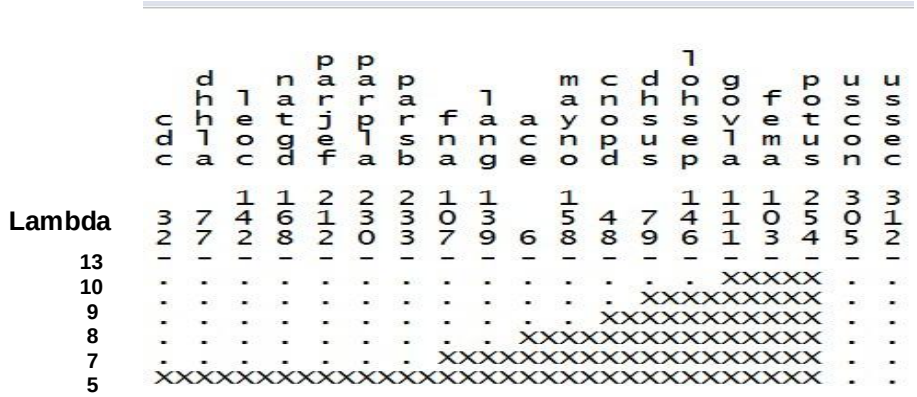


Figure 6-9 Hierarchical Lambda Set Partitions, Hurricane Katrina

Figure 6-10 shows the hierarchical lambda set partitions of the Hurricane Gustav response system. In this response system, the link between the Governor's Office of Homeland Security and the Emergency Preparedness and the Department of Social Services has the closest relationship with a Lambda value of 35. If that relationship were to be disconnected, the entire operation of activities of the Hurricane Gustav response system would have been significantly hampered. The overall Lambda value for the Hurricane Gustav response system is higher than that of the Hurricane Katrina response system, which means that the relationship among the core organizations of the Hurricane Gustav response system is stronger than that of the Hurricane

Katrina response system. Similarly, FEMA, the National Guard, the Army Corps of Engineers, the American Red Cross, the New Orleans Office of Mayor, and some parish governments have close relationships with the Governor's Office of Homeland Security and Emergency Preparedness and the Department of Social Services with a lower lambda value of 5.

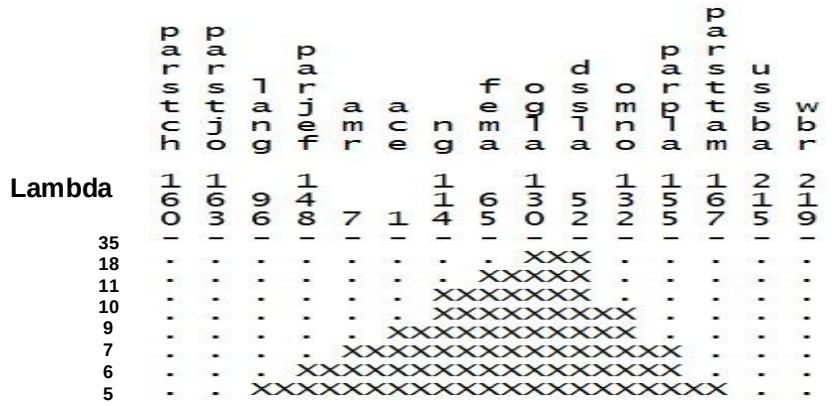


Figure 6-10 Hierarchical Lambda Set Partitions, Hurricane Katrina

6.2 DIFFERENCES IN NETWORK CHANGE OF HURRICANE KATRINA AND HURRICANE GUSTAV RESPONSE SYSTEMS

The clique analysis and Lambda set analysis identified how the entire hurricane response systems were composed of small groups, how the relationships between organizations were embedded in the interaction structure, and where the vulnerabilities are located in their relationships. Also, the identification of core organizations through the various tools of centrality measurement allowed this study to find the critical nodes of both hurricane response systems. These findings of the major features of actual structure for coordination and collaboration serve as the basis for developing intervention strategies for guiding the adaptive evolution of a complex system.

Before developing strategies for intervention, I examined how the response systems for Hurricane Katrina and Hurricane Gustav evolved naturally (meaning how they evolved without any strategic intervention in the relationship) during the period of preparation and response phase because it provides the baseline of system evolution when intervention strategies apply to interactions. The time period and data sources for examining the natural changing pattern are the same as for the content analysis; one week before and three weeks after the hurricanes' landfall. But the time periods were divided into five phases instead of dividing the entire duration by days for a better analysis of the natural evolution of the response systems for Hurricane Katrina and Hurricane Gustav.

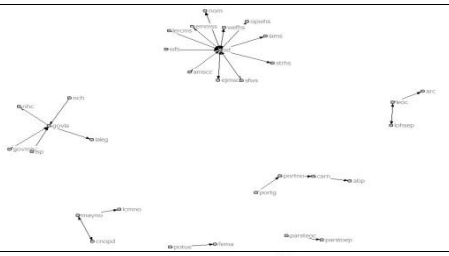
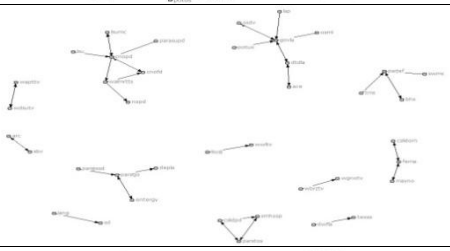
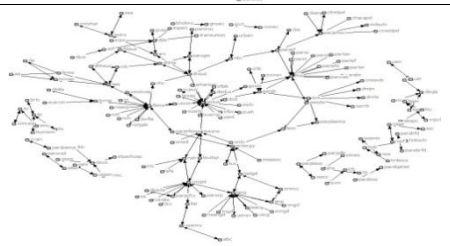
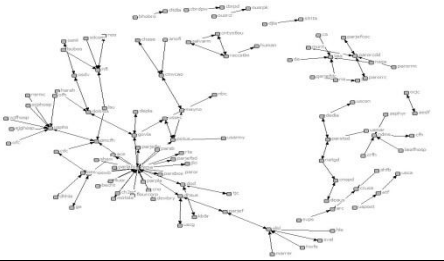
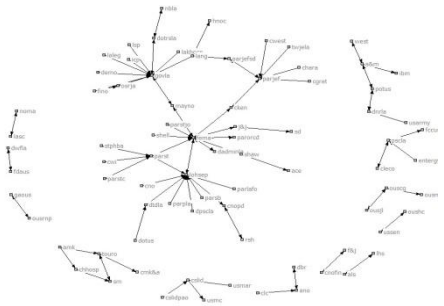
The first period is between the detection of the hurricane by the National Hurricane Center and the landfall of hurricanes; the second period falls between the landfall of the hurricane and three days after the landfall. Note that for the three days after landfall for both hurricanes, especially Katrina, each organization was isolated from the others and could not expect support from the other organizations in the system. Furthermore, because of flooding and the breakdown of the communication system following Hurricane Katrina, the regular activities of disaster response and mitigation were not possible. Also, local agencies such as Parish governments stocked just three days supplies with an expectation that the state and federal agency would reach to them within three days. The third period is the first full week following the three days of first response after landfall and the fourth and the fifth periods are the following second and third weeks respectively. The identification of network change by periods is descriptive by periodic time frames with basic network measures employed in this chapter such as total degree centrality, density, clustering coefficient, and number of cliques.

6.2.1 Network change in the Hurricane Katrina response system

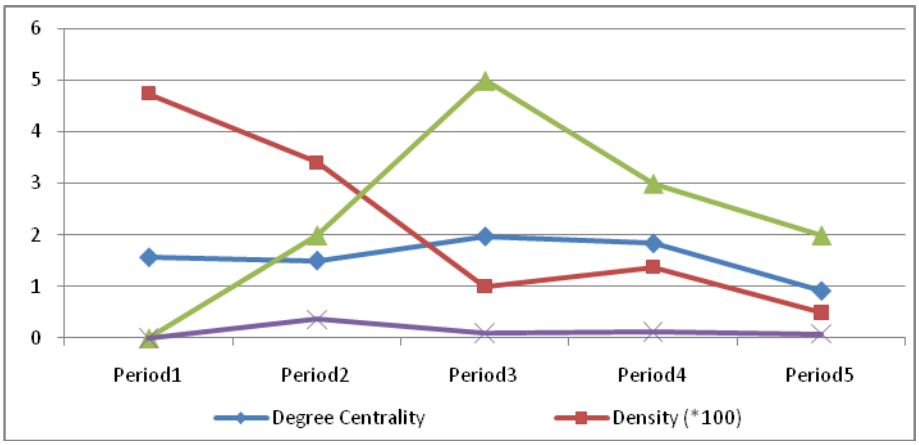
Table 6-7 combines the network map of each time frame with basic measures of network analysis such as density, clustering coefficient, number of cliques, and total degree centrality. First, the changing pattern of the network map of Hurricane Katrina response system shows that it evolves from a very fragmented form of interaction in the initial preparation phase toward a more closely connected form, and, with the advance of time, or with the phase transition from response to recovery, this connected form of a network hits a high in period three and decreases afterwards. As confirmed by the semi-structured interviews, this evolution pattern shows the quite fragmented form of the Hurricane Katrina response system before, and three days after, the landfall of Hurricane Katrina.

This intuitive finding from the network map can be supported by network measures: centrality, density, clustering coefficient, and number of cliques. Figure 6-11 shows the fluctuation of network measures by periods. Number of cliques and degree centrality increases and hits its highest point in period three and decreases again afterwards. Contrarily, the measure of density decreases as the Hurricane Katrina response system becomes normalized in period three, and also slightly increases again with the phase transition from response to recovery. The fluctuation pattern of the clustering coefficient is not consistent even though its pattern also increases until period two and decreases afterwards. This pattern is a bit unexpected, because given the increase of the number of cliques, it may reach a peak in period three.

Table 6-7 Evolution pattern of the Hurricane Katrina response system with network measures

Time Period	Network Sociogram	Network Measures	
August 27 - 28, 2005		Total Degree Centrality	Mean: 1.563, Std Dev: 1.853 Network Centralization = 32.47%
		Number of Cliques (Minimum size = 3)	0
		Density	0.0474
		Clustering Coefficient	0.000
August 29 -31, 2005		Total Degree Centrality	Mean: 1.5, Std Dev: 1.0 Network Centralization = 32.47%
		Number of Cliques (Minimum size = 3)	2
		Density	0.0340
		Clustering Coefficient	0.358
September 1 - 7, 2005		Total Degree Centrality	Mean: 1.964, Std Dev: 2.288 Network Centralization = 9.9%
		Number of Cliques (Minimum size = 3)	5
		Density	0.010
		Clustering Coefficient	0.092
September 8 - 14, 2005		Total Degree Centrality	Mean: 1.832, Std Dev: 2.515 Network Centralization = 22.27%
		Number of Cliques (Minimum size = 3)	3
		Density	0.0138
		Clustering Coefficient	0.124
September 15 - 19, 2005		Total Degree Centrality	Mean: 0.916, Std Dev: 1.561 Network Centralization = 5.98%
		Number of Cliques (Minimum size = 3)	2
		Density	0.0049
		Clustering Coefficient	0.080

*Hurricane Katrina landfall: August 29, 2008.
Source: *Times Picayune*, New Orleans, LA. August 27 – September 19, 2005. (Comfort & Hasse, 2006)



*Instead of the original value of density, this graph multiplied original value of density 100 times to adjust its scale and make its change visible.

Figure 6-11 Change of network measures by periods, Hurricane Katrina

Judging from these measures and network maps, the coordination and collaboration of the Hurricane Katrina response system was poor in the initial stages of preparation. Also, in period two, the first three days of the Hurricane Katrina response phase, there emerged a greater number of organizations in the response system, but due to the collapse of the levee system and the breakdown of the communication system, collaboration and coordination between agencies was not effective in this period. In period three, the entire response system started to adapt and cooperate together, its operations were normalized and there were relatively firm connections between organizations. During period four, the formerly connected system started to become disconnected again, primarily due to the phase transition from response to recovery, and possibly due to the preparation for the second large-scale hurricane to the Gulf area, Hurricane Rita, that landed on September 24, 2005.

6.2.2 Network change in the Hurricane Gustav response system

The same analysis was conducted to detect network change of the Hurricane Gustav response system. As in Hurricane Katrina, this study divides the entire duration into five periods for the identification of the evolution pattern of the Hurricane Gustav response system. The first period is between the detection of the Hurricane Gustav and its landfall on September 1, 2008. The second period is the first three days after Hurricane Gustav's landfall. The rationale for the creation of this period is to make a direct comparison with the previous analysis of the Hurricane Katrina response system that suffered severely from system breakdown in its initial three days of response to Hurricane Katrina. The third period is the first week following these initial three days after the Hurricane landfall, and the fourth and the fifth periods are the second and third weeks after the three days following Hurricane Gustav's landfall.

Similar to the study of Hurricane Katrina, this analysis created table 6-8 which includes network maps for the defined five periods and includes major network measures of network analysis such as centrality, density, clustering coefficient, and number of cliques operating in each period of the Hurricane Gustav response system. With the network maps in table 6-8, this study can intuitively check how the entire disaster response system for Hurricane Gustav evolved by periods. The first and most important difference when comparing these maps to those of the Hurricane Katrina response system is that the interacting organizations in the Hurricane Gustav response system in periods one and two were more closely connected with each other than were the organizations in Hurricane Katrina response system. Centering on the Governor's Office of Homeland Security and Emergency Preparedness, the Louisiana National Guard, and the Parish of Jefferson, organizations in the preparation period had already formed an allied response to Hurricane Gustav. This finding corresponds to semi-structured interviews. Many interviewees

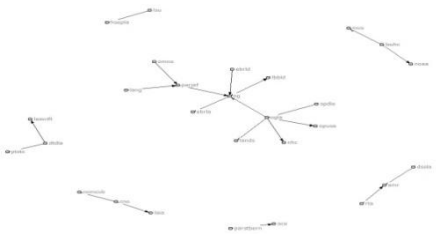
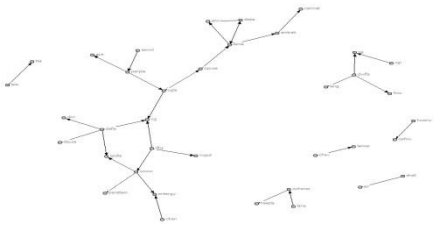
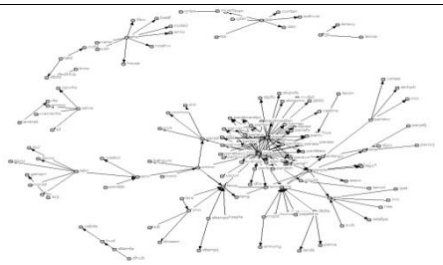
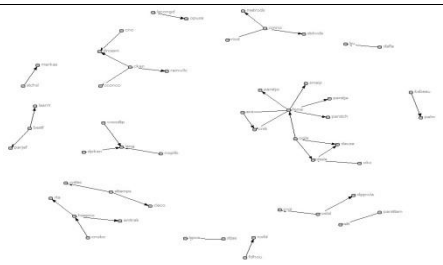
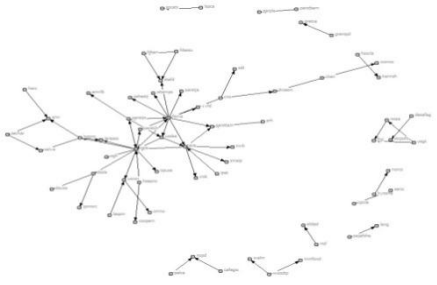
pointed out that the level of preparedness improved significantly for the response to Hurricane Gustav. Due to this increased level of preparedness, the network map of the first period shows an improved pattern of collaboration to that of Hurricane Katrina.

The second difference in evolution between the Hurricane Gustav and Hurricane Katrina response systems is that the entire disaster response system for Hurricane Gustav was re-activated or re-formed after period three which is the most active period during the preparation and response phase for both hurricanes. There are several possible explanations or hypotheses for this re-activation of the Hurricane Gustav response system. The first possibility is that Hurricane Ike, another category 2 Hurricane, made its final landfall on September 13, 2008 in the middle of the response phase of the Hurricane Gustav response system. While in conducting content analysis, this study removed all the activities for the response to Hurricane Ike from coding procedures, there is a reasonable possibility that the collaboration links among organizations such as the Governor's Office of Homeland Security and Emergency Preparedness, FEMA, the Army Corps of Engineers, and parish EOCs were activated again to respond to and mitigate the mixed impact of Hurricane Gustav and Hurricane Ike arriving almost at the same time.

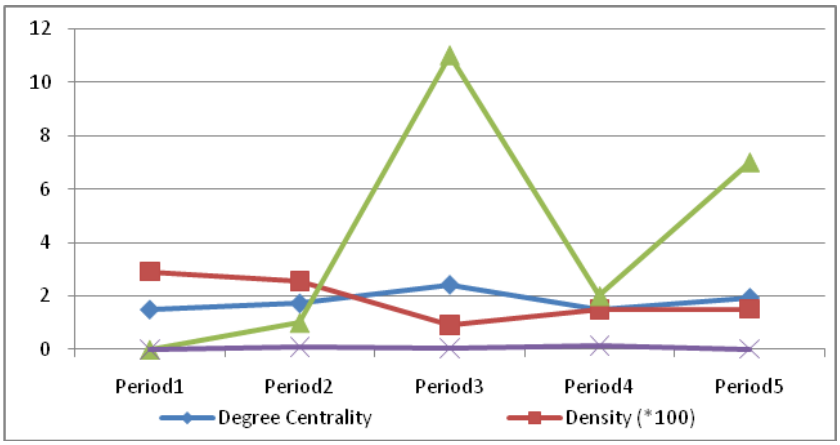
Also, due to the power outages in Baton Rouge and southern parishes in Louisiana lasting for almost two weeks, the collaboration connections between agencies could have been adversely affected and then restored after the recovery from power outages. This peculiar evolution pattern of the Hurricane Gustav response system can be supported by the major network measures in table 6-8. Total degree centrality, number of cliques, and clustering coefficient increase until period three, decrease in period four, and increase in period five which indicates the re-activation of Hurricane Gustav response system. Contrary to that, density decreases until period three and

increases slightly again in period four. This fluctuation pattern of major network measures for the each period of Hurricane Gustav management system is shown in figure 6-13.

