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Leveraging Intergovernmental and Cross-sectoral Networks to Manage Nuclear Power Plant Accidents: A Case Study from China

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Abstract

Addressing nuclear power plant accidents (NPPAs) overwhelms the capability of single jurisdictional government and spans the boundaries of multiple sectors. NPPAs management requires public sectors affiliating to multiple governments, private and non-profit sectors to interact with each other for sharing responsibilities, capabilities and information. How to leverage network to improve collaboration and coordination among all the involved organizations presents challenges for Chinese public administrators in NPPAs management. From the emergency management practice of the earliest nuclear power plants in China, this research investigates and conceptualizes governance mechanisms and associated interorganizational relationships involving in each jurisdictional governmental level and among multiple governments in this specific field. The inter-governmental and cross-sectoral NPPAs management network is built, visualized and analyzed at the levels of the node, link, subset of the nodes and whole network based on Social Network Analysis, and managerial implications of improving inter-organizational collaboration in this field are discussed. Our research shows that the current NPPAs network in China mainly relies on the resources and capabilities of public sectors, and the private and non-profit sectors should be integrated into the network for providing diversified emergency services. NPPAs management network is a hybrid network in the centralized political-administrative structure of China, and hierarchical, market and network governance mechanism play essential roles together and complement with each other in the multi-organizational environment. This network demonstrates the characteristics of selective integration, and the interorganizational relationships that should be paid more attention to be sustained are identified and emphasized from the network perspectives. Furthermore, the absence of collaborative relationships among the organizations that poses barriers to interorganizational collaboration is also discovered and the improvement approaches are discussed. This research provides guidance for improving collaboration in NPPAs management in China, and contributes literatures on emergency management network and interorganizational collaboration in the centralized political-administrative structure.

Keyword

Emergency management network; Interorganizational collaboration; network mechanism; hierarchical mechanism; Social Network Analysis

1. Introduction

By 2015, a total of 55 nuclear power plants have been constructed or are being operated in Mainland China, and most of them locate in the eastern coastal area. Despite rare breakouts of nuclear power plant accidents (NPPAs), all the occurred accidents worldwide, such as the 1979 Three Mile Island accident in the USA (Mamun, 2013), the 1986 Chernobyl accident in the Soviet Union (Hildegarde, 2016) and the 2011 Fukushima accident in Japan (Masashi, 2016), led to serious property damages and environmental destruction in the surrounding areas (Yuan, 2015). Obviously, the disastrous situation cannot be controlled by the companies operating the nuclear power plants, and overwhelms capabilities of single jurisdictional government. As a typical 'wicked problem' (Edward, 2008), responding to NPPAs presents challenges for the traditional management approach in Chinese governments, and require collaboration among multiple involved sectors and multiple levels of governments. However, during large-scale emergencies, such as NPPAs, collaboration and coordination is always identified as the main failure (Boin, 2014).

At present, in each governmental level, the jurisdictional governments establish network for managing NPPAs to mobilize and integrate all the resources of diversified sectors to tackle with the disastrous situation in China. The formed network becomes a tool to improve collaboration among organizations with NPPAs management responsibilities. In the same way, the federal government of USA set up the U. S. Federal Radiological Monitoring and Assessment Center to coordinate the environmental monitoring activities for improving information sharing (Nielsen, 2008). In the vertical dimension, NPPAs management requires

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multiple levels of jurisdictional governments to address the disastrous situation collaboratively. In China, according to the institutional arrangement of NPPAs management, the inter-governmental network is activated by provincial government once the nuclear pollution exceeds the boundary of nuclear power plants, and a whole network consisting of sub networks in multiple governmental levels forms and expands from top to down. The hierarchical mechanism is employed to arrange the inter-governmental relationships and improve the collaboration. Therefore, NPPA management involves inter-governmental and cross-sectoral collaboration and interactions and how to coordinate all of these organizations toward common objectives is an existing problem. In China, the NPPA management network is actually a hybrid one blending the hierarchical characteristics and network properties. In current time, NPPAs management networks in each governmental levels are designed and established independently, and how these networks interact and operate collaboratively and smoothly is an existing problem. Second, NPPA management is particularly expected to be urgent and decisive. The fragmentation of governmental and sectoral administrative boundaries is compounded by problems of limited time, along with limited understanding of each individual's roles and responsibilities among the involved organizations (Moynihan, 2005). Consequently, a particular lack of continuity and collaboration exists in NPPA management. Finally, in NPPAs management practice, the inter-organizational hierarchy and network arrangement are both employed to mediate the conflicts and improve collaboration among organizations. How hierarchical principles and network properties are meld and combined within this hybrid networks to shape inter-organizational interaction is existing problem with little empirical examination (Hermansson, 2016).