Table 6-8 Evolution pattern of the Hurricane Gustav response system with network measures

Time Period	Network Sociogram	Network Measures	
August 26 - 31, 2008		Total Degree Centrality	Mean: 1.5, Std Dev: 1.086 Network Centralization = 13.96%
		Number of Cliques (Minimum size = 3)	0
		Density	0.0291
		Clustering Coefficient	0
September 1 -3, 2008		Total Degree Centrality	Mean: 1.73, Std Dev: 0.973 Network Centralization = 32.47%
		Number of Cliques (Minimum size = 3)	1
		Density	0.0255
		Clustering Coefficient	0.099
September 4 - 9, 2005		Total Degree Centrality	Mean: 2.426, Std Dev: 4.723 Network Centralization = 28.25%
		Number of Cliques (Minimum size = 3)	11
		Density	0.0091
		Clustering Coefficient	0.044
September 10 - 14, 2005		Total Degree Centrality	Mean: 1.49, Std Dev: 1.036 Network Centralization = 11.47%
		Number of Cliques (Minimum size = 3)	2
		Density	0.0149
		Clustering Coefficient	0.133
September 15 - 21, 2005		Total Degree Centrality	Mean: 1.941, Std Dev: 2.086 Network Centralization = 15.47%
		Number of Cliques (Minimum size = 3)	7
		Density	0.0151
		Clustering Coefficient	0.216

***** Hurricane Gustav landfall: September 1, 2008.
Source: Times Picayune, New Orleans, LA. August 26 – September 21, 2008.



*Instead of the original value of density, this graph multiplied original value of density 100 times to adjust its scale and make its change visible.

Figure 6-12 Change of network measures by periods, Hurricane Gustav

6.3 EVIDENCE OF ORGANIZATIONAL LEARNING IN IMPROVING ORGANIZATIONAL CAPACITIES

In the previous section, this study checked evidence of organizational learning in building new structure for effective coordination/collaboration and also examined how each response system evolved by periods. In addition to this evidence of organizational learning in renewing the interaction structure, this section explores complementary evidence of organizational learning in the improvement of organizational capacities and their operations in response to Hurricane Gustav. This analysis uses the data set from semi-structured interviews.

Federal, state, and local organizations' efforts to design a new system since Hurricane Katrina and to make the disaster response system more resilient had been significant and proved to be successful, judging from its response activities to Hurricane Gustav. First, the preparation level was improved significantly since Hurricane Katrina, mainly because organizations worked on the new disaster management plan and let their employees become accustomed to those

changes in plans and procedures through year-round exercises and training. More importantly, these exercises were conducted in a joint manner, so the lack of preparedness that was evident in the Hurricane Katrina response system was sufficiently addressed in time for the response to Hurricane Gustav. Also the disaster response system for Hurricane Gustav invested enormous amounts of resources to improve the reliability and stability of its communication system. With new communication equipment, organizations could share information more accurately and accordingly, quickly allocate resources during their response to Hurricane Gustav.

Managers who participated in the semi-structured interview stated that organizations in the Hurricane Gustav response system retained more highly experienced personnel, secured more resources to the proper level of operation, and followed clearer disaster response plans and procedures with more reliable communication systems. These improvements also allowed for smoother collaboration between partners during the response to Hurricane Gustav. Table 6-9 listed the major changes in organizational capacities for effective coordination and collaboration in response to Hurricane Gustav.

Table 6-9 Structured codes for the part of improvements since Hurricane Katrina

Category	Concept	Code	Description	Frequency	Number of Organization
Improved Organizational Capacity	Improved Manpower	Training and Education	More required training and training programs	59	29
		Improved Personnel Welfare	More considerations for personnel's safety and working conditions	6	5
		Adaptive Leadership	Improved leadership based on learning from previous disasters	11	7
		Increased Expertise of Personnel	Increased level of expertise through disaster management experiences	9	9
		Staffing	Increased number of personnel for the operation of disaster management	7	6
		Total		92	
	Improved Resource Management	Private Vendor Management	Pre-identified and pre-contracted vendors for stable supplies provision	32	15
		More Regional Resources for Self Sufficiency	Using available regional resources to fill the needs gap until state and federal assistance	16	10
		More Available Resources	More resources for disaster response and mitigation in the system	9	4
		Pre-positioning of Resources	Positioning resources before hurricane landfall	20	10
		Exact Estimation of Needs	Estimating the exact needs of resources in advance	13	9
		Total		90	

	Improved Communication for Getting Common Operation Picture	Reliability	Increased reliability of communication system	11	7
		Clear Communication Procedures	Clear contact points and procedures for communication	12	9
		Application of More Advanced Technology	Communication equipment or reporting procedures with more advanced technology	26	15
		More Communication Equipment	More communication equipment	31	22
		Redundancy for Communication	More redundant communication facilities and equipments	15	12
		Reinforced Public Notification System	Reinforced information diffusion system for public's awareness of the situation	9	7
		Utilizing LNOs for On-site Information	Deployment of liaison officers in partners' emergency operation center	33	20
		Frequent Communication with Partners	More communication with partners during disaster response	32	17
		Total		169	
	Improved Planning Activities	New Operation Procedures	New procedures and plans for operation after hurricane Katrina	42	23
		Clear Role Definition	Clearly defined role of each organization and department	18	13
		Alignment of Plan among Organizations	Coordinated plan and timeline among organizations in the system	21	14
		Total		81	
	More Funding for System Improvement		More funding for the disaster management system improvement	3	3
Improved Collaboration Partnership	Building Rapport	Keeping Constant Working Relationship	Constant interactions with partners for building rapport	28	21
		Improved Collaboration through Co-planning	Co-planning with other partner organizations	25	13
		Trust through Co-exercise	Co-exercises with other partner organizations	25	16
		Total		78	
	Improvement in Interaction Structure	Collaboration under Unified System	Establish unified system for better coordination among organizations	14	8
		bureaucratic layers in decision making	High ranking personnel involvement for quicker decision making	7	6
		Building New Units for Coordination	Building new coordinating units in the system for better collaboration	4	2
		Total		25	
	Improved Supports from Partners	Support from Political Leaders	Support from political leaders for better collaboration	9	7
		Supports from National Network Partners	Personnel and resources within national network partners	10	7
		Support from Local/Regional Partners	Personnel and resources from partners in the same region	19	10
		Support from Partners in Civil Sector	Personnel and resources from civil sector partners	25	13

6.3.1 Improved level of preparedness of the Hurricane Gustav response system

As shown in figure 6-13, the average level of preparedness for Hurricane Katrina was rated as 2.94 (between poor and moderate) out of 5, but closer to moderate. For Hurricane Gustav, the total level of preparedness of the system increased from 2.94 to 4.44 (between good and very good). When organizations were sorted by level of jurisdiction, the level of preparedness has improved from 2.75 to 4.5 for federal/national, from 3.5 to 4.67 for regional, from 2.63 to 4.46 for state, and from 3.08 to 4.31 for parish/county organizations. Over 90% of interviewees agreed that this increased level of preparedness contributed significantly to the improved performance of the Hurricane Gustav response system.

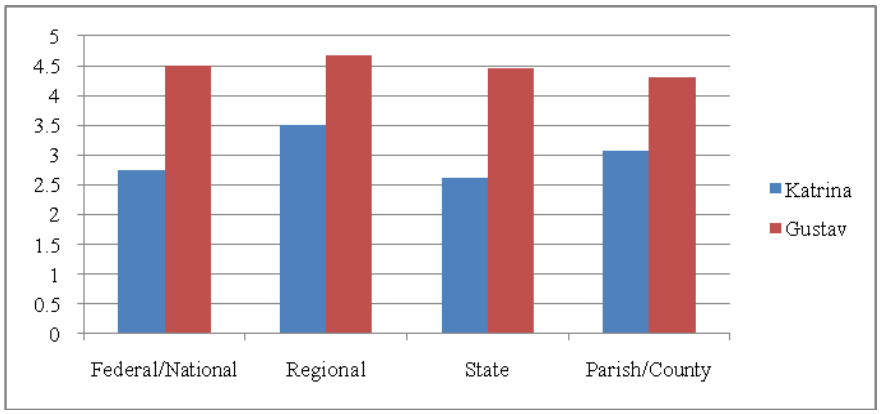


Figure 6-13 Improvement in level of preparedness between hurricanes

More specifically, this increased level of preparedness can be attributed to several factors such as: more detailed and clear planning for disaster response and mitigation, pre-positioning of resources, regular exercises and training, and increased expertise of personnel. Among those factors, 28% of interviewees pointed out the pre-positioning of resources was very critical in their successful response to Hurricane Gustav. The lack of available resources in the initial stage of response to Hurricane Katrina was the most severe criticism that the new disaster response system was required to address. For three years after Hurricane Katrina, the organizations in the

disaster response system revised resource management procedures and exercised those procedures regularly. These actions increased the level of available resources for the Hurricane Gustav response system.

> …we work to address that gap (lack of available resources in the initial response stage), how can we solve that gap? We had been addressing this and pre-positioning supplies both in Louisiana and in Fort Worth, Texas, to be ready to respond quickly… (FEMA)

> …Yes, we had food, water. Equipment was pre-staged for Gustav. It was not pre-staged like that for Katrina… Federal government preserves food and water a year in advance. They gave it to us early. Instead of bringing it to us last minute, after Katrina they decided to pre-stage food and water in our area well before the storm. Before the hurricane season starts, we have the equipment in here… (Orleans Parish)

With these pre-positioned resources, organizations in the Hurricane Gustav response system could function effectively. The effective response to Hurricane Gustav also can be attributed to the clearly defined organizational roles in disaster response plans. Furthermore, personnel from all level of organizations exercised these roles and operation procedures many times with other partners together. As a result, the level of preparedness throughout the region had improved significantly since Hurricane Katrina. As an interviewee from FEMA pointed out, this increased level of preparedness includes several different factors such as: improved communication systems and pre-positioned manpower and resources before the landfall of Hurricane Gustav which was not possible for the Hurricane Katrina disaster response system.

> …between Katrina and Gustav, we did a lot of improvement, wrote a lot of plans, made things work a lot easier. For Gustav it ran, as far as the parish government part of it, it ran much better than it did for Katrina… (Lafourche Parish)

> …Not only GOHSEP but DSS and DOT and the Guard and all the other state agencies to really dig down into the weeds to find out how we can be better prepared; how they can mitigate problems; how we can get our supplies in quicker, how we can coordinate that better; how we can provide better communications equipment; how we can evacuate people better, track them; how we can do the medical evacuations better – all these developed into more specific plans and into functional exercises… (FEMA)

6.3.2 Improvement in management of human resource

In addition to the advanced level of preparedness, the improved performance of Hurricane Gustav response system is attributed to the well-trained personnel of organizations. Almost all organizations, 29 organizations out of 36, mentioned and agreed that their level of training increased significantly, and accordingly, the level of expertise of their personnel also improved. Personnel in each organization had full knowledge of disaster management plans and, more importantly, they could build rapport with personnel in other major organizations. Compared to the lack of organizational learning from the Hurricane Pam exercise just before the landfall of Hurricane Katrina, this level of organizational learning allowed personnel to have enough time for exercises and training, which contributed substantially to improved operations during Hurricane Gustav.

Also, the increased number of exercises with partners developed adaptive leadership and increased expertise of personnel of core organizations in the Hurricane Gustav response system. Many interviewees from core organizations, 16 out of 36, or 44.4%, mentioned that the increased leadership and experience of creatively adapting to new situations contributed to a better response to Hurricane Gustav.

> …but during a catastrophic event you put that book away because you need to have this managerial entrepreneurship and the flexibility to adapt to whatever challenges you have with that management of the shelter… (American Red Cross)

In addition to the improved number of exercises, the organizations in the disaster response system for Hurricane Gustav also took employees' welfare into consideration in designing a new system. Learning from the failures of Hurricane Katrina, managers focused on the security of their personnel in operations. This secured environment increased the morale of

personnel and allowed them to commit themselves to disaster operations without having to be concerned about their own or their families' security.

> …good job of locating all our employees because that was step one, identifying all our employees were safe and making sure that our employees had housing, that they had a place to stay because clearly when an employee has personal issues going on or something like that, it's hard for them to focus on work… (Verizon Wireless)

Also, to fill the positions that were vacant after Hurricane Katrina, some organizations increased their number of personnel.

> …we're much better because we have a staff. For Katrina, the staff of my emergency operations center was three people. Three and now I have a staff of 10 so just that alone with the numbers of people we have and emergency managers… (Orleans Parish)

6.3.3 Improvement in management of physical resource

The most critical problem for the Hurricane Katrina response system was the lack of available resources and the delay of promised resources from partnered organizations. So the response system for Hurricane Gustav tried to secure more available resources before landfall. Many interviewees pointed out that the level of available resources for Hurricane Gustav was much higher than that of Hurricane Katrina.

> …Those four locations all had boats, food, water, generators, showers, we had communications, satellite phones, we have a new inter-operable radio system that if it goes down, we change our radio channel and we hit our towers that are in other areas of the region so we would not lose communication. We now own thirty one boats… (New Orleans Police Department)

Like this, the response system for Hurricane Gustav took great steps to increase the level of resources for its operation. Most importantly, organizations chose to strengthen partnerships with collaborating agencies within the system and activated this pre-contracted supply system before the landfall of Hurricane Gustav. This strategy began with the refinement of estimates of resource needs in response to large scale disaster such as Hurricane Katrina. To accomplish this,

they applied more advanced technology for resource management system such as Web-EOC[30] which made organizations identify the requests of resource allocation and to disseminate that information to other organizations in a timely manner. For example, the video imaging tool of Web-EOC provided organizations with vivid on-site images and assisted them to capture the exact situation instantly. With this, the organizations in the system were able to share real-time information with other agencies, and this allowed them to deploy resources more rapidly and accurately. (MARC, 2009)

> …It was mainly just getting them access down there but I guess we did monitor the damage assessments because that was wanted by the governor and other people, how long it was going to take to get the production back up. So I guess damage assessment was part of the picture too… (Department of Natural Resources, LA)

This application of more advanced technology to the disaster response system is evidence of the socio-technical approach that cyberneticists pursue in designing a more resilient adaptive system. Based on this more advanced resource management system, the Hurricane Gustav response system could position necessary resources before the landfall.

> …Well we had the misfortune of knowing what happened during Katrina and we had the ability to have time to plan for the prepositioning of cages and entering into contracts with the trucks and the MOU's with other organizations to stand up those shelters… (Department of Agriculture, LA)

To secure a sufficient level of resources for their operations, the organizations in the system also strengthened their collaborative partnerships with other agencies that could provide them with resources when organizations are most in need. The organizations, especially the parish governments that were the direct target of Hurricane Katrina could not have expected the instant delivery of resources from state and federal agencies. Therefore, based on these harsh experiences, they tried to be self-sufficient or independent for the first several days after

[30] The Web-EOC is a metro-wide system that allows Emergency Operations Centers (EOCs) to share information for resource allocation. It is a web-based information management system that provides a single access point for the collection and dissemination of emergency or event-related information. Web-EOC integrates data, video, messaging, and many other types of information.

hurricane landfall. They set up new protocols for resource exchange with regional parishes. If there were available resources in one parish, that parish shared its resources with other parishes in the same region. Parishes in southern Louisiana formed several regional collaboration systems and they also signed memoranda of understanding (MOU) among parish governments in the same region.

> …we would try to solve that problem and use our local resources, school buses and if we can get another parish to accept the evacuees, we're going to go ourselves, load them on the bus and bring them over here and man the whole thing as far as the staff to run the shelters, feed them, place to sleep the whole nine yards and that way it gives us, we have control to assist the parish and make sure that it's safe, okay to bring the citizens back… (Lafourche Parish)

> …I'm trying to be independent; that way we don't have to depend on anybody to get our people out of harm's way. Some things you've got to depend on the state and federal government for supplies, like fuel even though we've got contracts in place but it's better to have more than one resource because if our vendors go dry we've got to, you know… (Plaquemines Parish)

At the same time, organizations in the Hurricane Gustav response system could get more resources through regional private vendors. They contracted with private vendors such as Sysco, Wal-Mart, Lowes, and local grocery stores to provide the supplies to parish governments within hours after requests. This significantly increased the stability of supplies provisions to local organizations and also this provided redundancy in securing necessary resources to the level that their dependency on other state or federal agencies for resources decreased significantly.

> …what we do is we have arrangements with a business in the area and the organization we buy our food from, what we do is we get, like the food warehouse that provides food to us, their owner and two of their clerks come into our hospital, live here and survive during the storm and then after the storm we have total access to their warehouse because the warehouse has about a six month supply of food I have access to… (Ochsner Hospital)

Using these strategies, the organizations in the Hurricane Gustav response system successfully secured the necessary resources for their operations. In summary, learning from the failures of Hurricane Katrina, they tried to be independent during the first several critical days of response and strengthened their working relationships with regional and private partners. As a

result, the total level of available resources in the Hurricane Gustav response system was significantly increased compared to the levels of resources during Hurricane Katrina.