The existing literature on intergovernmental and interorganizational networks are mainly empirical research in western contexts. Network governance mechanism is treated as the main tool to arrange inter-organizational relationships, and hierarchical principles are always neglected (Beck, 2013; Kapucu, 2008). However, in the centralized political–administrative structure of China, one organization is not only the formal subordinate of the others, but also interacts and collaborate with others in the horizontal direction during NPPAs management. How to leverage the inter-governmental and cross-sectoral network to manage NPPAs is an existing problem in Chinese context, and present gap of the existing research. The fundamental challenges cover adopting and combining multiple governance mechanisms, and designing the effective network structure for improving collaboration in the multiple organization environment (Lei, 2015). Those are the key factors to regulate the network operation and determines the network effectiveness (Provan, 2012; Chad, 2015).

In this research, the earliest nuclear power base consisting of two power plants locating in the Shenzhen City, Guangdong Province in Southeastern China is selected as an empirical case. It provides a precious opportunity to examine and refine the conceptualization of NPPA management networks involving multiple levels of governments and multiple sectors. First, what kind of governance mechanisms are employed and combined to improve collaboration and coordination in Chinese centralized political-administrative structure context. Second, the organizations with formal responsibilities from multiple governmental levels and the diversified inter-organizational relationships among them are investigated. Third, this research aims to examine the whole intergovernmental and cross-sectoral network structure of NPPA management in China, and the network characteristics and their effects on the interorganizational interactions are discussed. This study proposes implications of NPPA management for improving inter-organizational collaboration and coordination. The content analysis of official regulations and emergency operation plans of NPPA management are used to examine the empirical case. Social network analysis (SNA) (Scott, 2013) is employed to represent, visualize, measure, and analyze the whole intergovernmental and cross-sectoral network. This research provides a conceptual framework to understand the intergovernmental and cross-sectoral interaction and the governance mechanisms in this specific filed. It also demonstrates the structure characteristics of the NPPAs management network, and guides the improvement of NPPAs management networks and the institutional arrangements reformation in this specific filed.

2. Literature review and theoretical background

The section presents previous network research in emergency management (Hu, 2015), which this research builds on and contributes to.

2.1 Collaborative emergency management

Large-scale emergencies require bringing together all stakeholders and holistic management (Comfort, 2006a; Comfort, 2006b). Public organizations affiliating to multiple levels of governments, private and nonprofit organizations should communicate information, share resources and expertise, and conduct joint decision-making and coordinated efforts to address

such complex issues (Kapucu, 2012, 2014). In fact, emergency management is typically a dynamic process of interorganizational collaboration involving interactions and exchanges among interdependent organizations toward achieving common objectives (Thomson, 2009). The main challenges are how to improve the interorganizational collaboration, where multiple governance mechanisms need to be mobilized (Rodriguez, 2007). The hierarchical mechanism influences behavior by imposing constraints and characterizes interactions among organizations with hierarchical/vertical relationships. In particular, the political–administrative structure in China is hierarchical, and centralized command and control are mainly employed to regulate the inter-organizational relationships in emergency management. Meanwhile, the growing number of horizontal interorganizational relationships require management tools falling outside the boundaries of hierarchical structure.

Market and network mechanisms provide another supplement approaches to improve collaboration in this multi-organization environment. Market mechanisms rely on prices or incentives reorienting the desires of organizations and their behavior. Such mechanism is an effective tool to combine resources of private organizations to emergency management. Network governance emphasizes the shared value and trust to encourage interorganizational collaboration. Each governance mechanism represents different modes of interactions and exchanges with its own specific logic (Powell, 1990). Formal control in the form of unified and centralized command is an important mean to coordinate the diversified and dispersed network actors quickly. Network governance based on trust and work relationships can act as a low-cost alternative to formal control mechanisms to improve interorganizational collaboration. In emergency management practice, all of the governance mechanisms can be combined and completed with each other to pursue shared objectives (Moynihan, 2007). However, there is a shortage of empirical research on how to employ and combine these governance mechanisms to improve inter-organizational collaboration in the Chinese centralized political-administrative structure (Hermansson, 2016).

Interorganizational networks have become one of the most preferred tools to manage large-scale emergencies requiring the involvement of multiple governments and organizations (Kapucu, 2006, 2014). They provide an adaptive and flexible approach to address complex issues spanning organizational boundaries, such as emergency management, and are shaped by organizational, environmental, and political-administrative contexts. Although networks comprise a range of interactions among multiple stakeholders, a focus on governance involves employing institutions and structures of authority and collaboration to allocate resources, and to coordinate and control joint actions across the network as a whole (Provan, 2010). According to existing literature, the emergency management network doesn’t replace hierarchical administrative structures; instead, it adds one more layer of interorganizational interactions, as public sectors are interwoven with counterparts from the same government, or other governments of the same sort (O’ Toole, 2014). Therefore, the inter-organizational relationships consist of both hierarchical and horizontal ones depending on the governance mechanism for regulating their interactions.