6.3.4 Improvement in communication system

The disaster response system for Hurricane Gustav also reinforced its communication system after the significant failures of Hurricane Katrina. Because the breakdown of the communication system, the disaster response system for Hurricane Katrina collapsed and limited coordination in response to Hurricane Katrina. Organizational efforts to build a reliable communication system can largely be divided into two parts. First, they invested sizable amounts of money to purchase and upgrade its communication infrastructure. As a result, they could be equipped with more advanced communications devices that are critical for the interoperability of disaster response activities.

The advanced communication equipment of the Hurricane Gustav response system helped organization address the most serious problem of the communications system breakdown. It provided the organizations with redundancy and compatibility of communications equipment, resulting in a comparatively reliable communications system for the Hurricane Gustav response system. This capacity, in turn, contributed to better collaboration and coordination for information and resource exchange among organizations in the system.

> *More advanced technology*: …we had the interactive - all the photos, the interactive web-based conference calls that actually showed the hurricane on our screen and they briefed us on the directions, the speed all of that. We didn't have that for Katrina… (Ascension Parish)
>
> *More communication equipment*: …So one of the biggest things is we have multiple on multiple levels of communication infrastructure. We have cell phones, we have satellite phones, we have voice over IP phones, and we have our own channel on the state police radio network with our own repeaters. Our computer server room has two different generator backups… (Army Corps of Engineers)
>
> *Redundancy in communication*: …There was a lot more redundancy of satellite, microwaves, voice over internet protocol. There was a lot more robust system. More radio towers, a redundant

> radio system. We have a 700, 800 megahertz system so [if] one is having problems we can go to the other. So a lot more redundancy, a lot more robustness to the system for Gustav… (Louisiana State Police)

Secondly, organizations in the system revised their communication procedures to make them clearer than that of Hurricane Katrina. One of the problems identified by semi-structured interviews was that personnel in some organizations could not identify their communication partners instantly; that is, they did not know who the contact person for information sharing was. To address this problem, some efforts were made to make this contact point clearer and more easily reachable by partners in the system.

> *Clear communication procedures*:..Now that is something that's easily accomplished now because we've planned for it, we've set up communications systems to be able to do it, we've planned for it and we do it in exercise all the time and it happens very smoothly… (Department of Wildlife and Fisheries, LA)

> *Clear communication partners:* …I guess the one good thing that happened after Katrina was everybody now knows how to get in touch with everybody and FEMA had set up a really good network of how to get in touch with everybody… (New Orleans International Airport)

Most respondents to the questions of semi-structured interviews agreed that the revision of communication procedures and the clarification of contact points decreased confusion or entropy in the system. The communication channels were reinforced by the exercises and they also deployed more of their own personnel, liaisons, in their partners' emergency operations centers (EOC). More than 20 out of the 36 organizations pre-positioned their liaison officers (LNOs) in their partner's EOC, and these officers played a critical role in facilitating communication with partners. This shows that, even with advanced information technology, face-to-face interaction is still important in collaboration and coordination for effective response to disasters. With direct contacts with partners during the critical phase of disaster response, organizations could collaborate more effectively in exchanging knowledge and resources.

> *LNOs in partner EOC*: …I can tell you it's a lot smoother and faster by having [the] LNOs there. Of course they would love to have [the] LNOs have the decision authority and have a big truck full of supplies that he could pull a trigger on but we just can't… (Army Corps of Engineers)

Due to the increase in communications equipment and the application of more advanced technology for interoperability and redundancy, and due to the utilization of liaison officers, effectiveness in information and resource exchange increased significantly during the preparation and response phases to Hurricane Gustav. This improved communication during Hurricane Gustav was also possible due to the regular exercises with partners. Nearly all interviewees mentioned that the increased communication among organizations contributed enormously to the successful response to Hurricane Gustav. Also, the improved communications system for Hurricane Gustav was not limited to the organizations within the disaster response system. They devised a new communication system or notification system to the public living in the region that was under mandatory evacuation order. They reinforced the community notification system and introduced an evacuee tracking system that was not available during Hurricane Katrina.

> *Greater number of communications:* ……There's constant communication between the region and the states so we watch the weather channel just like the state does. We know something's coming into the Gulf so we're already sending liaisons… (FEMA)

> *Public Notification system*: …Things that we saw, problems that we saw within Katrina we prepared for Gustav. Then again we were communicating. We were talking. Who has a right to know? The public, so every day when we were meeting as a group, we would then talk to the news media so the public could see us… (Louisiana State Police)

6.3.5 Improvement in planning activities

The previous section noted that revised plans made the contact point and operation procedures clearer and that these changes contributed to improved communication during Hurricane Gustav. This finding goes hand-in-hand with the clear definition of organizational roles in the new operating procedures. These newly defined organizational roles and operational procedures were regularly drilled jointly with other organizations, which enabled personnel in each organization to understand their roles in the entire disaster response system and how to collaborate with other organizations in case of a large disaster like Hurricane Gustav.

Behind the joint operations and exercises, there was joint planning to make each individual organization's plan align with other local, state, and federal plans. As a whole, the disaster response system for Hurricane Gustav tried to have a system-wide plan that was comprised of individual but mutually coordinated plans. Since Hurricane Katrina, FEMA provided special assistant teams to make federal, state, and local disaster response plans aligned and all organizations dispatched managers or deputy managers to the simulation room in the Governor's Office of Homeland Security and Emergency Preparedness to build integrated disaster response plans. In this joint planning activity, they gathered and compared each agency's emergency management plan and made sure they were aligned and possibly coordinated in case of crisis. Once there were new procedures, they were practiced jointly to test whether it could work effectively under actual disaster conditions.

> …Katrina was kind of a disaster so we knew where our weakness was at so agencies got together and worked those things out. They would invite us to their meetings on how they plan to prepare for hurricane or any natural disaster… (Ascension Parish)

> …Again, Katrina opened our eyes to a lot of different things. Our plans after Katrina, all of our plans are in sync with each other. We all know what we're doing and we coordinate our plans together… (Orleans Parish)

6.3.6 Summary of improvement in capacity of national response system since Hurricane Katrina

The various improvements made to the response system for Hurricane Gustav were based on lessons learned from Hurricane Katrina. Organizations in the disaster response system have worked extensively for three years on human resource management, resource management, planning, and the construction of advanced communication system. The improvement in communication for information diffusion is most significant, as the organizations have increased their organizational capacities by retaining more competent and experienced personnel, securing resources more reliably, and developing working disaster management plans. Considering the

significant failure in communication during the response to Hurricane Katrina, the focus on building reliable communication systems is very relevant.

This advance in communications contributed to the improvement in collaborative partnerships. Organizations worked mostly together in a well coordinated manner and this was possible by building solid relationships with partners through constant interaction, co-planning, and co-exercises and building mutual rapport. Further, the analysis of semi-structured interview shows that each organization gained better support from its partners in the disaster response network. By improving organizational capacities in several ways, the organizations in the Hurricane Gustav response system made significant advances in their collaboration partnership. The improvements in organizational capacity allowed them to acquire, process, and transmit on-site information more accurately and quickly to other organizations in the system. The reinforced collaborative partnership complements the improvement in organizational capacity and together, helps organizations to function more effectively in several ways.

First, the improvement in collaborative partnership strengthens the interaction links among organizations. With reinforced links, the organizations in the Hurricane Gustav response system interacted in more stable and reliable ways with other partners. For example, when the collaboration procedures were not clear enough for any two organizations to interact, the managers of those two organizations would learn how to interact with their partners through the regular working relationships in exercises and planning. Similarly, if they encounter a breakdown of the communications system, they could develop alternative ways of collaboration based on working relationships or rapport that has been established through prior interactions.

Secondly, if organizational managers build trust or rapport, the problems of collaboration, such as hidden agendas, rivalries among organizations, lack of transparency in operations, and

bureaucratic incompetency could be remedied or lessened significantly because they understood one another's strengths and weaknesses and how one agency's action can affect the performance of remaining agencies. This mutual understanding enables them to share what they know and what they have more effectively with partners.

7.0 ASSESSING EFFECTS OF STRATEGIC INTERVENTION ON THE PERFORMANCE OF HURRICANE RESPONSE SYSTEMS

The findings from social network analysis that identified strengths and weaknesses of hurricane response systems provide suggested implications regarding where and how to intervene strategically to guide resilient system evolution over time. To develop intervention strategies and assess their effects on the performance of disaster response systems, this analysis also needs to develop a performance measurement metric. Using this metric, I quantitatively measured the changes in performance when individual or combined strategies are actually applied in a simulation of a disaster response system.

The elaboration of plausible strategies and the assessment of their effects on the system evolution can be analyzed with agent-based simulation because, as Simon argued (1999), the bounded rationality of human beings in searching and deciding the most relevant policy alternatives can be effectively addressed by computational simulation. This study, through comparative analysis of the Hurricane Katrina and Hurricane Gustav response systems, identified the problems that organizations faced in response to Hurricane Katrina, checked what measures were taken since that time to make organizations perform and collaborate more effectively, and explored what factors mostly contributed to the organizational adaptation under changing conditions of crisis. Based on the findings from social network analysis and semi-structured interviews, I extracted several critical parameters to be used for the design of policy alternatives

for effective organizational adaptation to changing conditions. Those identified factors were operationalized and used as an input to an agent-based computational simulation model. Briefly, the processes of conducting agent-based computational simulation includes the identification of core parameters, an operationalization of those core parameters, the exploration of simulation space, and the identification of the system's adaptive pattern to changing conditions.

7.1 IDENTIFICATION AND OPERATIONALIZATION OF CORE PARAMETERS FOR THE CONSTRUCTION OF A COMPUTATIONAL SIMULATION MODEL

7.1.1 Identification of core factors in designing policy alternatives for intervention

Table 7-1 shows the factors that most managers suggested to be considered in designing a more resilient and stable disaster response system. The managers stated that reliable collaboration partnership among organizations and resilient system evolution can be mainly attained through co-training, co-planning, and maintaining a steady relationship with partners. Additionally, they agreed that well-trained personnel who are able to deal with changing operations are a highly desired resource for their adaptive operations.

From the factors listed in table 7-1, the top 8 parameters that are most frequently noted by interviewees are listed in table 7-2. Those parameters are: training and education, new operation procedures, utilization of liaison officers for on-site information, private vendor management, and frequent number of communications with partners, advanced communication equipment in number and technology, and keeping reliable partnerships.

Table 7-1 Structured codes for future disaster management

Code 1	Code 2	Code 3	Description	Frequency	Number of Organizations
Factors for Better Collaboration	Communication	More communication with partners	More communication during disaster response and mitigation	9	9
		Application of more advanced technology	Application of more advanced technology	7	6
		More communication equipment	More equipment for better communication	2	2
		Total		18	
	Building Rapport with Partners	Mutual Understanding of Other's Role and Limitation	Clear understanding of other's role and weakness	6	6
		Constant Co-training, Planning, Operation	More co-planning, co-training, and co-operation exercises	19	13
		Establish Working Relationship through Interaction	Constant interactions with partners for constant working relationship	24	20
		Developing Community Partnership	Reinforcing partnerships with community and education for public benefit	7	4
Factors for Better Operation	Resources Management	More available resources in the system	Securing more available resources for the system	4	4
		Exact resource assessment for demands and supplies	Developing resource management system for exact estimation	3	3
		Total		7	
	Human Resource Management	More consideration for personnel welfare	Investment in personnel welfare during disaster response and mitigation operations	4	3
		Staffing	More personnel for operation	5	5
		Experienced leadership for adaptation	Securing more experienced managers for adaptation	10	9
		More training and education	More required training programs for personnel	16	14
		Total		35	
	Planning	Constant planning for adaptation	Frequent updates for appropriateness of the disaster management plan	16	13
		Aligned and shared timeline	Aligning each disaster plan with other partner organizations	10	8
		Total		26	
	More Funding for System Improvement		More funding for education, equipment, facilities, and planning	7	6

Table 7-2 Critical parameters identified by number of comments by interviewees

Parameters	Description	Frequency
Training and Education	More required training and training programs	59
New Operation Procedures	New procedures and plans for operation after Hurricane Katrina	42
Utilizing Liaison Officers for On-site Information	Deployment of liaison officers in partners' emergency operation center	33
Private Vendor Management	Pre-identified and pre-contracted vendors for stable supplies provision	32
Frequent Number of Communication with Partners	More communication with partners during disaster response	32
More Communication Equipment	More communication equipment	31
Keeping a Constant Working Relationship	Constant interactions with partners for building rapport	28
Application of More Advanced Technology	Communication equipment or reporting procedures with more advanced technology	26

However, the selection of core parameters for building a computational simulation model cannot entirely depend on the frequency of parameters, because the frequency is also contingent on several other features of the organizations such as emergency support function, level of jurisdiction, and source of funding. For example, the Louisiana Public Service Commission emphasized the role of communication because its main function is to gather information on the management of natural gas and oil facilities on the shores of the State of Louisiana, but comparatively did not stress a stable working relationship with partners due to its mission pre-set by the state disaster response plan.

I added one more criterion in selecting core parameters for building computational simulation model, the number of organizations that mentioned a given parameter during the interviews. The list of the top 6 parameters mentioned by the largest number of organizations with the highest frequencies is shown in table 7-3. The parameters identified through semi-structured interviews have system-wide influence on organizations' performance and collaboration: training and education, new operation procedures, advanced communication equipment, regular working relationships, utilization of liaison officers for on-site information, and a high number of communications with partners.

Table 7-3 Critical parameters identified by number of comments by interviewees

Parameters	Description	Number	Number of Organization
Training and Education	More required training and training programs	59	29
New Operation Procedures	New procedures and plans for operation after hurricane Katrina	42	23
More Communication Equipment	More communication equipment	31	22
Regular Working Relationship	Regular interactions with partners for building rapport	28	21
Utilizing LNOs for On-site Information	Deployment of liaison officers in partners' emergency operation center	33	20
Frequent Number of Communication with Partners	More communication with partners during disaster response	32	17

Combining the critical parameters identified in table 7-2 and 7-3, I set the five most critical parameters for the computational simulation as: training and education, advanced communication equipment, utilization of liaison officers for on-site information, clear operation procedures, and regular working relationships with partners. In addition to these five parameters, this study added one more parameter, the level of available resources that is identified in the content analysis of situation reports. In total, six parameters are used in building an agent- based computational simulation model.

7.1.2 An operationalization of critical parameters of computational simulation model

After the identification of core factors for the computational simulation model, this study operationalized each core parameter to manipulate them within the computational simulation model. To better operationalize core parameters, I defined the meaning of strategic intervention. In an effort to design a more stable and adaptive complex adaptive system, I considered two possible ways of intervention. The first one is the intervention for the improvement of organizational capacities in processing information, and the second one is the reinforcement of collaborative partnerships/structure in response to changing conditions. With these intervention strategies, I expect that organizations in the complex adaptive system can easily identify collaboration partners for joint responses to crisis, process information accurately, and as a result, allocate the required resources in a timely manner.

Figure 7-1 clarifies the link between the core parameters of computational simulation and the domains of operationalization. The first parameter of training and education helps organizations in the system find interaction partners more quickly and accurately. Also, this parameter of training and education helps organizations to produce more accurate information

and to transmit critical information more rapidly to partnering organizations for the construction of a common operation picture.

The second parameter of pre-positioning of resources, or having enough resources for the initial stage of disaster response, contributes to the reduced number of requests for resource allocation in the entire response system. Considering that the organizational capacity of core organizations was overwhelmed by an excessive number of requests for resource allocation in Hurricane Katrina, pre-positioned resources, especially for the local agencies, can reduce the need for resources in the initial stage of disaster response. This action decreased the burden of information processing and coordination of core organizations in the adaptive system.

The third parameter, advanced communication equipment, assists organizations to identify interaction partners more quickly, process information more accurately, create action knowledge, and transmit it to other partners in the system. Also, with the investment in advanced communication technology and equipment, organizations communicate with redundancy and interoperability that can lead to reliable communication channels among organizations in the response system. In the same context, the utilization of liaison officers (LNOs) for on-site information can contribute to more rapid and accurate transmission of critical information to partnering organizations. With accurate on-site information, organizations in coordinating positions in the system can see the big picture of the operation and make faster and more efficient organizational decision for timely resource allocation.

The fourth parameter of clear operation procedures helps organizations in the disaster response system find interaction partners faster and more accurately. With joint-training, each participating organization knows how and with whom it is supposed to interact and collaborate in response to crisis. Like this, regular working relationships between agencies helps them to find

partners faster and more efficiently. It also allows them to reduce the number of resource allocation requests to other organizations because these reliable and established relationships make it possible to secure promised resources without adding additional resource allocation requests to other organizations in the disaster response system.

In summary, the best strategic intervention scenario to secure effective performance is to pre-position available resources before hurricane landfall, deploy liaison officers to major partnering organizations, regularly update the disaster management plans, educate and train personnel, and be equipped with the most advanced communication equipment. However, due to legal and budgetary limitations, selection and concentration of choices are inevitable in applying these intervention strategies. For this selection and concentration purpose, findings from social network analysis in finding core actors and critical links in Chapter 6 can guide this study to the wiser 'selection' of organizations and the effective 'concentration' of limited resources in designing a complex adaptive system. Figure 7-1 shows the links between identified parameters and their operationalization.

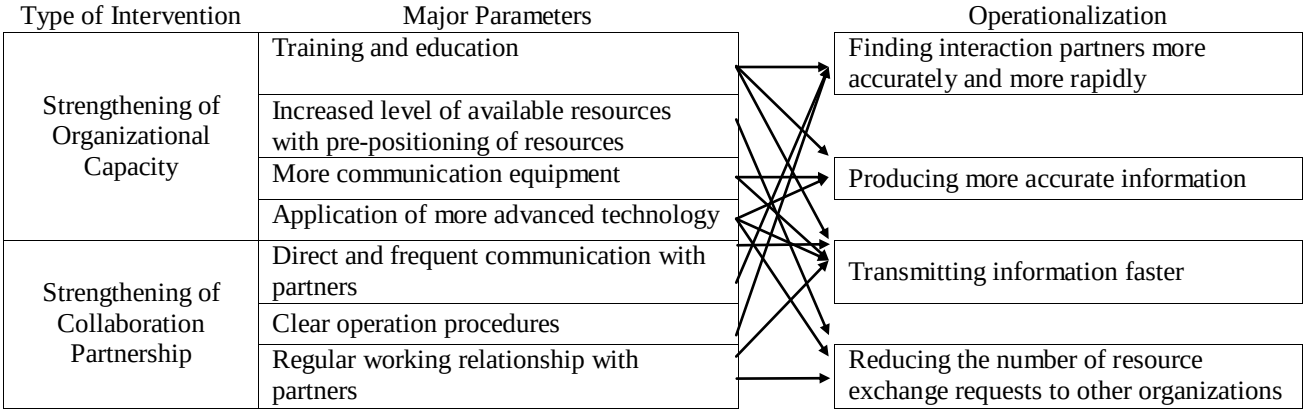


Figure 7-1 Operationalization of core parameters for building a computational simulation model

7.1.3 Exploration of parameter space for building a computational simulation model

After the operationalization of core parameters, I assigned probability to each parameter because the effect of each parameter on the performance of an adaptive system can be explored in the probabilistic computational simulation space. In this section, I explored the possible value or probabilities of major parameters within the computational simulation model. Table 7-4 shows the assigned value and probability of major parameters according to the level of each parameter (1=high, 2=moderate, 3=low). First, the parameter of level of training and education is related to the amount of information that any organization can process at one time and the accuracy of information that this organization can produce and transmit to other partners in the system. When personnel are well trained, it can process 10 units of information at one time with 90% accuracy, 5 units when moderately trained with 50% accuracy, and only one unit when poorly trained with 10% accuracy. The number of requests that any organization can process at one time is important because if there are too many requests for resources allocation from partnering organizations, especially in a very limited time, the organization with untrained personnel cannot respond to those requests appropriately and eventually returns a 'no-response' to those requests.

Due to the advantage of joint training, if agencies work together for personnel training, organizations with highly trained personnel can find interacting partners with 90% success in the first trial. As described in Figure 4-6 (the algorithm of agent-based simulation model), when any organization failed in the first trial to identify collaboration partners, it can retrace all the procedures in the algorithm which means a severe delay in identifying collaboration partners. Similarly, the level of available resources affects the number of requests for resource allocation in the system. When organizations have enough resources, they have little need to request resource allocation to core organizations. So, when organizations have a high level of available

resources in the initial stage of response, organizations request resources less. In this set of computational simulation, this study assumes that organizations with high levels of resources request resources to core organizations just once per one time frame and when organizations suffer from a lack of resources; they initiated 10 requests per one time frame.

When organizations are well equipped with the most advanced communication systems, and organizations deploy liaison officers in major partnering organizations, they transfer critical information faster and more accurate, and they can find organizations for possible collaborations more easily and accurately. Also, when organizations have well defined operation procedures and plans, they can process more information and effectively identify organizations for collaboration. Finally, if organizations keep a regular working relationship and build trust with partnering organizations, they find interaction partners very effectively and quickly. All six operationalized core parameters and their simulation space are listed in table 7-4.

Table 7-4. An exploration of parameter space of computational simulation model[31]

Key Input Parameters	Number of Requests for Resource Allocation			Number of Requests Processed at One Time			Accuracy of Information This Organization Processed/Transmitted			Possibility of Success in Finding Interaction Partners		
Level of Training and Education of Personnel				1=high	2=moderate	3=low	1=high	2=moderate	3=low	1=high	2=moderate	3=low
				10	5	1	p=0.9	p=0.5	p=0.1	p=0.9	p=0.5	p=0.1
Level of Available Resources	1=high	2=moderate	3=low									
	1	5	10									
Level of Communication Equipment and Advanced Technology							1=high	2=moderate	3=low	1=high	2=moderate	3=low
							p=0.9	p=0.5	p=0.1	p=0.9	p=0.5	p=0.1
Utilizing LNOs for On-site Information							1=high	2=moderate	3=low	1=high	2=moderate	3=low
							p=0.9	p=0.5	p=0.1	p=0.9	p=0.5	p=0.1
Clear Operation Procedures				1=high	2=moderate	3=low				1=high	2=moderate	3=low
				10	5	1				p=0.9	p=0.5	p=0.1
Keeping Constant Working Relationship with Partners										1=high	2=moderate	3=low
										p=0.9	p=0.5	p=0.1

[31] The three values of probability assigned to each parameter are 90%, 50%, and 10% to make its distribution follow Bernoulli distribution with α=0.1. This study expects the worst performance with 10% possibility of information process and finding interaction partners and the best performance with 90% possibility (Willink 2010). Each value of simulated performances can range between them (Carley 2010).

7.1.4 Construction of computational simulation model

The probability of success in requested resource allocation between organizations depends on the organizational capacities in processing information and the strength of their reciprocal collaboration partnerships. Furthermore, the organizational capacity in processing information is contingent on the level of training of personnel, the advanced communication equipment, and the level of available resources. Similarly, the collaboration partnerships depend on the deployment of liaison officers, regular working relationships, and clear operation procedures. Based on the simulation space for each core parameters, this study can construct a formula for a computational simulation model of this study.

The formula of computational simulation can be phrased like this:

P (success in resource allocation) = *f* (organizational capacity, collaborative partnership)

And, when each component is divided into the core parameters of this study, it can be rephrased like this,

Probability of Success in resource allocation = w1 (level of training and education of personnel) + w2 (level of available resources) + w3 (advanced communication equipment) + w4 (utilization of liaison officers) + w5 (clear operation procedures) + w6 (constant working relationship) + ε

In this equation, w_n indicates the weight of each parameter in a computational simulation model that is defined by semi-structured interviews and the frequency of core parameters mentioned by managers in participating organizations. The following section reports the results of the computational simulation and examines how each intervention strategy can be applied to improve the probability of successful resource allocation, and eventually, to make organizations effectively adapt and evolve toward reliable operations.

7.2 ASSESSING PERFORMANCE OF ORGANIZATIONS IN RESPONDING TO CHANGING CONDITIONS WITH INTERVENTION STRATEGIES

To measure the effectiveness in resource allocation, this study devised a performance metric, the ratio of resource alignment (refer to chapter 4 computational simulation section), and evaluated the overall network performance for each time frame. This section starts with the exploration of a natural evolution pattern of the Hurricane Katrina and Hurricane Gustav response systems. The natural evolution pattern means that there is no application of intervention strategies to the current system's evolution. The natural evolution patterns without strategic intervention serve as the baseline for the computational simulation and this analysis compares them against the evolution patterns with strategic interventions.

To do the comparison, I constructed "what-if" scenarios. First, I virtually removed the core nodes or organizations from the entire disaster response system and checked how an entire system recovers from and adapts to this sudden condition of the removal of core organizations. The relevance of this projection is that, due to the sudden adverse effects of a crisis, many core organizations may malfunction. Ensuring system recovery and returning to normal operations is critical to building a complex adaptive system. Similarly, I conducted a what-if analysis in a scenario by removing critical collaboration links. In this case, I determined how organizations creatively adapt to unexpected changing conditions and generate temporal links for effective collaboration.

As the next step for assessing network performance in response to changing conditions, I applied the intervention strategies in the computational simulation. In other words, I increased the organizational capacities in information processing and transmission and reinforced the interaction links for the construction of reliable collaboration between organizations. Finally, I

explored possible structural changes in designing a system that could adapt to complex and changing conditions.

7.2.1 The comparison of patterns of natural evolution for the hurricane response systems

For the creation of a baseline for the performance comparison of hurricane response systems, I conducted an initial computational simulation with no changes from the current response systems for Hurricane Katrina and Hurricane Gustav. Figure 7-2 shows the natural evolution pattern of the Hurricane Katrina and Hurricane Gustav response systems when there is no strategic intervention to current conditions. The Y-axis represents the resource alignment ratio and the X-axis represents the time span of the simulation.

According to Figure 7-2, the overall resource alignment ratio of the Hurricane Katrina response system is around 0.26 when it plateaus after t= 73 while the overall resource alignment ratio of the Hurricane Gustav response system is around 0.30 when t=72. This means that 26% of overall resources could be successfully shared without any strategic intervention in the Hurricane Katrina response system, while 30% of overall resources could be successfully shared in the Hurricane Gustav response system. For both hurricane response systems, this resource alignment ratio is far from satisfactory because this means that less than 30% of resources will be delivered to requesting organizations under conditions of the current system of disaster response. This evolution pattern of the resource alignment ratio without intervention works as the base line for the comparison of the performance of various simulated response systems with interventions.

Judging from the natural evolution pattern of the two hurricane response systems, I confirmed a favorable response to the three policy challenges in designing complex adaptive systems. The first challenge is to lift the overall resource alignment ratio using various types of

intervention strategies. The second challenge is to shorten the time period that the resource alignment ratio reaches the satisfactory plateau area in which there is no significant performance improvement from strategic interventions. Observing the severe problem of delays in resource allocation of the Hurricane Katrina response system, I explored possible policy alternatives for ensuring a speedier response to requests for resource allocation. The third policy challenge is to make complex systems adapt quickly to unexpected changes from environments and recover from the adverse impacts of crisis accordingly. For example, in Figure 7-2, the deterioration of the resource alignment ratio is not peculiar, but there is a significant possibility of the functional death of core organizations. If any core organizations cannot function properly within the system, other peripheral organizations in the system need to adapt to this uncertain situation and find possible partners for interaction and collaboration. Also, if there is a downturn in the resource alignment ratios in the initial stage of disaster response, relevant strategies need to be implemented to lead this evolution pattern upward.

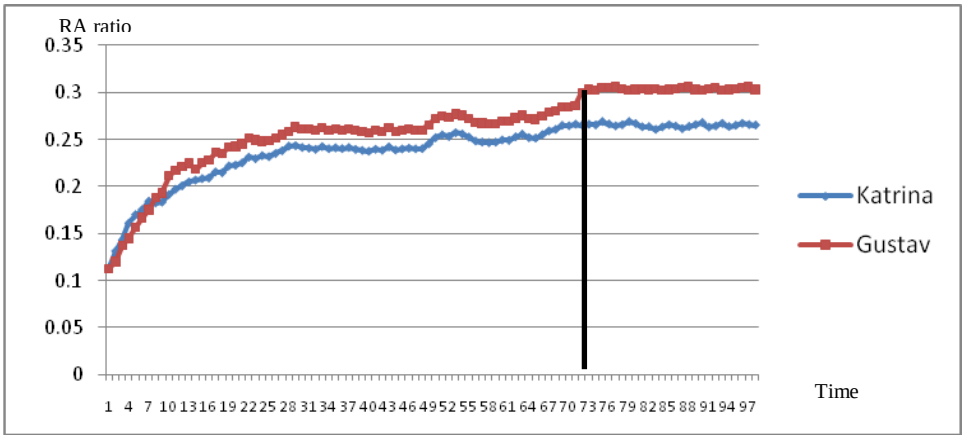


Figure 7-2 Natural evolution pattern Hurricane Katrina and Hurricane Gustav management system

7.2.2 The effect of critical nodes and collaboration links removal

To assess how the entire system can evolve without core coordinating organizations, I investigated the effect of the functional death of core organizations. Among various intervention strategies such as an increased investment in communication equipment, an increased amount of training and education needs to be implemented over one year (over one fiscal year for the allocation of new budget for the advanced education). Moreover, the establishment of rapport and reliable working partnership among organizations cannot be attained shortly. Accordingly, if core organizations cannot function properly due to damages from crises, any possible partnering organizations need to replace them to address the possibility of quick recovery from crises. By doing this, organizations in the system creatively adapt to this uncertain situation and they can develop a new way of collaboration that would not be possible under normal circumstances.

Due to various reasons, the response system for Hurricane Katrina and Hurricane Gustav already experienced these unexpected malfunctions of core organizations. In Hurricane Katrina, this was mainly due to the communication system breakdown and the secondary flood from levee system breakdown. Under this condition, many core organizations could not interact effectively and were eventually isolated during the most critical days of first response. In Hurricane Gustav, the organizations faced an unexpected blackout leading to similar types of isolation among organizations even though the storm's impact was not as severe as Hurricane Katrina.

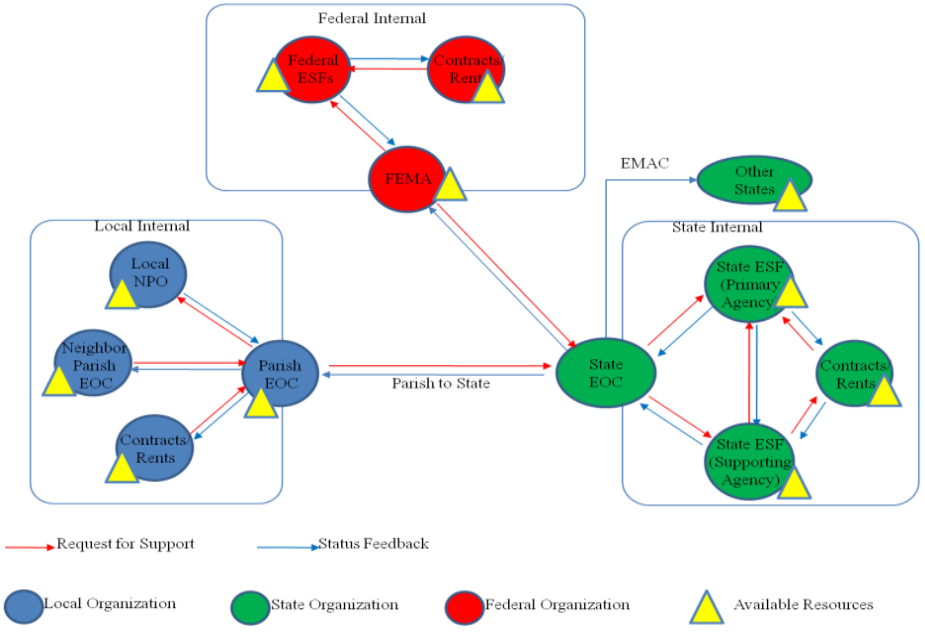
There are two types of functional death in a complex adaptive system. The first type is the functional death of nodes and the second type is the disconnection of collaboration links among organizations. For the first what-if analysis of core nodes removal, I have already identified the core organizations using several centrality measures and clique analysis. The

organizations identified through these measures can be virtually removed from the network. Then, I examined how the removal of core nodes from the system affects the resource alignment ratio, and whether they rebound from the downturn and recover.

More specifically, the core organizations that have high total degree centrality and coreness, such as FEMA, Louisiana Office of Homeland Security and Emergency Preparedness, Louisiana Office of Governor, New Orleans Police Department, Army Corps of Engineers, Louisiana National Guard, Office of the President of the United States, and New Orleans Office of Mayor were removed alternately from the simulated Hurricane Katrina response system. The node removal was conducted in time=10 of computational simulation. The reason for this study to set the removal time as t=10 is that it corresponds to the initial three days of 30 days of activity of the Hurricane Katrina response system. Figure 7-4 shows the recovery pattern of the entire response system after the removal of core nodes from the network. Also, Table 7-5 shows the minimum resource alignment ratio after the core nodes are removed and it shows how long it takes for the entire system to recover completely to the level of the previous resource alignment. Additionally, these projections reveal whether the entire disaster response system can fully recover from the damage of core node removal. For example, for the Hurricane Katrina response system, if the resource alignment ratio can come back to around 26% after several time units of recovery, this analysis assumes that the system has completely recovered from the impact of functional death of a core organization in the system. I removed the core organizations of FEMA, Louisiana Office of Homeland Security and Emergency Preparedness, Louisiana National Guard, and Parish of Jefferson respectively.

In addition to these core organizations identified by social network analysis, I used the conceptual interactions that were defined in the state emergency management plan (LOHSEP

2005). According to this plan, there are several local, state, and federal agencies that connect other organizations to the entire disaster response system as shown in Figure 7-3. I chose these organizations as subjects for core node removal because they had the highest centrality measures and they took the most important brokerage positions in the disaster response system for Hurricane Katrina. Thus, I selected one federal (FEMA), one state (Louisiana Office of Homeland Security and Emergency Preparedness), and one local (Jefferson Parish) organization for the core nodes removal. The Louisiana National Guard was also removed because this military organization acted as an additional resource provider to the disaster response system for Hurricane Katrina.