2.2 Network analysis in emergency management

Over the past decades, increasing attentions have been paid to the research and practice of collaborative network structure arrangements, and their effects on participants and network effectiveness in emergency management (Comfort, 2006; Hu, 2015; Kapucu 2006). Especially, SNA is used to measure the structural and relational patterns of emergency management networks. In contrast to conventional statistical analysis focusing on the attributes of actors, network analysis emphasizes interactions among actors and refers to a broad range of methods for analyzing theoretical constructs and concepts that are defined as relational processes and outcomes (Scott, 2013).

Most of the literature applied SNA to identify the key organizations and analyze the embeddedness of network nodes and its effects on individual behavior in emergency management networks (Hu, 2015; Branda, 2014; Kun, 2007). Kapucu identified the key organizations in emergency response network of the September 11, 2001 terrorist attacks (Kapucu, 2006). In the subsequent research, he employed the SNA tool to build and analyze the interorganizational network of the Federal Response Plan, the National Response plan, and the National Response Framework to examine the evolution of disaster management systems in the USA, and network degree centrality analysis demonstrates that network complexity increases (Kapucu, 2009). Kapucu examined the betweenness centrality in interagency communication networks and explored factors contributing to effective interorganizational communication, and those factors inhibiting their development (Kapucu, 2006). Hossain applied centrality measures to represent the interconnectedness of nodes in the emergency response network and tested the hypotheses of their implications on improving interorganizational coordination (Hossain, 2008). Furthermore, researchers applied SNA to compare

formal emergency management networks and actual networks, and evaluate the performance of the networks to improve relevant policies and systems. Kapucu analyzed the outcomes of emergency management networks through the structure and interorganizational interactions, and discussed the structural difference between formal versus informal and planned versus actual networks (Kapucu, 2011). Hu built the affiliation networks of actual disaster response networks with formal networks and applied SNA to measure the degree centrality of organizations to understand how organizations can effectively coordinate activities during emergencies (Hu, 2015). Relatively less research focused on the subgroups of networks through clique analysis and structural equivalence analysis in the emergency management network. By investigating the intergovernmental and cross-sectoral interactions of the response to Hurricane Katrina, Kapucu discovered that boundary spanners play important roles in linking subsets of organizations by clique analysis (Kapucu, 2010). Guo employed the block model to analyze the entire network structure of a municipal government in China and analyzed the structural properties of structural holes and intermediaries in the context of the Chinese local government (Guo, 2015).

Overall, despite the existing considerable research on network structures in the past decade, they have examined the structure of dyadic or triadic relationships and not the entire network. The existing network research in emergency management has been critiqued for the lack of theory construction, methodological rigor, and conceptual clarity (Hu, 2015). In particular, theoretical foundations concerning governance mechanisms and their connections to network configuration and designing are left and unexamined. Moreover, these research only consider the interorganizational interactions in the horizontal dimension, and think that the hierarchical relationships pose barriers to collaboration among organizations and neglect them in building the emergency management network. Finally, the existing literature mainly conducted research on emergency management network in a singular government level. Intergovernmental collaboration and how it affects the network structure and operations still require further investigation. All of these gaps motivate our research.

3. Case description, data source, and research method

3.1 Case description

Both the Daya Bay and Ling Ao Nuclear Power Plants are in the same nuclear power base locating in Shenzhen City, Guangdong Province, China, and are the earliest nuclear power plants in China. NPPAs in these plants will make the around area be exposed to the risk of radiative pollution (Duncan, 2014). As shown in Figure 1, the nuclear power plants are represented by a special icon and locate at the seaside. The around region covered within a 10 miles radius from the nuclear power plants is called the plume exposure pathway, in which the radiative pollution is critical. The provincial, municipal, and local governments and operational company of the nuclear power plants are required to collaborate with each other to reduce the damages for protecting the health and safety of the public and the environment.