Source: State of Louisiana Emergency Management Plan (2008)

Figure 7-3 Bridging role of local, state, and federal agencies defined in Louisiana Emergency Management Plan

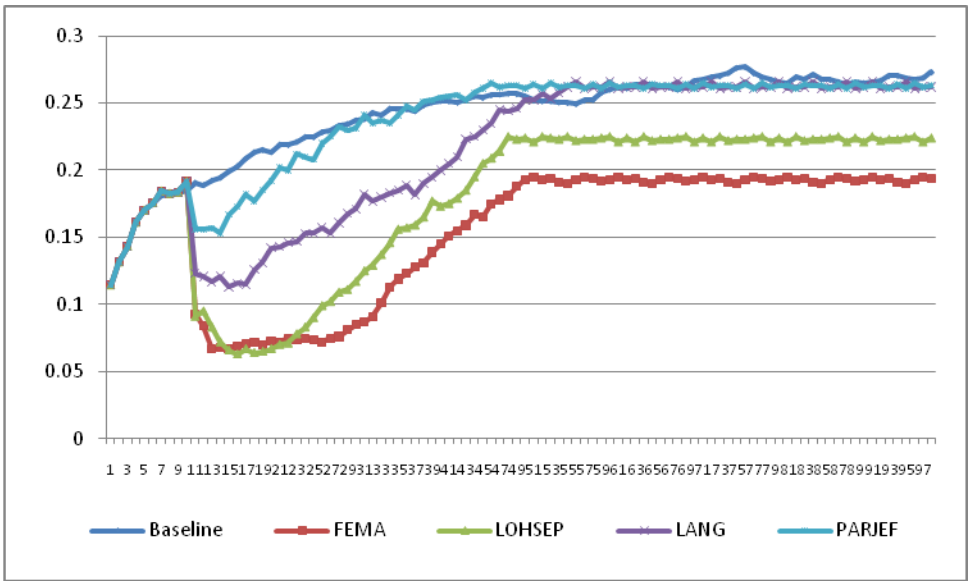


Figure 7-4 Resilient recovery pattern of Hurricane Katrina response system after the core node removal

As shown in figure 7-4, when the Federal Emergency Management Agency was removed from network, the resource alignment ratio dropped almost 10% instantly and continued to drop until reaching 6.7%. After the lowest point of 6.7%, it started its recovery until the final point of 19% around t=73. But the performance of entire system could not recover completely to the previous level of resource alignment ratio 26%. It shows that the system cannot be completely resilient after the removal of FEMA. Similarly, when the state level core organization, the Louisiana Office of Homeland Security and Emergency Preparedness, was removed from the network, the overall resource alignment ration dropped to 6.3% from 19%. This shows that the impact of removal of LOHSEP is of greater significance to the disaster response system. However, this study observed the system can recover more rapidly than in the case of FEMA removal. Within a 34 unit time span, the performance of the entire system recovered to the previous level of 19% and this is faster than the case of FEMA removal.

The significance of the removal of the Louisiana National Guard is less than that of FEMA and LOHSEP. When the Louisiana National Guard was removed, the resource alignment

ratio dropped to 11.3%, and within a 28 unit time span, it came back to the 19% level of resource alignment ratio. Similarly, the impact of the removal of a local parish Emergency Operations Center, in this case the Parish of Jefferson EOC, did not have a significant impact on the overall performance of the disaster management system. Its impact is local and the disaster response system could easily come back to the 19% level and this recovery could be done more rapidly than the removal of state and federal level core organizations.

Table 7-5 Comparison of an effect of core nodes removal

Removed Nodes	Full Organization Name	Minimum RA Ratio	Duration of System Disturbance	Full Recovery
FEMA	Federal Emergency Management Agency	6.70%	57 (from t=10 to t=66)	No
LOHSEP	Louisiana Office of Homeland Security and Emergency Preparedness	6.30%	34 (from t=10 to t=43)	No
LANG	Louisiana National Guard	11.30%	28 (from t=10 to t=37)	Yes
PARJEF	Parish of Jefferson	15.30%	10 (from t=10 to t=19)	Yes

7.2.3 The effect of critical link removals

Using Lambda set analysis, I examined the most critical collaboration links in the response systems of Hurricane Katrina and Hurricane Gustav (refer chapter 6). This Lambda set analysis determined the most critical links that leave the system most fragmented when removed. Using this, this study removed all the collaboration links among FEMA, LOHSEP, the Office of the President of the United States, the Louisiana Office of Governor, the New Orleans Office of Mayor, and the New Orleans Police Department. Figure 7-5 shows the resilient recovery pattern of the Hurricane Katrina response system. The removal of core links also was done after t=10.

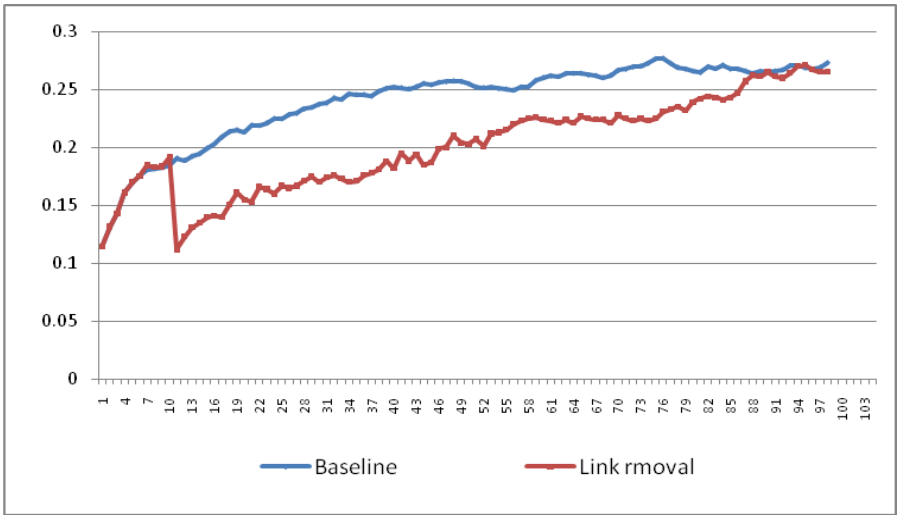


Figure 7-5 Resilient recovery pattern of Hurricane Katrina response system after core links removal

According to Figure 7-5, the entire system recovers from the first sharp drop in the resource alignment ratio. To other organizations in the system, the removal of collaboration links between the previous core coordinating organizations means the longer geodesic distance between core organizations and the other organizations. Thus, after the removal of collaboration links among core organizations, other organizations needed to connect to the core organizations using several different but longer collaboration links within the system. As shown in Figure 7-5, this pattern delayed the recovery speed of the Hurricane Katrina response system. It shows that the entire system can reach to the complete recovery level around 26% of resource alignment ratio, but its phase toward that plateau area is quite delayed from t=73 to t=94. Therefore, the adverse impact of collaboration link removal would make the system less resilient to adversarial impacts from disasters.

7.3 AGENT-BASED COMPUTATIONAL SIMULATION WITH STRATEGIC INTERVENTION

From the exploration and operationalization of critical parameters, I earlier defined the types of intervention as the following strategies: the increase in the level of training and education, the increase in investment for building advanced communication system, and an improvement in the level of available resources. Individually or combined, these factors may reduce the cognitive burden of organizations in the disaster response system.

With mutual trust, the utilization of liaison officers, and the clearer operation procedures, the organizations in the system can find interaction partners more accurately. Additionally, these factors help organizations shorten interaction time because with accurate information and stable collaboration, organizations can easily access partnering organizations. Also, they may find contact points for possible resource allocation more quickly and the rapport established through a joint operation allows them to keep the stable collaboration partnership. Based on the discussion above, this study examines how those strategic interventions can help the response system evolve and collaborate in more effective ways.

7.3.1 Assessment of improved organizational capacities on system's performances

To assess the effects of strategies for improving organizational capacities on the performance of complex systems, this study considers the investments on communication equipment as the first means of strategic intervention. As this study operationalized, organizations with advanced communication equipments can produce the required information more accurately and can transmit them faster to other organizations in the system. This strategic intervention can be

performed only upon the core organizations that were identified through social network analysis, not to all organizations in the disaster response system due to the limited resources to invest for communication system improvement.

This analysis assumes that if any organization has a high level of communication equipment in number and technology, it can process more information at the same time (this study sets 10 as the maximum amount of information an organization can process at one time) and it can produce more accurate information, meaning it reduces the time for any organization to successfully exchange the necessary resources. For the assignment of probability, I assigned p=0.9 to any organization with highly advanced communication system. In other words, with a 90% success probability, an organization with highly advanced communication systems can complete one cycle of resource allocation. If they cannot succeed, they return to the first state of the simulation algorithm until it completes one cycle of resource allocation. This study assumes that, if they return to the processes again, it takes two more unit time spans (t=2) or delays in the completion of resource allocation.

Also, I expected that, with advanced communication equipment, an organization's cognitive capacity necessary for accurate and timely information processes can be increased 5 times (when its communication equipment is moderate) or 10 times (when its communication equipment is high). Similarly, with a high level of communication equipment, each organization can complete one cycle of resource exchange at one time within t=2 with 90% probability. If not, the failure of getting accurate information may delay the resource exchange over t=4, 6, 8, etc. The other parameter, the level of training and education of personnel, works in the same way as the level of communication equipment. The last parameter that affects the changes to the resource alignment ratio is the level of available resources of individual organizations in the

system. If there is a high level of resources available in any organization, this may reduce the number of requests for resource allocation in the system. In this way, I assume that this also has the same effect of increased capacity in the reverse because, with a small number of requests for resource exchange, then there is a lighter workload for core organizations.

The result of the computational simulation with the improved organizational capacity is presented in Figure 7-6. According to these results, with five-time improved capacity for information processing and communication, organizations in the disaster response system can achieve a higher level of resource allocations. Its highest resource alignment ratio is around 36% which is much higher than the level of naturally achieved resource alignment ratio (compared to 26% in figure 7-2). Also, it can reach the highest ratio much faster than the baseline (t=58 compared to t=73) meaning organizations can adapt faster than the previous response systems.

The simulation results show that, with a five-fold increase in advanced organizational capacities for information processes and communications, the performance of the entire disaster response system can be improved by approximately 34.6%. It remains unclear why a ten-fold improvement in organizational capacity of core organizations has a similar effect with that of five-fold improvement. In figure 7-6, the result shows that, when organizational capacities were increased ten times, the increase of resource alignment ratio takes the almost the same pattern with five times improvements. This implies that there can be other factors than improvement in organizational capacities and those factors may lead to the effective improvement in resource allocation among organizations in the system. In this context, I examined the effect of strengthening collaboration links on the improved performance of the system.

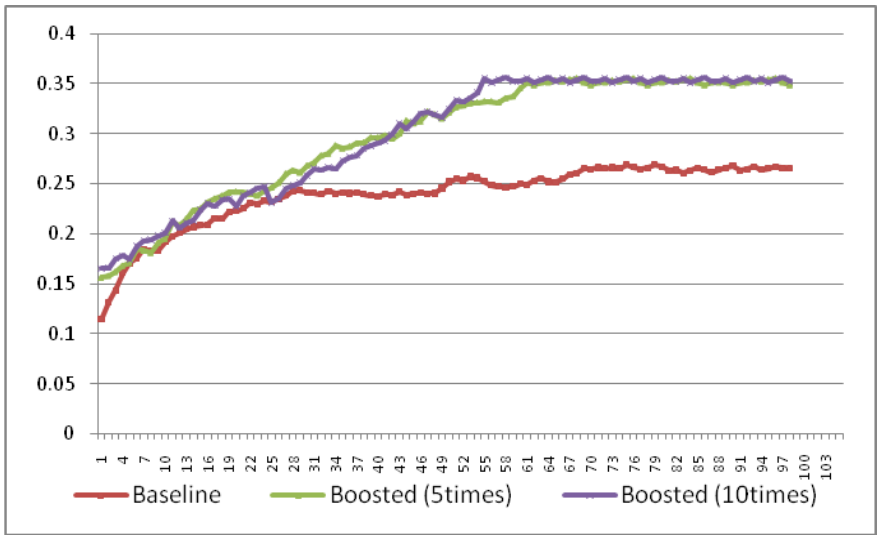


Figure 7-6 Evolution pattern of a disaster response system with increased cognitive capacity

7.3.2 Effects of strengthened collaboration links between core organizations

The three major factors included in the simulation model are: the utilization of liaison officers, the maintenance of regular working relationships, and clearer operation procedures. With an application of these factors, I anticipate that these parameters will enable the system to achieve more effective and timely resource allocation. Similarly to the previous analysis, with high levels of regular working relationships, each organization can complete one cycle of resource exchange at one time within t=2 with 90% probability. If not, the failure of getting accurate information may delay the resource exchange over t=4, 6, 8, etc. In the simulation model, it takes one transaction time unit (t=1) for organizations (with high level of regular working relationships with core organizations) to find its interaction partners. If their working relationship is moderate, then it takes t=4 for them to find appropriate interaction partners, and if they have a low level of working relationship with partners and, accordingly they do not know how and with whom to

interact, it takes t=8 for these organizations to find the appropriate interaction partners to get necessary resources.

Figure 7-7 shows the simulated evolution patterns of the performance of a system with an adjusted strength of collaboration links. If any two organizations keep strong collaboration links, it takes just one simulation time unit (t=1) for the completion of resource exchange and this transaction succeeds with a 90% probability. Again, this study intervened in the system in time 10. The system's evolution identified in Figure 7-7 shows that the strengthening strategy for collaboration links works well in improving the performance of the disaster response system. With this strategy, the resource alignment ratio, which means how accurately any organization can detect, contact, and acquire the necessary resources from other organizations for its mission completion, almost doubled.

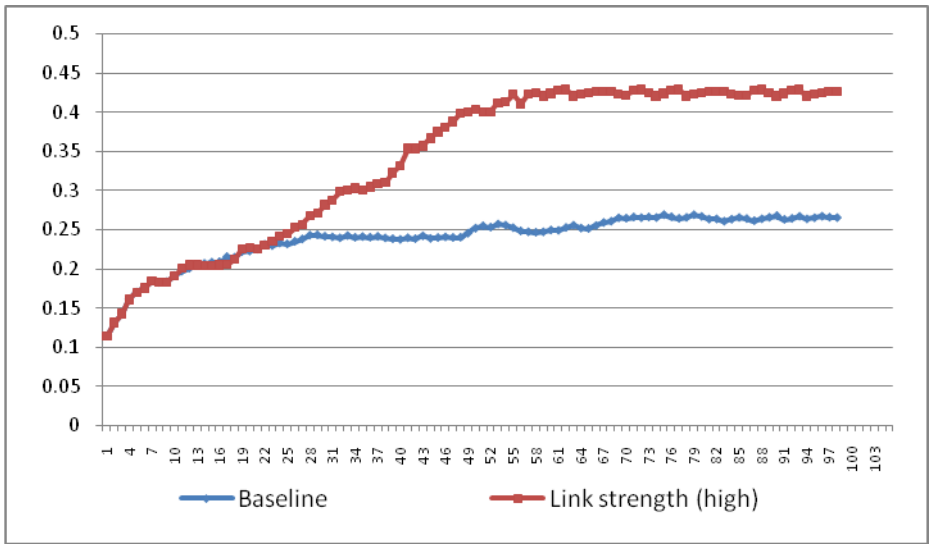


Figure 7-7 Evolution pattern of Hurricane Katrina response system with strengthened links

7.3.3 Effect of structural change on resource exchange

In addition to the improved organizational capacities and strengthened collaboration links, this study explores the possibility of performance improvement through the re-engineering of the interaction structure. Up until the previous section, this study's interest was mainly in the improvement of organizational capacity and collaboration partnerships, not in the intervention to the interaction structure itself. Due to limits set by national and state level disaster management plans, there is little room for this study to reengineer interaction structures. So, rather than allow total renovations in interaction structures, I explored one possible structural change that does not require major revisions to major disaster management plans.

Figure 7-4 presented the simulated fluctuation of the resource alignment ratio in response to the removal of core organizations in the system. From that point, I considered how organizations can cope with the unexpected functional death of state coordination organizations such as LOHSEP. According to Figure 7-4, the performance of the disaster response system dropped severely after the removal of LOHSEP and took multiple time spans to recover from the damage from this sudden removal of a core organization.

The concept of structural intervention derived from the analysis of semi-structured interviews. During the semi-structured interviews, managers from parish emergency operation centers, such as the manager of Assumption Parish EOC, mentioned the role of the regional coordinator whose job was to facilitate discussion among parishes in the same regional area on the various regional issues. This regional discussion group does not represent governance in the sense that it has neither the legal authority to coordinate disaster response activities nor resources to mobilize in case of crisis. However, if state level coordinating organizations such as LOHSEP become functionally dead, then the Governor of State of Louisiana can activate these regional

organizations as active coordinating agencies for the replacement of core state coordinating agencies, instead of waiting until the core agencies come back to normal operation.

> **…** Exactly, to coordinate, mutual aid within the community as well as communicate with the state on regional issues. The regional directors, for instance, we had a meeting yesterday with the 9 regional directors of the state so we're the [go-]**between the state and the locals for information**. In [an] emergency, everybody communicates with the state but in our planning activities, exercises, **we're the ones that help coordinate that instead of the state trying to talk to 64 parishes**. **The 9 regional coordinators collect the information and we go out and communicate that to the other parishes in our region.** (Assumption Parish)

Based on this virtual scenario, I created three regional coordinating agencies that can be activated just after the removal of a state coordinating agency from the disaster response system. Figure 7-8 compares the resource alignment ratio between the case of functional removal of LOHSEP and the case of replacement by regional coordinating organizations. According to the *what-if* analysis presented in figure 7-8, the gap originated from the functional death of core agency may quickly be filled by the activation of several regional agencies.

The activations of three regional agencies that coordinate the responding activities of the southern parishes in the State of Louisiana was done in t=12 after the functional death of Louisiana Office of Homeland Security and Emergency Preparedness (LOHSEP) in time 10 (t=10). As this study determined in Figure 7-8, the entire disaster response system recovers faster from the absence of LOHSEP since time 10. After t=40, the disaster response system started to perform even better than the performance under the natural evolution over time. For the explanation of this improved performance, this study assumes that a reduced workload on the Louisiana Office of Homeland Security and Emergency Preparedness (LOHSEP) due to the dispersed number of requests for resource exchange allows the system to perform better. But the possible failure in coordinating overall activities in response to disasters needs to be considered.