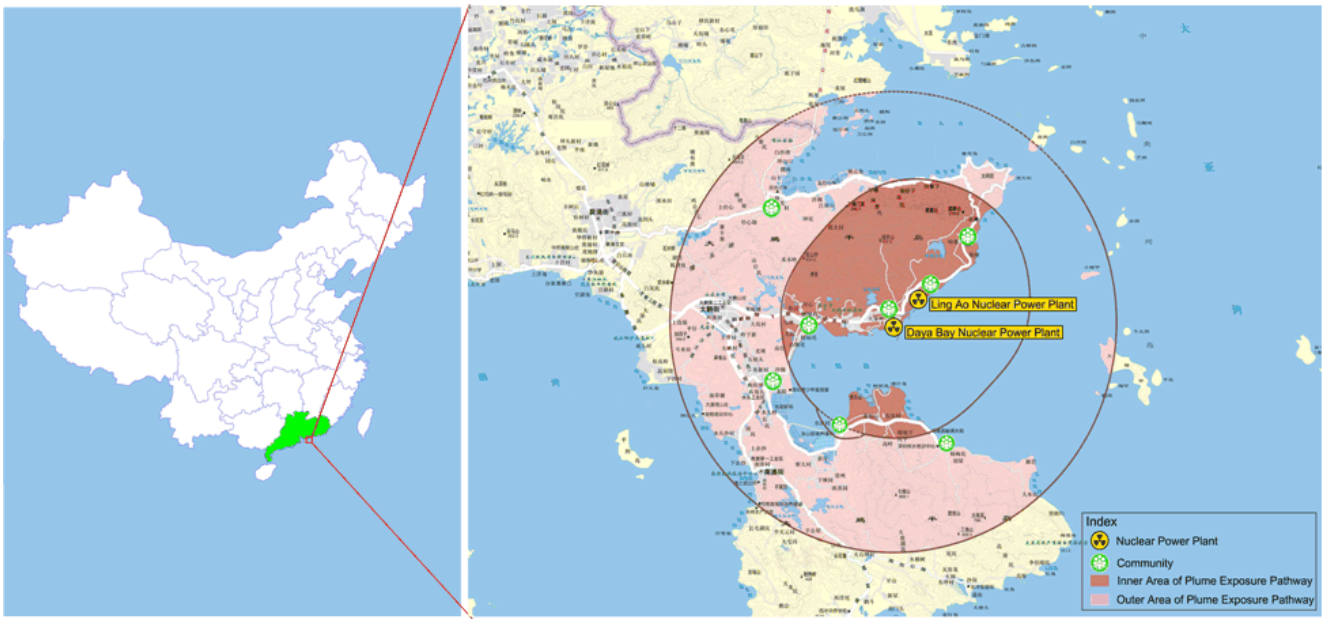

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Figure 1. The map of nuclear power plants and the plume exposure pathway zone

The official regulations on nuclear safety in China state that the operators take charge of on-site emergency management of NPPAs within the scope of the nuclear power plants, which is a secured zone. Multiple levels of jurisdictional governments are responsible for protecting residents, properties and the environment in communities surrounding the nuclear power plants, particularly in areas within the plume exposure pathway. That is called off-site NPPA management. In the existing institutional arrangement, the Guangdong provincial government arranges for the Department of Environmental Protection of Guangdong Province to coordinate all the responsible organizations for managing the NPPAs in the nuclear power plants. In the municipal governmental level, the Emergency Management Office of Shenzhen City is responsible for coordinating with all the organizations in this level to tackle with NPPAs. In practice of NPPA management, multiple levels of jurisdictional governments collectively conduct extensive planning, exercises, and outreach to better protect the surrounding communities in the event of NPPAs. Once the NPPAs break out and the pollution exceed the operational region of the nuclear power plants, the operation company should report the information to Guangdong provincial government. The Guangdong provincial governments' officials make the decision of evacuating and sheltering residents of the surrounding communities of the NPPAs and activate the inter-governmental NPPA management network. This context provides an opportunity to examine intergovernmental and cross-sectoral collaboration in the field of NPPA management in China.

3.2 Data sources

This research focuses on the institutional network involved in managing NPPAs, which consists of formal inter-organizational relationships among organizations with NPPA management responsibilities. Two main data sources are involved. First, official documents on managing NPPAs were collected for identifying the involved organizations and their interaction. The main documents are list in Table 1. Those provide credible data for building NPPA management network. In particular, the emergency operation plans specify each organization's role, responsibilities and tasks, and provide guidance to coordinate efforts of participating organizations in each government level during emergency management of NPPAs. Second, one public officials from the Department of Environmental Protection of Guangdong Province and two emergency managers from the Emergency Management Office of Shenzhen City were interviewed to investigate the involved organizations and governance mechanisms for managing and controlling network actors in each level of government. These data sources complement with each other and enrich our understanding of the emergency management networks of NPPAs in this research.

Table1. The list of collected official documents on NPPA management

No.	Name of the official document
1	National Emergency Operation Plans for Nuclear Accidents in China[1]
2	Prevention and Controlling of Radioactive Pollution Act[2]
3	Regulations on Emergency Management for Nuclear Power Plant Accidents[3]
4	Emergency Operation Plans for Nuclear Accidents of Guangdong Province[4]
5	Regulation on Prevention and Emergency Management for Nuclear Accidents of Civil Nuclear Facilities in Guangdong Province[5]
6	Offsite Emergency Plan of Nuclear Accidents in the Daya Bay and Ling Ao Nuclear Power Plants[6]
7	White Paper of Nuclear Emergency Management in China[7]

3.3 Research method

This research focus on the institutional emergency management network and governance mechanisms of achieving interorganizational collaboration in NPPAs management as a case study (Yin, 2013). The main purpose of this study is to examine the structure and patterns of network relationships and their effects on the behavior of participators and their interaction. SNA (Scott, 2013) has gained prominence in emergency management research for the investigation of relational and structural