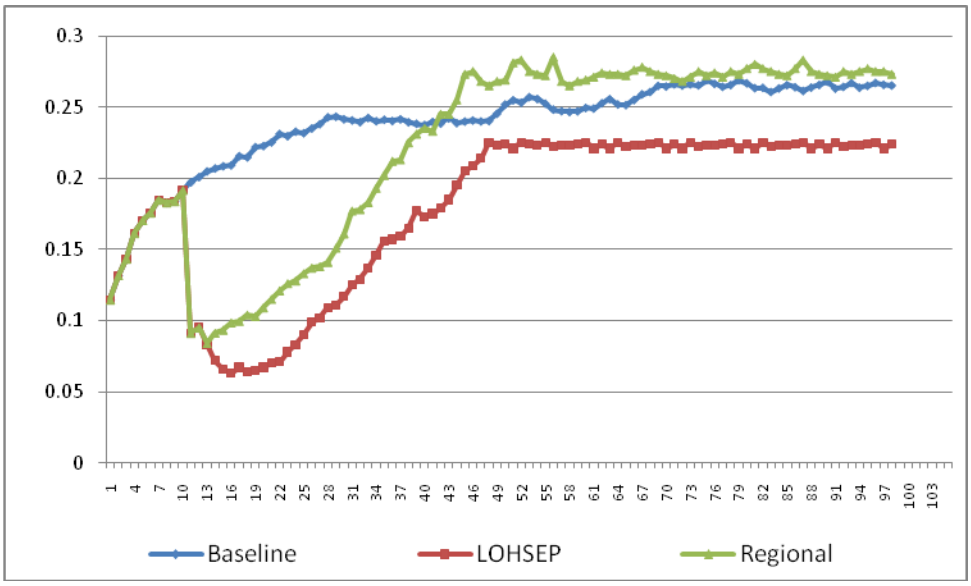


Figure 7-8 Resilient recovery from the core organization removal, activation of three regional agencies

8.0 SUMMARY AND POLICY IMPLICATIONS FOR DESIGNING COMPLEX ADAPTIVE SYSTEMS

Providing a safe and secure environment to citizens has been a fundamental, critical and compelling responsibility of government for a long time. Since the 9/11 terrorist attack, the United States government has committed significant resources, attention, and time to establish the Department of Homeland Security (DHS) to improve national security. However, DHS's ineffectiveness in responding to the 2005 hurricanes on the Gulf Coast raised critical questions of whether the United States government actually learned from previous crises. Again, since Hurricane Katrina, the United States government engaged in further efforts to design an advanced national system for effective disaster response and mitigation. But, it is also proved that, without organizational learning, those additional efforts do not necessarily secure system's adaptation to rapidly changing conditions.

To address the issue of successful organizational adaptation through learning processes, this study conducted a comparative analysis of the Hurricane Katrina and Hurricane Gustav response systems and determined whether there is any evidence of organizational learning between the two storms, how those lessons were institutionalized for the revised response to Hurricane Gustav, and how organizations could effectively manage information and resources in a strategic and innovative ways. Using identified evidence of organizational learning and their effects on improved performance, I discuss some possible strategies or policies for facilitating

organizational adaptation and the creative exploitation of explored knowledge from the previous events (March 1991).

8.1 IDENTIFIED MAJOR CHALLENGES TO BE ADDRESSED FOR EFFECTIVE ORGANIZATIONAL ADAPTATION

The major problems identified from semi-structured interviews and the content analysis of situation reports mirrored the findings in previous research and official reports (FEMA, 2006; White House, 2006; House of Representatives, 2006). From the content analysis of the semi-structured interviews and situation reports, this study sorted the main problems into four parts: 1) lack of a collaborative mindset and attitude such as rivalries and territorialism between organizations, 2) communication system breakdown, 3) lack of experienced personnel, available resources, and 4) lack of proper collaboration plans, procedures. These problems became more explicit when organizations were isolated during the initial stage of response and mitigation and combined together, these factors caused a severe problem in collaboration and coordination during system's response to large scale disasters.

8.1.1 Lack of collaborative practices and culture

Due to the lack of collaboration experience, organizations in the Hurricane Katrina response system did not make their operations clear and open to other organizations. This lack of transparency in operation could not allow organizations to develop system-wide collaboration protocols for the response to Hurricane Katrina. Also, the lack of collaborative experience

worsened the situation and prevented organizations from collaborating when it was critical for the system's response to the disaster. Rather than collaborating, some major actors, organizations, or managers of those organizations, relied on the traditional command and control system and sometimes went far beyond the limits of legal authority for intervention. As a result, some political leaders stepped into the relationships between organizations which distorted and caused confusion in resource exchange. Combined with bureaucratic incompetency and irrelevant interaction structures that hampered collaboration among agencies, the collaboration links among agencies were weakened to the level of isolation. During the most critical period of the response, organizations in the system could not exchange necessary information and resources with other organizations. Worsening the situation were rivalries, turf-battles, or territorialism among organizations competing with each other to increase their own organizations' power in the field of disaster management. With this territorialism, effective coordination among organizations could not be achieved in response to Hurricane Katrina.

8.1.2 Communication system breakdown

Over 90 percent of interviewed managers in semi-structured interviews mentioned that the major problem they faced was the failure in maintaining a reliable communication system. With collapses of the communication system at multiple levels, organizations were deprived of their critical tool for collaboration. For the peripheral organizations, they could not transmit on-site information to coordinating organizations in a timely manner and, at the same time, they could not receive necessary resources urgently needed to operate effectively as the first responders. For the core coordinators such as LOHSEP and FEMA, they could not develop the common operating picture required for coordinated responses to disasters.

The main reasons for communication breakdown ranged from the lack of equipment or advanced technology, and unclear written and practiced procedures. These factors prevented each organization from processing and producing actionable knowledge for other organizations in the system. Without advanced technology, the communications system for Hurricane Katrina was not stable and redundant. Rather, it was vulnerable to outside impacts from disastrous conditions.

8.1.3 Lack of experienced personnel and available resources for responding organizations

In addition to the failures of the communication system, the disaster response system for Hurricane Katrina had an inadequate level of personnel and resources. Due to the frequent turnover in major positions after the 9/11 terrorist attacks (Bergel et al. 2007), the level of expertise and the morale of employees in the disaster management field had been severely downgraded and vacant core positions were not instantly filled by experienced personnel at the time of Hurricane Katrina. Thus, many organizations in the Hurricane Katrina response system were exposed to threat and they struggled with limited personnel in number and experience. Accordingly, the burden for each individual organization increased to an unmanageable level. This made all the information processes and disaster response operations slow down significantly.

Further, the organizational responses to Hurricane Katrina worsened by a lack of available resources for their operations. In particular, the delays and failures to respond to resource allocation requests were verified as one of the most severe problems. According to the Stafford Act (Pub.L. 106-390, 2000) and National Response Plan (2004), the responsibility for the initial response lay at the local agencies. If additional resources are needed, the federal and other state agencies were to be contacted for the provision of requested resources. Because there

were not enough resources available within the initial boundaries of the system, organizations had to rely upon resources from outside. However, findings from the semi-structured interviews reveal that resource exchange within local and state boundaries, with outside organizations at the federal level, and with other state agencies significantly failed. Also, organizations could not estimate the level of need for resources in the initial stage of disaster response mainly due to the lack of experience in coping with such a large disaster. Furthermore, organizations in the system did not invest enough resources to build an advanced resource management system and failed to integrate it into the system's overall disaster response system. As a result, pre-positioning of available resources, a critical element of disaster management, was not possible for the Hurricane Katrina response system.

8.1.4 Lack of disaster management plans/procedures

The agencies in the disaster response system for Hurricane Katrina also suffered from the absence of clear disaster management plans and operating procedures. In many cases, the organizations could not identify and follow clearly defined plans and procedures in response to Hurricane Katrina. This was particularly true regarding resource allocation, and even the contact points at the local, state and federal levels were not clearly defined in the response plans. The semi-structured interviews revealed that this problem was caused by the absence of plans for actions and the lack of training of existing plans. Considering that the National Response Plan (NRP) was introduced to the system only in December of 2004, organizations were still not familiar with its details in time for Hurricane Katrina. But some managers answered that the disaster management plans were not clear and flexible enough to be used as a basis for the organizations' operations for disaster response and mitigation.

When the normal disaster management plan did not work and new working procedures for collaboration are required, the managers in major disaster management organizations needed to demonstrate a competency in sense-making and adaptation. But, the rigidity in applying disaster management plans and procedures inhibited them from exerting that kind of leadership for the response to Hurricane Katrina. Also, the lack of alignment of plans worsened the situation. Each plan's timeline, main partners, working procedures were not compatible with others, and as a result, there were unnecessary competitions among organizations for the procurement of limited resources instead of effectively coordinated responses to disasters.

8.2 EVIDENCE OF ORGANIZATIONAL LEARNING AND STRATEGIC UTILIZATION OF LEARNING FOR EFFECTIVE ADAPTATION

From the content analysis of semi-structured interviews and situation reports, this study could identify significant positive evidence of organizational learning and strategic efforts to develop more stable and resilient disaster response systems. They committed significant resources to secure a stable and interoperable communication system, reinforced collaboration partnerships, and updated disaster management plans through the constant fine-tuning of processes. The most desirable aspect of these efforts is that most changes were made in a joint manner, which clearly facilitated the coordinated operations in the preparation and response to Hurricane Gustav..

8.2.1 Improvement in human resource management

The improved performance of the Hurricane Gustav response system is partially attributed to the well-trained personnel of organizations. Most organizations improved their level of training significantly, and accordingly, the level of expertise of their personnel also improved. Personnel in each organization had full knowledge of disaster management plans and, more importantly, they could build rapport with personnel in other major organizations. Compared to the lack of organizational learning from the Hurricane Pam exercise just before the landfall of Hurricane Katrina, this level of organizational learning from regular exercises contributed substantially to improved operations during Hurricane Gustav.

Since Hurricane Katrina, most organizations introduced regular and periodic exercises for evacuation and sheltering of refugees, and those exercises were conducted jointly with major partnering organizations. This increased number of exercises with partners developed adaptive leadership and improved the expertise level of personnel. Also, to fill the positions that were vacant after Hurricane Katrina, organizations increased their number of personnel. Combined with the increased welfare of personnel and their family members, this contributed to the improved performance of Hurricane Gustav management system.

8.2.2 More available resources and advanced communication systems

One of the most critical problems for the Hurricane Katrina response system was the lack of available resources and the delay of promised resources from partnered organizations. In response, the disaster management system for Hurricane Gustav tried to secure more resources before landfall. Many interviewees pointed out that the level of resources available for the

response to Hurricane Gustav was much higher than that of Hurricane Katrina, partially due to the pre-positioning of resources. In addition to that, the disaster management system for Hurricane Gustav took great steps to increase resources available for its operation. First, organizations chose to strengthen partnerships with collaborating agencies within the system; this partnering strategy began with the refinement of estimated needs of resources in response to large-scale disasters.

To address the problem of getting accurate situation awareness, the State of Louisiana had purchased Web-EOC and recommended local and state governments to use it for their coordinated operations. With this Web-EOC, organizations could track critical information and successfully form a common operation picture through intelligence, surveillance, reconnaissance, and information management tools. Also, to address the failure of communication systems breakdown, organizations in the Hurricane Gustav response system reinforced its communication equipment after Hurricane Katrina. First, the response system for Hurricane Gustav invested sizable amounts of money to purchase and upgrade its communication infrastructure. As a result, the organizations in the system obtained more advanced communications equipments, and they could achieve the interoperability of communication equipments. Second, by making contact points clearer and easily reachable, organizations could collaborate with less confusion in communications. Finally, the communication channels were reinforced by deploying more of their own liaisons in partners' emergency operations centers (EOC). This shows that, even with advanced information technology, face-to-face interaction is still important in collaboration and coordination. With this direct contact with partners, organizations collaborated more effectively in exchanging knowledge and resources during the response to Hurricane Gustav.

8.2.3 Strengthening collaboration partnership with local and non-public agencies

The organizations, especially the parish governments that were the direct target of Hurricane Katrina, could not have expected the instant delivery of resources from state and federal agencies. Based on this failure, since Hurricane Katrina, they tried to be self-sufficient or independent from other agencies for the first several days after hurricane landfall. The first change that they made is that they set up new protocols for resource exchange with regional parishes. If there were available resources in one parish, that parish shared its resources with other parishes in the same region. Like this, parishes in southern Louisiana formed several regional collaboration systems and they also signed memoranda of understanding (MOU) for the rapid resource sharing purposes.

At the same time, organizations could get more resources through new private vendor management activities. They contracted with private supply companies to secure reliable supplies to parish governments. This increased the stability of supplies to local agencies and also provided redundancy in securing necessary resources to the level that their dependency on other state or federal agencies for resources decreased significantly in the initial state of disaster response. As a result, combined with pre-positioning of state and federal resources, the total level of available resources for local agencies in the Hurricane Gustav response system was increased, compared to the levels available during Hurricane Katrina.

The findings from content analysis, social network analysis, and semi-structured interview were used to develop a computational simulation model. The critical factors identified from semi-structured interviews were operationalized and assigned probabilities of successful information processing and the completion of resource allocation. To check the effect of individual policy alternatives developed from identified core parameters, the computational

simulation began by testing robustness or resilience of the un-interfered response system for Hurricane Katrina. The system robustness and resilience were tested with both simulated node and link removal. Under both of these scenarios, the analysis checked how quickly and how effectively the entire system restored from the adverse impact of crisis.

In the next step of simulation, the study applied each of the developed intervention strategies and checked how those policy alternatives can contribute to the effective resource allocation and eventually help organizations be more adaptive to unexpected external changes. The critical parameters identified and transformed into policy alternatives included: advanced communication equipment, new operational procedures, and utilization of liaison officers, trust from a constant working relationship, increased level of resources, and improved training and education of personnel. In the next section, this study presents the findings in reference to the three research questions of this study.

8.3 IDENTIFICATION OF CORE FACTORS AND ASSESSMENT OF EFFECTS ON SYSTEM'S PERFORMANCE

Through the content analysis of newspaper articles and situation reports, I identified the challenges that the Hurricane Katrina response system actually faced during its response to rapidly changing conditions. Also, using social network analysis, I identified the structural features of two hurricane response systems and found evidence of organizational learning in renovating interaction structure. According to these measures and network maps from social network analysis, the interaction structure of Hurricane Gustav response system took the form of cellular network which was more organized than that of Hurricane Katrina. This means that the

response operations defined by disaster response plans were more effective for the Hurricane Gustav compared to those for Hurricane Katrina.

8.3.1 Examination of structural features of two hurricane response systems

According to the examinations of interaction structure, during the communication system breakdown and unexpected collapse of collaboration channels, organizations in the Hurricane Katrina response system could not fully rely on disaster management plans and had to create unexpected collaboration links with any organization that could provide resources and information urgently required in adapting to complex circumstances. Thus, the density was high and the clustering coefficient and centrality was low for the Hurricane Katrina response system. By comparison, organizations in the Hurricane Gustav response system collaborated as defined in the plans and the interaction pattern shows low density and high centrality and clustering coefficients. I further conducted a clique analysis to explore how an entire disaster response system evolved from small components or groups of organizations. I identified that the subgroups of the Hurricane Gustav response system are mainly composed of state and local agencies leading to close collaboration among local and state organizations. This analysis also presented the larger subgroup where core organizations were more connected than those of the Hurricane Katrina response system.

To determine which organizations are most structurally important in networks and which play key network roles, I used centrality measures in social network analysis. In calculating centrality, I focused on the coreness from an embedded position and the coreness from a number of links. The one difference between Hurricane Katrina and Hurricane Gustav response systems, and accordingly an evidence of organizational learning, is that the identified core organizations

in the Hurricane Gustav response system were relatively consistent across the measures of centrality. But, the organizations identified as core agencies in the Hurricane Katrina response system were not consistent across measures. The fact that some organizations identified as core nodes in one measure did not take the central role in other measures reveals disorganized features of the Hurricane Katrina response system.

Finally, to determine what parts of the disaster response system were comparatively vulnerable to impacts from the outside, I conducted fragmentation and Lambda set analysis. According to the results, when collaboration links are disconnected among main coordinating organizations, both disaster response systems for Hurricane Katrina and Hurricane Gustav may collapse into pieces which prevent an effective collaboration between organizations in the system. The findings from the social network analysis reveal where strategic interventions could be made in the response system and how to guide organizations to adapt more creatively to complex conditions.

8.3.2 Assessing intervention strategies on performance of organizations in adaptation to changing conditions

Through semi-structured interviews, I identified five core factors to be considered in designing a complex adaptive system. These identified factors were operationalized to be developed as intervention strategies in a computational simulation. From this operationalization of core factors, I developed a simulation space, and assigned probability to identified core parameters. Also, to compare network performance and evolution patterns with and without intervention strategies, I devised a performance measurement tool, the resource alignment ratio, that measures how effectively available resources can be allocated in a timely manner.

To facilitate the resource allocation and guide the more resilient evolution of a disaster response system, I proposed two types of strategic intervention to test through computational simulation: intervention to improve organizational capacity, and intervention to reinforce collaboration structure. Through computational simulation, I analyzed how each policy alternative can be developed from core parameters and how those strategies would contribute to performance improvement and effective systemic adaptation. With more training and education, higher level of available resources, and an application of advanced communication equipment and technology, organizations in the system could process more information with improved accuracy. The simulation results show that, with intervention strategies, organizations could adapt to changing conditions more effectively.

At the same time, I examined the effect of parameters that may strengthen the collaboration links among organizations. The parameters such as the establishment of trust through regular working relationship, the utilization of liaison officers, and clearer operation procedures, contributed to efficient and timely interactions. According to computational simulation results, these factors allow organizations to find interaction partners faster and secure timely information and resources sharing.

Finally, in addition to these strategic interventions, I examined the effect of the possible recovery in interaction structure of disaster response system. From the computational simulation, I found that, when core coordinating organizations were removed from the entire system or when they were overwhelmed by enormous number of requests for resource allocation, the performance of disaster response system deteriorated severely and could not recover completely from the impact of the functional death of core organizations. To overcome this problem, I created virtual regional coordinating agencies and examined whether these newly created

coordinating agencies could provide a functional redundancy to the system and whether they could make system recover from the adverse effects sooner. The results were affirmative and the findings suggest considering the creation of regional coordinating agencies that can backup core coordinating organizations quickly after their functional death.