1 http://www.gov.cn/yjgl/2013-07/09/content_2443474.htm, accessed on 26th November 2016
2 http://www.gov.cn/fwxx/content_2265078.htm, accessed on 26th November 2016
3 http://www.gov.cn/fwxx/content_2265078.htm, accessed on 26th November 2016
4 http://www.gdemo.gov.cn/yasz/yjya/zxya/sgznlya/200808/t20080811_61210.htm, accessed on 26th November 2016
5 http://fgk.chinalaw.gov.cn/article/dffg/201007/20100700337022.shtml, accessed on 26th November 2016
6 http://www.psxq.gov.cn/main/a/2012/k01/a415_1721.shtml, accessed on 26th November 2016
7 http://news.xinhuanet.com/politics/2016-01/27/c_1117908680_10.htm, accessed on 26th November 2016

properties of networks. In this research, the SNA tool NetMiner[8] was employed to visualize and measure the network structure.

The four steps in conducting network analysis and discussing emergency management networks for NPPAs management include (1) identifying the organizations and defining the boundary of the network; (2) evaluating interorganizational relationships; (3) visualizing the network; (4) analyzing the emergency management network; and (5) discussing the network analysis results and how to improve the design of the emergency management network.

SNA provide an effective tool to measure the network structure configuration. The detailed network measures involved in this research is list as following:

(1) Centrality analysis

Centrality measures the embeddedness of a node and indicate the positions of the node in the whole network, which influences the behavior of organizations in NPPA management. The centrality measure indicators include the degree centrality, betweenness centrality, closeness centrality and effect centrality. The degree centrality of a network node is computed by the portion of nodes that are adjacent to each node (Scott, 2013). This network measure indicator only considers the direct network ties of nodes and measures the local centrality of nodes in the network. The organization having higher degree centrality indicate that it interacts with more other organizations. The betweenness centrality of a node or link measures the extent to which it locates in the short path of between the other two nodes in the network (Scott, 2013). The more times a node/link appears in these paths, it has higher value of betweenness centrality. Moreover, a node/link with higher value of betweenness centrality indicate that it has higher control over the information between other organizations. Closeness centrality value measures how close a node is to all of the other actors in the network and is calculated by the sum of distances from a node to all of the other nodes (Scott, 2013). This network measure can be used to estimate the information sharing in network, assuming that if a node have lower close centrality, it can exchange information more quickly (Kapucu, 2010). Effect centrality is the measure for the effect strength from a given node to all of the other nodes through every path between them. In contrast to the degree centrality, the effect centrality value of a given node considers both the direct and indirect network ties among all the nodes. Meanwhile, unlike closeness centrality, the effects of a given node takes into account the strength of the transmitted effect in the path (Scott, 2013).

(2) Clique analysis

A clique is a subset of node in the network where one node interact with each other directive (Scott, 2013). The clique analysis in SNA search the cohesive structure of a network. In the interorganizational network, each clique provides a platform to facilitate collective activities through full exchange of information and resources with other organizations, excluding others from exchange of information and resource sharing (Comfort, 2006). Thus, one possibility is that interactions in a close and dense interorganizational network increase the opportunity for network actors to share information, knowledge, and resources with each other, enforce common norms, and cultivate trust between each other. Meanwhile, the common nodes in multiple cliques can play an important roles in linking these groups as boundary spanners (Kapucu, 2010). The attribute of size is the number of organizations composing the cliques, and the cohesion index is computed by the number of network ties among organizations in a clique and the number of external ties, which are among the organizations in the same clique and those that are excluded from the clique.

(3) Brokerage role analysis

The intermediary position of a node can be measured in three nodes. In a triad, one node has an intermediary position between the other two nodes, and five different brokerage roles may be distinguished depending on the group comprising these three nodes belong to. From the brokerage measure (Gould, 1989), the brokerage is called a coordinator if the three nodes belong to the same group, a representative when the brokerage belongs to the sender group, a gatekeeper when it belongs to the receiver group, an itinerant broker when it belongs to a group that is neither the sender nor the receiver group, and finally, a liaison when all three nodes belong to different groups. Given a partition of network nodes, SNA facilitates counting the number of times each node takes on these specific structural positions and thus helps determine the main types of brokerage roles taken on by the nodes. In NPPA management network, the brokerage role analysis provide a way of detecting the above intermediary position of an organization.

8 http://www.netminer.com/main/main-read.do, accessed on 2rd October 2016

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(4) Block analysis

Block analysis demonstrates structural characteristics of the network at level of subset of nodes (Scott, 2013). All the nodes in the network are divided into several subsets, called blocks or positions. Then, the density of the links in each blocks and between each pair of blocks are computed. When the density of a block is higher than a given threshold, the block is '1' block; otherwise, it is '0' block. In the same way, if the resulted density between each pair of block is lower than the specific threshold, it deems that there doesn't exist a relationship between them; otherwise, the relationship between them is added. Generally, the density of the whole input network is set to be the threshold. In this research, the block analysis discovers the new sociorelation among the blocks.

4 Understanding governance mechanisms and interorganizational relationships

This section examines the governance mechanisms and underlying interorganizational relationships at each governmental level and among multiple levels of government in the field of NPPA management. It provides a conceptual framework for understanding the intergovernmental and cross-sectoral network of NPPA management and its operation.

4.1 Governance mechanisms and cross-sectoral relationships in each governmental level

Responding to NPPAs requires a range of capabilities and skills, and overwhelms the jurisdictional government. In China, each jurisdictional government has conducted a number of interorganizational innovations (Mandell, 2003) and employed network governance mechanism to coordinate multiple separate administrative sectors toward common objectives (Lu, 2016). Meanwhile, the traditional bureaucratic structure also play an essential role to achieve rapid and coordinated response in the time-critical situation (Moynihan, 2008). Both hierarchical and network mechanisms play different roles depending on the underling interorganizational ties, and complement each other to improve collaboration in in field of NPPA management.

4.1.1 Hierarchical mechanism in NPPAs management

The command-and-control model is a typical tool of hierarchical mechanism for encouraging interorganizational collaboration in institutional emergency management system in China (Lu, 2016). In fact, the interorganizational hierarchies and centralized authority facilitate rapid and effective collaboration in the time critical situation during emergencies. In the Guangdong Provincial Government and Shenzhen Municipal Government, the institutional administrative structures formalize the hierarchical inter-organizational relationships among public organizations with NPPA management responsibilities. The hierarchical mechanism emphasizes the importance of a clear hierarchy of authority and tends to influence the behaviors of subordinate organizations through directives and imposing constraints. In the emergency management practice, the hierarchical mechanism provides an effective approach to regulate interorganizational exchanges and interactions for improving collaboration.

However, NPPA management require the capacities and skills of organizations outside the administrative structure of jurisdictional governments, such as the vertical management sectors affiliating to higher governments, private sectors and nonprofit organizations. The traditional hierarchical mechanism lack the capacity to coordinate organizations without hierarchical relationships. Moreover, hierarchical mechanism cannot adapt to the dynamic and complex environment during emergencies. Therefore, network mechanisms are added to hierarchical mechanism with in the emergency management system in each jurisdictional government toward managing interdependence and interaction among organizations in the field of NPPAs management.

4.1.2 NAO mode of network mechanism in NPPAs management

As previously discussed, planning and responding to NPPAs involves vertical management public sectors affiliating to higher government, private sectors, and nonprofit sectors, which are outside of the administrative structure of jurisdictional governments. The fragmented authority requires to build horizontal relationships falling outside the bureaucratic structure for improving collaboration among all the involved organizations. The network governance mechanism emphasizing trust and negotiation among organizations based on the horizontal relationships (Robins, 2011) is employed to facilitate collaboration among involving organizations, and complement with the hierarchical mechanism.

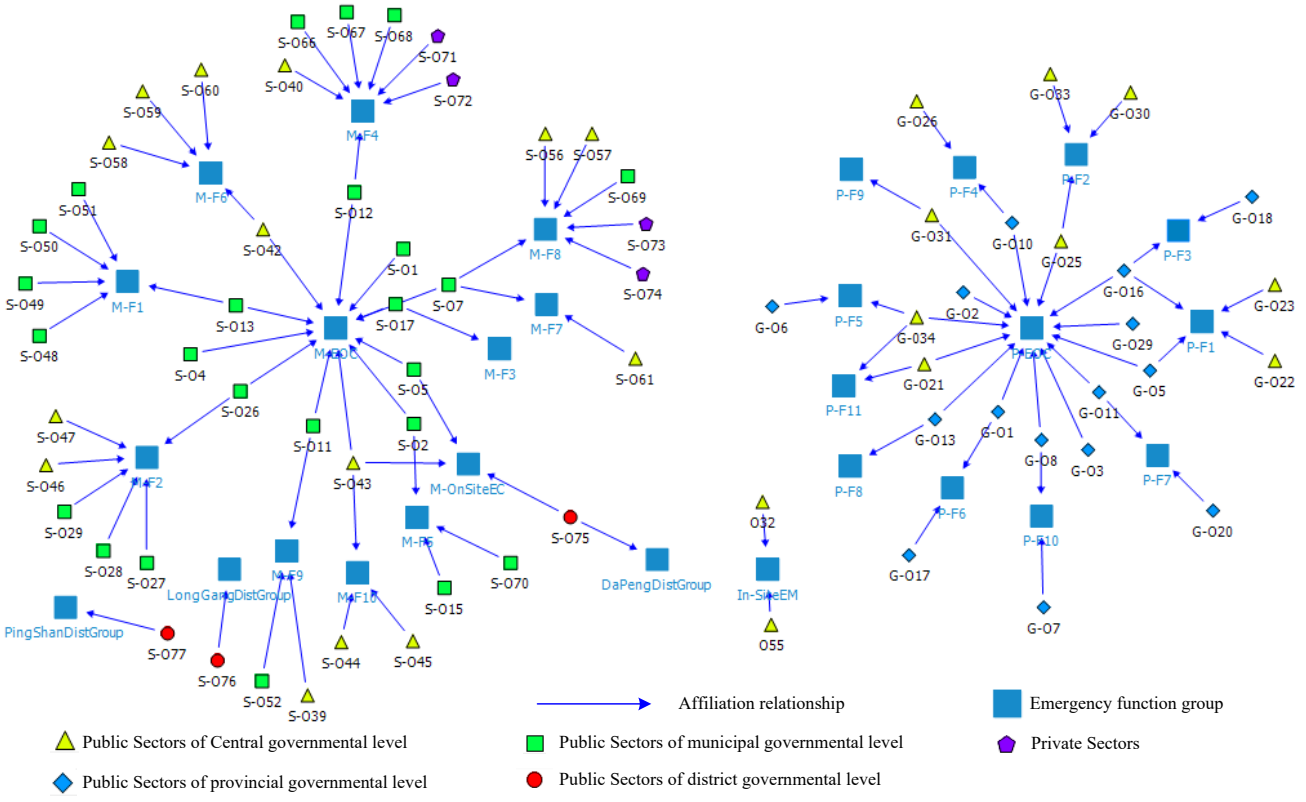
In this empirical context, the jurisdictional governments arranges a governmental sector to manage all the participating organizations in the governmental level, which function as network facilitator or broker. It is a separate and distinct administrative entity called network administrative organization (NAO) (Provan, 2010), intended not to only provide emergency service directives but also to manage and control the operations of the NPPA management network in the governmental level. In addition,