8.4 POLICY IMPLICATIONS IN DESIGNING ADAPTIVE SYSTEM FROM THE RESULTS OF THIS STUDY

The analyses of semi-structured interviews, social network analysis, and computational simulation verify that there is ample evidence of organizational learning and strategic uses of that learning in designing new systems for disaster response and mitigation. To address challenges from low levels of preparedness, organizations pre-activated the response system and pre-positioned necessary resources for better preparation to Hurricane Gustav. To overcome the problem of insufficient experienced personnel after the 9/11 terrorist attacks, organizations increased frequencies of training, introduced advanced education programs, and more importantly, made them a requirement for position deployment and promotion. As a response to communication systems breakdown, organizations in the Hurricane Gustav response system invested resources on purchasing advanced communication equipment and communication systems for an effective log of transactions between organizations, and made them interoperable with agencies in the private and nonprofit sectors both inside Louisiana and beyond. Finally, to address the severe failures in coordination compounded by a lack of working plans, the organizations in the Hurricane Gustav response system worked together to develop a new disaster management plan and operational procedures. These findings from various analyses

highlight the evidence of strategic application of organizational learning in building effective disaster response systems.

One of the important implications is that organizations, for their effective adaptation, need to develop various tools for facilitating organizational learning when making changes. As discussed, organizations in the Hurricane Gustav response system invested significant resources and efforts to restore damaged communication systems and build new effective systems for the creation, transformation, and transmission of critical information. With investments on communication systems, they need to be equipped with an extensive knowledge management system that maintains a permanent comprehensive record of the event or incident, and that can be used as a means to facilitate organizational learning. For example, with Web-EOC, organizations, besides obtaining real time incident related information, have capacities to access specific incident related data at any time during or after the incident. The advantage of obtaining and keeping chronological records of operation in information and resource sharing for organizations is that they can draw, interpret, create reports, and learn from that configurable information management tool.

Under the leadership of FEMA, all local, sub-regional, and state organizations jointly developed new operation plans, and more importantly, they exercised those developed disaster management plans together. According to semi-structured interviews, the impact of joint operation in planning, exercising, and drilling was significant, especially from the perspective of strategic learning. Through several sets of joint simulated operations in regular exercises, organizations in the Hurricane Gustav response system built rapport that was critical in real collaborations. As proved in the Hurricane Gustav response system, an established trust among core personnel contributed to the improvement of successful coordination and collaboration.

Also, it helped organizations shorten the interactions time due to the pre-exercised collaborative relationships. Therefore, in building an adaptive system for disaster response and mitigation, organizations need to maintain collaborative partnerships.

But, to make effective use of established mutual trust, adaptive systems need to address the problem of turnover in major positions of organizations. The failure of the Hurricane Katrina response system exemplified how well established trust can disappear with the turnover or retirement of key personnel. So, while organizations in the system work on the institutionalization of regular joint operations for the development of mutual trust among agencies, they also need to develop policies to retain experienced core personnel for effective collaborative operations with partners. As the semi-structured interviews suggest, organizations need to develop a special program for education and improve the level of welfare for their personnel in case of major crises.

Third, an application of advanced technology for the effective communication, knowledge management, and diffusion of organizational learning is central to developing capacity for system adaptation. Combined with the cultivation of experienced personnel, an application of advanced technology is an example of the construction of socio-technical system that cyberneticists (such as Snook 2002) pursue in designing resilient systems. To build a socio-technical system for organizational adaptation, organizations need to focus on the role of advanced communication equipment and data management tools that facilitate the processing, transmitting, storing, and extracting of critical information both for enhanced performance and organizational learning. Also, they need to focus on the training and education softwares to facilitate strategic learning and develop more experienced and collaborative personnel.

Finally, organizations need to maintain joint operations at every step of organizational adaptation to changing conditions. It requires organizations to invest more resources into co-planning, co-exercising, and co-operating activities from the initial stage of operations. From a strategic learning perspective, the best advantage from these co-operative activities is the accumulated memory of collaboration. Based on accumulated experiences and memories of collaboration, organizations in the adaptive system can achieve a creative mental model for a new practice of action (Mausolff 2004). With that model, they can complement imperfect plans and effectively fill gaps from mismanagement or weaknesses of individual organizations.

Through these analyses, I have developed and recommended a set of policy implications regarding how to design a complex adaptive system in which organizations assess the situation and creatively adapt to changing conditions. The application of those recommendations in the development of policy alternatives can be difficult due to the complex features of the environment and the high degree of interdependency among them. Yet, once organizations effectively implement those alternatives, they will create common operational bases of knowledge that allow them to adapt to changing conditions more effectively. With common operational knowledge base, organizations will access a single display of relevant operational information and share it with all organizations participating in the adaptive system. Especially, the establishment of common operational knowledge is significant for the core organizations due to their positions as coordinators of action among other organizations in the system. When core organizations are well informed by the terminal/peripheral organizations in the adaptive system, they can make decisions with improved accuracy in a timely manner, thereby enabling the system adapt to changing conditions more effectively.

8.5 LIMITATIONS OF THE RESEARCH AND RECOMMENDATIONS FOR FUTURE STUDY

To address the complex issue of designing adaptive systems to changing conditions, I conducted a comparative analysis of two hurricane response systems with a mixed methods approach of content analysis, social network analysis, semi-structured interviews, and agent-based computational simulation. But there are limitations in this research that limit the generalization of the findings from this study.

First, the case used for the comparative analysis was just two hurricanes, Hurricane Katrina and Hurricane Gustav. Also, the region that was affected by these two hurricanes was restricted to the State of Louisiana. To overcome this weakness in a small-N case study, and to generalize the findings from this study, the next research on designing adaptive systems needs to extend research boundaries to other states in the United States or other international disaster response cases. Horizontally, the next study will cover cases in which organizations in the interdependent response system fail to learn and adapt to complex conditions and compare those cases to identify the core factors for effective adaptation and the generalization of findings. For example, the next study could include hurricane cases in other states of the United States such as Florida, Mississippi, Alabama, and Texas. Vertically, the next study will consider the evolution patterns of previous complex adaptive systems by including the former major crises, such as Hurricane Andrew in 1992 and check how the entire system is evolving from the long-term perspective.

The second challenge and limitation of this study is securing a more detailed real-time interaction log from the Federal Emergency Management Agency and the Governor's Office of Homeland Security and Emergency Preparedness. Even though, I sought detailed interaction

patterns using various types of documentary data and semi-structured interviews, the information on actual resource exchange was scattered and sometimes unknown. From the lessons gained since Hurricane Katrina, organizations in the system used Web-EOC in their response to Hurricane Gustav, and they created and managed a detailed real-time interaction log for future reference purposes. If those records for actual interactions can be obtained, a future study for designing adaptive systems could be based on more accurate and well organized data for social network analysis and computational simulation.

APPENDIX A

LETTERS TO STUDY PARTICIPANTS

Dear _____

Thank you for granting your time for this interview.

I am a doctoral candidate at the University of Pittsburgh's Graduate School of Public and International Affairs working on research for my dissertation, "Designing Adaptive System for Disaster Response and Mitigation." My research examines the disaster management systems that evolved following Hurricane Katrina and Hurricane Gustav. As part of my research, I am conducting interviews that focus on patterns of collaboration and communication among organizations in the two disaster management systems. Through this analysis, I seek to identify and compare critical factors that support organizational learning in disaster risk assessment and response for the future development of effective disaster management systems.

I am contacting you because of your organization's involvement in responding to Hurricane Katrina and Hurricane Gustav. This interview includes questions assessing your organization's strengths and weaknesses in its collaboration with other agencies in the emergency response system in terms of sharing resources and information. This will take approximately thirty minutes. Please answer all questions according to your candid observations, judgment, and practice. Findings from these interviews will be used for scientific purposes only. All

information you provide to this research will be kept under professional standards of confidentiality.

If you have any concerns or questions related with this interview, please contact me any time at nao2@pitt.edu. Thank you so much again for your time and thoughtful contribution for this interview.

Sincerely,

Namkyung Oh

APPENDIX B

SEMI-STRUCTURED INTERVIEW QUESTIONNAIRE

Section 1: Assessment of Organizational Preparedness and Capacity

1. What is your organization's mandated responsibility for responding to disasters?

2. Comparison of Overall Performance:

    1) How would you evaluate your organization's overall level of disaster preparedness before the landfall of Hurricane Katrina?

    Very Poor Poor Moderate Good Very Good

    2) How would you evaluate your organization's overall level of preparedness before the landfall of Hurricane Gustav?

    Very Poor Poor Moderate Good Very Good

    3) If there is any difference between two hurricanes in preparedness, what factors do you think caused this difference? _____

3. What information sources alerted and prepared you in advance of the hurricanes?

    1) List three in order of importance (Katrina): 1_____; 2_____; 3_____

    2) List three in order of importance (Gustav): 1_____; 2_____; 3_____

4. Will you evaluate your organization's capacity (including equipment) in:

Hurricane K	Very Poor	Poor	Moderate	Good	Very Good
Communications Equipment	1	2	3	4	5
Managerial Entrepreneurship	1	2	3	4	5
Number of personnel specialized in disaster management	1	2	3	4	5

Training level of Personnel	1	2	3	4	5

Hurricane Gustav	Very Poor	Poor	Moderate	Good	Very Good
Communications Equipment	1	2	3	4	5
Managerial Entrepreneurship	1	2	3	4	5
Number of personnel specialized in disaster management	1	2	3	4	5
Training level of Personnel	1	2	3	4	5

Section 2: Collaborative Partnership in Communication and Resource Delivery

1. How would you evaluate your organization's overall level of joint operation or collaboration during the response phase of;

    1) Hurricane Katrina?

Very Poor	Poor	Moderate	Good	Very Good
1	2	3	4	5

    2) Hurricane Gustav?

Very Poor	Poor	Moderate	Good	Very Good
1	2	3	4	5

2. Who were your major partners (organizations) in disaster operations? Please identify them:

    1) For Hurricane Katrina?
    1._____; 2. _____; 3. _____; 4. Others: _____

    2) For Hurricane Gustav?
    1._____; 2. _____; 3. _____; 4. Others: _____

    3) Had you worked with these agencies on previous disasters? If so, how many times?

3. What kinds of information/resources did your organization provide to (or receive from) these organizations in disaster operations? Please identify.

    1) For Hurricane Katrina?
    1._____; 2. _____; 3. _____; 4. Others: _____

    2) For Hurricane Gustav?
    1._____; 2. _____; 3. _____; 4. Others: _____

4. What were the major problems in interacting with other agencies in carrying out your responsibilities?

    1) Please list the three most important for Hurricane Katrina:

1._____ 2._____3._____4. Other_____

2) Please list the three most important for Hurricane Gustav:
1._____ 2._____3._____4. Other_____

5. What actions did your organization take to address these problems during the response phase? Please illustrate with actual examples.

   1) For Hurricane Katrina?

   2) For Hurricane Gustav?

Section 3: Improving Effectiveness of Future Disaster Management System

1. What changes, if any, have been made to improve performance after Hurricane Katrina? Please list in order of importance:
   1._____2._____3._____4. Other_____

2. Do you think these changes contributed to preparedness for response to Hurricane Gustav? If so, in what ways were those changes affected?

   _____

3. What do you think are the most important factors in improving effectiveness of collaboration among agencies in the system? Please name the three most important, in your judgment.
   1._____ 2._____3._____ 4. Other_____

4. What do you think are the most important factors that inhibited collaboration among agencies in response operations? Please name the three most important factors, in your judgment.
   1._____ 2._____3._____ 4. Other_____

5. What factors should be considered to make your organization more stable and resilient in its operation for the future disasters? Please name the three most important, in your judgment
   1._____2._____3._____4. Other_____

Section 4: Demographic Information

1. Name of Interviewee: _____
2. Name of Organization: _____
3. Position of Interviewee: _____
4. Years of Service in the Position: _____
5. Level of training in disaster management: _____
6. Total Working Years in Disaster Management Field: _____
7. Total Number of Disaster Incidents Participated:_____
8. Phone: _____ E-mail:_____

APPENDIX C

ORGANIZATION LIST WITH ACRONYMS

236th Louisiana Air National Guard Combat Communications Squadron	236th ccs	Baton Rouge Visitors and Convention Bureau	brvcb
911 Emergency Call Centers	911	Bechtel National, Inc.	becht
Air Force Academy	afa	BellSouth	bell
Air National Guard: 159th Fighter Wing	159th FW	Best Western Hotels	bwest
Air National Guard: 1st Air Force	1AF	Boasso America Corp.	boas
Alaron Trading Corp.	atc	Boh Bros. Construction Co.	bhobro
Algiers Economic Development Foundation	aedf	Bonnabel High School	bhs
Allstate Insurance	ai	Boomtown Casino	boom
Alvarez & Marsal	a&m	BP, PLC	bp
American Airlines	aa	Broadmoor Construction Inc.	bci
American Broadcasting Corporation	abc	Brookings Institution	brook
American Red Cross	arc	Bureau of Alcohol, Tobacco, Firearms and Explosives	atf
American Red Cross Southwest Service Area Office	arcssao	Carnival Corporation	carn
America's New Orleans Fund, Inc.	anofi	Catch 22 Foundation	cat22
Anadarko Petroleum Corp.	apc	Catholic Charities of the Archdiocese of New Orleans	ccano
Apache Corp.	ac	Catholic Charities USA	ccusa
Aramark	amk	Catholic Life Center	clc
Archdiocese of New Orleans	ano	Centers of Disease Control and Prevention	cdc
Arden Cahill Academy	aca	Ceres Gulf, Inc.	ceres
Area's Levee Board Officials	albo	CH2M Hill	ch2m
Arkansas National Guard	ang	Chalmette Refinery Field Hospital	crfh
Army Corps of Engineers	ace	Chalmette Refining LLC	crllc
Arthur Monday Senior Citizens Center	amscc	Charity Hospital	chahosp
Ascension Baptist Church	abapc	Charter Communications, Inc.	cci
Associated Branch Pilots	abp	Chase Bank	chase
Astor Crowne Plaza	acp	Chateau Sonesta Hotel	csh
AT&T	at&t	ChevronTexaco Corp.	chev
Atonement Lutheran School	als	Children's Hospital	chhosp
Baptist Mercy Hospital	bmh	Cingular Wireless	cing
Barriere Construction Co.	bcc	City of Algiers	calg
Bass Enterprises	bass	City of Baton Rouge, Department of Public Works	cbrdpw
Baton Rouge Metropolitan Airport	brma	City of Baton Rouge, Police Department	cbrpd
Baton Rouge Technology Center	brtc	City of Gretna	cgret

City of Gretna, Police Department	ctretpd	Conference USA	conusa
City of Harahan	chara	Continental Airlines	ca
City of Harahan, Police Department	charapd	County of Harris, Texas	cntyhar
City of Kenner	cken	County of St. Louis, Missouri	cntystlou
City of Kenner, Police Department	ckenpd	Covington Field Hospital	cfh
City of Los Angles Fire Department	clafd	Cox Communications	cox
City of Mandeville	cmand	Delta Airlines	da
City of New Orleans	cno	Democratic Party	demo
City of New Orleans Sewerage & Water Board	cnoswb	Department of Administration, Louisiana	dadminla
City of New Orleans, City Attorney Office	cnwcao	Department of Agriculture and Forestry, Louisiana	dagla
City of New Orleans, City Council	cnocc	Department of Commerce, United States	dcus
City of New Orleans, Department of Health	cnodh	Department of Culture, Recreation and Tourism, Louisiana	dcrtla
City of New Orleans, Finance Department	cnofin	Department of Defense, United States	dod
City of New Orleans, Fire Department	cnofd	Department of Economic Development, Louisiana	dedla
City of New Orleans, Housing Authority	cnoha	Department of Education, Harris County Texas	dedhct
City of New Orleans, Police Department	cnopd	Department of Education, Louisiana	dedla
City of Slidell	cslid	Department of Education, United States	dedus
City of Slidell, Fire Department	cslidfd	Department of Emergency Preparedness, Louisiana	depla
City of Slidell, Office of the Mayor	cslidom	Department of Environmental Quality, Louisiana	deqla
City of Slidell, Police Department	cslidpd	Department of Health and Hospitals, Louisiana	dhhla
City of Slidell, Public Affairs Office	cslidpao	Department of Health and Human Services, United States	dhhsus
City of St. Gabriel	cstgab	Department of Homeland Security, United States	dhsus
City of Vancouver	cvan	Department of Housing and Urban Development, United States	dhudus
City of Westwego	cwest	Department of Insurance, Louisiana	dila
City of Westwego, Police Department	cwestpd	Department of Justice, Louisiana	djla
Civil Air Patrol - Louisiana Wing	cap	Department of Justice, United States	djus
CJ Brown	cjbro	Department of Labor, Louisiana	dlla
Clarence M. Kelly & Associates	cmk&a	Department of Natural Resources, Louisiana	dnrla
Cleco Corp.	cleco	Department of Public Safety and Corrections, Louisiana	dpscla
Coalition to Restore Coastal Louisiana	crcla	Department of Social Services, Louisiana	dssla
Coast Waterworks, Inc.	cwi	Department of State, Louisiana	dosla
Coldwell Banker Phelps & McKey Realtors Inc.	coldwel	Department of State, United States	dosus
Columbia Broadcasting Service	cbs	Department of the Treasury, Louisiana	dotrsla
Columbia Sussex Corp.	csc	Department of Transportation and Development, Louisiana	dtdla
Department of Transportation, United States	dotus	Federal Emergency Management Agency, United States	fema
Department of Wildlife and Fisheries, Louisiana	dwfla	Federal Housing Administration	fha
Devon Energy Corp.	devon	Fertility Institute of New Orleans	fino
Dewberry Technologies	dewbry	Florida National Guard	fna
Dillard University	dilu	Fluor Corp.	fluor
Diocese of Baton Rouge	dbr	Foley & Judell	f&j
Disaster Mortuary Operational Response Team	dmort	Freddie Mac	fremac
Division of Administration, Louisiana	dala	French Quarter Hotel	fqh
Dixie Electric Membership Corporation	demco	Geico	geico
Dixon Correctional Center	dcc	General Accountability Office, United States	gaous
DMJM Harris-AECOM	dmjm	General Electric	ge
Drug Enforcement Agency, United States	deaus	General Motors	gm
DRW Investments LLC	drw	George Washington University	fwu
E.J. Morris Senior Center	ejmsc	German Air Force	gar
East Jefferson General Hospital	ejghosp	Gootee Construction Inc.	gote