a broad structure called the emergency management committee is established to work alongside the NAO. The committee consists of a subset of organizations, which are formed to address strategic-level problems and concerns about NPPA management, leaving operational decisions and tasks to the NAO. Such arrangement improves the shared emergency situation, common identified objectives and problem, and consensus-based decision-making. The horizontal relationships among participating organizations and NAO are formalized and sustained. These relationships also depict how the involved organizations interact and collaborate with each other. The NAO mode of network governance mechanism provide an effective way to promote broad collaboration in emergency management. Moreover, it facilitate diverse collaborative partners to access a wide range of resources and information in this field.

4.1.3 Shared mode of network mechanism for performing emergency functions

Another policy tool for improving cross-sectoral collaboration is emergency function group. It groups organizations with similar resources and capabilities for delivering specific emergency services. The policy tool provides an interorganizational platform for improving repeated interactions and trust, which facilitates to form and sustain horizontal relationships among the involved organizations. In the prepare phase, all the involved organizations design the operation procedures together, and conduct joint training and exercises. Once NPPAs break out, the emergency function group is activated and all the members collaborate with each other to provide the specific emergency service. The aim is to achieve more streamlined, efficient, and effective emergency response operations. As discussion, the network mechanism based on the preexisting horizontal relationships improves collaboration among the members in the group, and the mode of network governance is akin shared governance (Provan, 2010). In the emergency function group, participants from the member organizations make decisions and manage network activities together.

In this section, affiliation networks are utilized to represent organizations and their corresponding emergency function group involving in NPPAs management in the provincial and municipal government levels. The affiliation networks describe the actors' affiliation relationships with social structures, such as professional associations, organizations, or social events (Hu, 2014). Detailed affiliation network in this empirical context is shown in Figure 2. All the organizations in the same emergency function group interact and collaborate with each other in NPPAs management. That provide the basis for identifing horizontal relationships among them.



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Principal emergency function groups: P-EOC, Emergency command group; **P-F1**, Environment monitoring group; **P-F2**, Communication group; **P-F3**, Emergency medical and radiation protection group; **P-F4**, Public security and traffic controlling group; **P-F5**, Decontamination group; **P-F6**, Propagation and information transmission group; **P-F7**, Hidden, evacuation, and settlement group; **P-F8**, Transportation group; **P-F9**, Electricity supplying group; **P-F10**, Logistics supporting group; **P-F11**, Meteorological group; **Municipal emergency function groups: M-EOC**, Emergency command group; **M-F1**, Emergency medical group; **M-F2**, Public security and traffic controlling group; **M-F3**, Hidden, evacuation, and settlement group; **M-F4**, Transportation group; **M-F5**, Propagation and information transmission group; **M-F6**, Communication group; **M-F7**, Electricity supplying group; **M-F8**, Logistics supporting group; **M-F9**, Environment monitoring and radiation protection group; **M-F10**, Decontamination group; **M-F11**, Meteorological group; **M-OnsiteEC**, Onsite emergency command group; **In-SiteEM:** Group of organizations in nuclear power plants.

Figure 2. Affiliation network of emergency function groups in NPPA management

As the above discussion of NPPA management practice, the hierarchical and network principles are combined and complement with each other for controlling the operations of NPPA management networks in each government level. The horizontal relationships do not replace the inter-organizational hierarchies in the bureaucratic structure; instead, they add one or more layers of interorganizational relationships (O'Toole, 2014).