Ecole Classique School	ecs	Government of Afghanistan	gvafg
Eighth Coast Guard Auxiliary District	ecgad	Government of Bangladesh	gvban
Elayn Hunt Correctional Center	elayn	Government of Canada	gvcan
Eleanor McMain Magnet Secondary School	emmss	Government of Cuba	gvcub
Emergency Management Assistance Compact	emac	Government of Qatar	gvqat
Entergy Corp.	entergy	Government of Saudi Arabia	gvsa
Environmental Protection Agency, United States	epaus	Government of Sri Lanka	gvsl
Episcopal High School	ehs	Government of Thailand	gvthai
Equifax	equi	Government of The Netherlands	gvneth
Ernest N. Morial Convention Center	enmcc	Governor of Louisiana	govla
Experian	esperi	Governor of Mississippi	govmiss
Exxon Mobil Corp.	exxon	Greater New Orleans Expressway Commission	gnoec
Fannie Mae	famae	Gulf Royal Dutch Shell, PLC	shell
Federal Aviation Administration	faa	Harrah's New Orleans Casino	harah
Federal Bureau of Investigations	fbi	Harvy Lincoln Elementary	hle
Federal Communications Commission, United States	fccuss	Henry's Kitchen	hkit
Federal Deposit Insurance Corp.	fdic	Herb Wallace Fire Station	hwfs
Federal Disaster Mortuary Operational Response Team	fdmort	Heritage Foundation	herfnd
Federal Drug Administration, United States	fdaus	Hibernia National Bank	hnb
Hibernia National Bank Operation Center Houston	hnboch	Lamar Dixon Center	lamar
Hibernia National Bank Operation Center Shreveport	hnbocs	Latter & Blum Inc.	l&b
Hilton Hotels	hilton	Legal Council for the Mayor of New Orleans	lcmno
Historic New Orleans Collection	hnoc	Liberty Bank and Trust	lbt
Home Depot	hmdepo	Lift	lift
Homeland Security Division of LOHSEP	hls	Little Sisters of the Poor's Mary Joseph Residence	lspmjr
Houma Courier	hc	LM Ericsson	lme
Houma Terrebonne Civic Center	htcc	Louis Armstrong International Airport	laia
House Tax Writing Committee	htwc	Louis Armstrong International Airport Field Hospital	laiafhosp
Houston Astrodome	astro	Louisiana Air National Guard	laang
Houston Independent School District	hisd	Louisiana Arts and Science Center	lasc
Houston's Toyota Center	htc	Louisiana Associated General Contractors	lagc
Hyatt Hotels	hyatt	Louisiana Banking Association	lba
Illinois Conservation Police	icp	Louisiana Bond Commission	lbc
Independent Schools Associations of the Southwest	isas	Louisiana Democratic Party	ldp
Institute for Regional Forecasting	irf	Louisiana Emergency Operations Center	leoc
International Aid	intaid	Louisiana Gaming Control Board	lgcb
International Business Machines	ibm	Louisiana Governor's Office of Film and TV	lboftv
International Council of Shopping Centers	icsc	Louisiana Heart Hospital	lhh
International Longshoreman's Association	ila	Louisiana High School Athletic Association	lhsaa
Israel Augustine Middle School	iams	Louisiana Hospital Assocation	lha
J&J Maintenance, Inc.	j&j	Louisiana Legislative Black Caucus	llbc
JetBlue Airways	jetblu	Louisiana Legislature	laleg
John Curtis Christian School	jccs	Louisiana National Guard	lang
Joint Legislative Committee on Insurance	jlci	Louisiana Notary Association	lna
Kellogg Brown & Root Services	kb&r	Louisiana Nursing Home Association	lnha
Kentucky Fried Chicken	kfc	Louisiana Occupational Therapy Association	lota
Kentucky Utility Crew	kuc	Louisiana Office of Financial Institutions	laofi

Kenyon International Emergency Services	kies	Louisiana Office of Homeland Security and Emergency Preparedness	lohsep
L.E. Rabouin Career Magnet School	lercms	Louisiana Offshore Oil Port, Inc.	loop
Lafourche Telephone Company	latelco	Louisiana Oil Spill Coordinator's Office	losco
Lake Pontchartrain Hurricane Levee System	lphls	Louisiana River Pilots Association	lrpa
Lakeland Hospital	lakhosp	Louisiana Shrimp Association	lsa
Lakeview Regional Medical Center	lakrmc	Louisiana State Fire Marshal	sfm
Louisiana State Police	lsp	National Association of the Advancement of Colored People	naacp
Louisiana State University	lsu	National Basketball Association	nba
Louisiana State University Board of Supervisors	lsubos	National Bond Lawyers Association	nbla
Louisiana State University Department of Psychiatry	lsudop	National Broadcasting Corporation	nbc
Louisiana State University Health Care Services Division	lsuhcsd	National Center for Missing and Exploited Children	ncmec
Louisiana State University Hurricane Center	lsuhc	National Disaster Medical System	ndms
Louisiana State University Medical Center	lsumc	National Football League	nfl
Louisiana State University Police Department	lsupd	National Guard	natgd
Louisiana State University School of Journalism	lsusj	National Hurricane Center	nhc
Louisiana State University, Manship School for Mass Communications	lsumsmc	National Marine Fisheries Service	nmfs
Louisiana Supreme Court	lsc	National Mortgage Bankers Association	nmba
Louisiana Supreme Court Committee on Bar Admissions	lsccba	National Trust for Historic Preservation	nthp
Lowe's	lowes	National Weather Service	nws
Lt. Governor of Louisiana	ltgovla	Natural Hazards Research and Applications Center at the University of Colorado	nhrac
Lutheran High School	lhs	New Jersey Air National Guard	naangd
LVI Services, Inc	lvi	New Mexico National Guard	nmngd
MaCann Protective Services	macan	New Orleans Chamber of Commerce	nocc
Major League Baseball	mlb	New Orleans Emergency Management System	noems
Mandeville Police Department	mpd	New Orleans Hornets	noh
Marrero Marrero-Estelle Fire Station	marrer	New Orleans Metropolitan Convention and Visitors Bureau	nomcvb
Marriott Hotels	mariot	New Orleans Mission	nom
Mayor of New Orleans	mayno	New Orleans Museum of Art	noma
Memorial Medical Center	mmc	New Orleans Saints	nos
Metairie Park Country Day	mpcd	North Shore Regional Medical Center	nsrmc
Metairie Transit Facility	mtf	North Shore Square Mall	nssm
Michoud Assembly Facility	maf	Northrop Grumman Corp.	ngc
Minerals Management Service, United States	mmsus	Northwest Airlines	na
Moody's	moody	O. Perry Walker High School	opwhs
Motorola, Inc.	motola	Ochsner Foundation Clinic	ofc
Ms. Mae's Bar	mmb	Ochsner Foundation Hospital	ofh
Munters	munt	Office of Community Services, Louisiana	ocsla
Murphy Oil Corp.	murph	Office of Councilwoman Jackie Clarkson	ocjc
National Aeronautical and Space Administration	nasa	Office of Financial Institutions, Louisiana	ofila
National Association of Home Builders Research Council	nahbrc	Office of Former President Bush	ofpb
Office of Former President Clinton	ofpc	Office of US Senator Charles Grassley	
Office of Homeland Security, New Orleans	ohsno	Office of US Senator Hillary Clinton	ouscg
Office of Management and Budget, United States	ombus	Office of US Senator Joseph Lieberman	oushc
Office of Senator David Vitter	osdv	Office of US Senator Max Baucus	ousjl
Office of Senator Harry Reid	oshr	Ohio National Guard	ousmb
Office of Senator Mary Landrieu	osml	Operation Life-Line Depot	ongd
Office of State Representative Arthur Morrel	osram	Oppenheimer & Company	olld

Office of State Representative Cedric Richmond	osrcr
Office of State Representative Joe Salter	osrjs
Office of State Representative John Alario	osrja
Office of State Representative Nita Hutter	osrnh
Office of State Representative Peppi Bruneau	osrpb
Office of State Senator Cleo Fields	osscf
Office of State Senator Craig Romero	osscr
Office of State Senator Don Hines	ossdh
Office of State Senator Edwin Murray	ossem
Office of State Senator Mike Michot	ossmm
Office of State Senator Robert Barhnam	ossrb
Office of State Senator Walter Boasso	osswb
Office of the Chief of Staff to the Governor of Louisiana	cosla
Office of the Mayor of Atlanta	omatl
Office of the Mayor of Las Vegas	omlv
Office of the Mayor of San Francisco	omsf
Office of the President of the United States	potus
Office of the Vice President of the United States	ovpus
Office of US Representative Bobby Jindal	ousrbj
Office of US Representative Charles Rangel	ousrcr
Office of US Representative Charlie Melancon	ousrcm
Office of US Representative Dennis Hastert	ousrdh
Office of US Representative Mark Foley	ousrmf
Office of US Representative Nancy Pelosi	ousrnp
Office of US Representative Peter King	ousrpk
Office of US Representative Thomas Tancredo	ousrtt
Office of US Representative William Jefferson	ousrwj
Parish of Orleans, Civil District Court	parorcdd
Parish of Orleans, Communications District	parorcd
Parish of Orleans, Levee District	parorld
Parish of Orleans, Office of the Coroner	paroroc
Parish of Orleans, Recorder of Mortgages	parorrm
Parish of Orleans, Register of Conveyances	parorrc
Parish of Orleans, School District	parorsd
Parish of Plaquemines	parpla
Parish of Plaquemines Emergency Management Agency	parplaema
Parish of Plaquemines, Office of the Sheriff	parplaos
Parish of Plaquemines, School District	parplasd
Parish of St. Bernard	parsb
Parish of St. Bernard Emergency Management Agency	parsbema
Parish of St. Bernard, Fire Department	parsbfd
Parish of St. Bernard, Office of the Coroner	parsboc
Parish of St. Bernard, Office of the Sheriff	parsbos
Parish of St. Bernard, Police Department	parsbpd
Parish of St. Bernard, Port, Harbor and Terminal District	parsbphtd
Parish of St. Bernard, School District	parsbsd
Parish of St. Charles	parsc
Our Lady of Holy Cross College	o&c
Our Lady Wisdom Health Care Center	olhcc
Owner-Operator Independent Driver's Association	olwhcc
P&O Ports	ooida
Papa John's franchise near Rouse's Supermarket	p&o
Parish of Ascension, School District	papa
Parish of Assumption, Police Department	parascsd
Parish of East Baton Rouge	parasupd
Parish of East Baton Rouge, Fire Department	parebr
Parish of East Baton Rouge, School Board	parebrfd
Parish of East Baton Rouge, School District	parebrsb
Parish of East Feliciana	parebrsd
Parish of Jefferson	paref
Parish of Jefferson Emergency Management Agency	parjef
Parish of Jefferson, Clerk of Courts	parjefema
Parish of Jefferson, Correctional Center	parjefcoc
Parish of Jefferson, District Court	parjefcc
Parish of Jefferson, Emergency Medical Services	parjefdc
Parish of Jefferson, Morgue	jefems
Parish of Jefferson, Office of the Coroner	parjefm
Parish of Jefferson, Office of the Sheriff	parjefooc
Parish of Jefferson, School District	parjefos
Parish of Lafayette	parjefsd
Parish of Lafayette, School District	parlaf
Parish of Lafourche	parlafsd
Parish of Orleans	parlafo
Parish of Orleans Prison	paror
Parish of St. Tammany, Public Works Department	parstpwd
Parish of St. Tammany, School District	parstsd
Parish of Tangipahoa	partan
Parish of Terrebonne	parter
Parish of Washington	parwas
Parish of West Baton Rouge	wbr
Pete Maravich Center Field Hospital	pmcfh
Pinnacle Entertainment	pinnacl
Port of Galveston	portg
Port of New Orleans	portno
Professional Golf Association	pga
Public Service Commission, Louisiana	pscla
Radio Amateur Civil Emergency Service	races
Rainbow/PUSH	push
Reality Executives Integrity First Real Estate	reifre
Regional Assistance Center for the County of St. Louis, Missiouri	raccstlm
Regional Transit Authority	rta
Regions Bank	regbnk
Ridgewood Preparatory School	rps
Risk Management Solutions, Inc.	rms

Parish of St. Charles, School District	parscsd
Parish of St. Gabriel, Morgue	parsgm
Parish of St. James, School District	parsjsd
Parish of St. John the Baptist	parstjo
Parish of St. John the Baptist, School District	parbsd
Parish of St. John, School District	parsjosd
Parish of St. Tammany	parst
Parish of St. Tammany Council	parstc
Parish of St. Tammany, Assessment Office	parstao
Parish of St. Tammany, Clerk of Courts	parstcc
Parish of St. Tammany, Emergency Operations Center	parsteoc
Parish of St. Tammany, Office of Emergency Preparedness	parstoep
Parish of St. Tammany, Office of the Sheriff	parstos
Parish of St. Tammany, Police Department	parstpd
South Louisiana Electric Cooperative Assocation	sleca
Southeastern Motor Freight	smf
Southern Baptist Volunteers	sbv
Southern Methodist University	smu
Southgate Towers	st
Southwest Airlines	swa
Southwinds Motel	swm
Sports Authority	sa
Sprint Wireless	sprint
St. Charles Parish Hospital	scphosp
St. Martin's Episcopal School	stmes
St. Rita's Nursing Home	strita
St. Tammany Parish Home Builders Association	stphba
St. Tammany Parish Hospital	stparhosp
St. Ville Elementary Library	svel
St. Vincent de Paul Society	svps
Standard & Poor	s&p
State Farm Insurance	sfi
State of Arkansas	arkansas
State of Louisiana	LA
State of Mississippi Emergency Operations Center	misseoc
State of Texas	texas
Stella Worley Middle School	swmc
Stennis Space Center	ssc
Sunshine Garden Health Food Store in Covington	sghfs
SuperDome	sd
Superdome Commission	sdcom
Sylvanie F. Williams School	sfws
Tenet Healthcare Corp.	tenet
Terrytown 5th District Volunteer Fire Department	tdvfd
Texas National Guard	tngd
Texas Workforce Commission	twc
The Humane Society	human
Royal Sonesta Hotel	rsh
Salem Lutheran School	sls
Salvation Army	salvarm
Sarah T. Reed High School	strhs
Second Harvest Food Bank	shfb
Senate Committee on Homeland Security and Government Affairs	schsga
Senate Finance Committee	sfc
ServiceMaster	sm
Shelter in Corpus Christi Texas	scct
Sheraton Hotels	sheraton
Slidell Memorial Hospital	smhosp
SMG	smg
Social Security Administration, United States	ssa
South Carolina National Guard	scngd
The Spirit of America	soa
The WorkSource	work
Tiger Athletic Foundation	tiger
Times-Picayune	tp
TJC Engineering, Inc.	tjc
Touro Infirmary	touro
Town of Grand Isle	twngi
Town of Grand Isle Police Department	twngipd
Town of Jean Lafitte	twjela
TransUnion	transunion
Treasure Chest Casino	tcc
Truman Middle School	tms
Tulane National Primate Research Center	tnprc
Tulane University	tu
U.S. Joint Forces Command: Standing Joint Forces Headquarters	sjfhq
United Airlines	ua
United States Army	usarmy
United States Army: Logistics Readiness Center	lrc
United States Coast Guard	uscg
United States Congress	uscon
United States Customs Agency	usca
United States Defense Mapping Agency	usdma
United States Fish & Wildlife Service	usfws
United States Geological Survey, St. Petersburg Laboratory	usgsspl
United States Marine Corps	usmc
United States Navy	usnav
United States Post Office	uspost
United States Public Health Service	usphs
United States Secret Service	ussec
United States Senate	ussen
University of Memphis	um
University of Southern Mississippi	usm
Urban League	urban

The Shaw Group, Inc	shaw	Verizon Wireless	verizon
Voluntary Organizations Active in Disaster: Louisina Chapter	voad		
W.G. Yates & Sons Construction Co.	wgy&s		
Waffle House near Covington	waffle		
Wal-Mart	walmrt		
Wal-Mart (Tchoupitoulas Street)	walmrtts		
Walter P. Moore & Assoc.	wpm&a		
WAPT – TV	wapttv		
Warren Easton Fundamental High School	wefhs		
Washington - St. Tammany Electric Cooperative	wstec		
WBRZ – TV	wbrztv		
WDSU – TV	wdsutv		
West Jefferson General Hospital	wjfhosp		
West Jefferson Medical Center	wjmc		
Western Union	west		
Westwego Alario Center	westweg		
WGNO – TV	wgnotv		
Whole Foods	whole		
William Franz School	wfs		
Winn-Dixie's Riverside Market Place	windix		
WVUE – TV	wvuetv		
WWL – TV	wwltv		
Zephyr Field Field Hospital	zephyr		

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