4.2 Intergovernmental collaboration and relationships

Managing NPPAs overwhelms capabilities of emergency management network in one government level, and spans across boundaries of multiple levels of governments (Ansell, 2010). However, the emergency management network in each government level is designed and sustained independent; thus, how to improve collaboration and coordination among multiple levels of jurisdictional governments is an existing problem when tackling NPPAs. This section examines and analyzes governance mechanisms of regulating intergovernmental interactions and underlining interorganizational relationships which occur between provincial governmental and municipal government.

4.2.1 Hierarchical mechanism and inter-organizational hierarchy

Mobilizing operations across jurisdictional boundaries in vertical dimension always follows a top-down mandated approach to coordinate the interdependent interaction. In particular, the political-administrative structure is centralized, and the command and control model is always employed to address the coordination failure in emergency management (Guo, 2015). In China, the higher level government have the authority to direct and control the operation of subordinate governments, and government in lower levels reports the information of situation and response operation to higher level governments. Furthermore, the business sectors in higher level governments have work relationships with those in lower governmental level within the same business domain, thereby having the authority to provide resource support and guidance to them in emergency management. In fact, that is a kind of hierarchical mechanism, and play the essential role to coordinate inter-governmental operations. Moreover, it relies on the interorganizational hierarchies, which are defined formally in the administrative structure in China. The intergovernmental ties are mainly of this kind. By the interorganizational hierarchical relationships, intergovernmental collaboration can be achieved rapidly. However, the hierarchical mechanism lack sufficient capability to adapt to the dynamic environment and to satisfy the required resources.

4.2.2 Network mechanism and horizontal relationship

Leveraging various resources effectively from different governmental levels require more than the top-down initiative and the hierarchy governance mechanism. Among organizations responsible for NPPAs management that are outside the line of formal authority, other interorganizational arrangements and governance mechanisms are required when they find that mutual interests are served through reciprocal collaboration. Therefore, network mechanism is essential for improving cross-boundary behavior of multiple organizations at different governmental levels. In contrast to the hierarchical mechanism, negotiation and communication play the main role in network mechanism to improve collaboration among organizations. Common understanding and shared values are important in this governance mechanism.

Therefore, in the practice of NPPA management, except for hierarchical relationships among organizations in multiple government levels, the horizontal interorganizational relationships are formed and sustained among them. Intergovernmental relationships could take the form of horizontal network ties to improve intergovernmental collaboration and coordination (O'Toole, 2004). For example, the sectors without hierarchical relationship and in different government levels communicate, negotiate, and interact with other sectors to share resources and information during NPPAs management. In fact, various governance mechanisms are simultaneously employed to regulate the intergovernmental interactions and operation relying on interorganizational relationships in hierarchical and horizontal dimension in NPPA management.

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5 Network analysis of the emergency management network

The previous section introduces governance mechanisms and underlining inter-organizational relationships in Chinese emergency management system of NPPA. The institutional NPPA management networks in each government level are designed and sustained independently. Once the nuclear pollution exceeds the boundary of nuclear power plants, a holistic network consisting of networks in multiple governmental levels are established rapidly. The network structure affects the inter-governmental and cross-sectoral collaboration, and determine the success or failure of the NPPA management (Boin, 2014). In this section, the holistic intergovernmental and cross-sectoral network consisting of provincial and municipal NPPA management networks is built up, visualized, and analyzed by the SNA tool NetMiner. The characteristics of network structure are examined by network measures, and their effects on interorganizational collaboration and interaction are also analyzed in the empirical context.

5.1 Identifying the participating organizations

The participating organizations are defined as those with formal emergency management responsibilities or those who perform tasks toward achieving the objectives of NPPA management. These organizations are identified using two complementary procedures. First, content analysis of laws, regulations, and official documents about NPPAs management are used to identify organizations with explicit responsibilities. In particular, the emergency operation plan of NPPAs and their supporting procedures in provincial and municipal governments are the main data sources for identifying such organizations. Second, the classical experience-based method is conducted to verify the organizations in the initial list and identify new organizations for appending to the list. The key informants from the Department of Environmental Protection of Guangdong Province and the Emergency Management Office of Shenzhen City are interviewed. In fact, the holistic NPPA management network consists of provincial network of municipal network. Organizations in each NPPA management network in each governmental level are identified independently. As shown in Table 2, 111 organizations are identified, consisting of 34 organizations in network of provincial governmental level and 77 organizations in network of the municipal governmental level.

Table 2. The participating organizations in each emergency management network

Organization type \ NPPA management network		Organizations in Municipal network	Organizations in Provincial network
Public sectors	Central government level	17	13
	Principal government level	0	21
	Municipal government level	53	0
Private sectors		4	0
Nonprofit sectors		0	0
Total number of organizations		77	34

In networks of each governmental level, the participating organizations consist of public and private sectors, proving that each government has not established collaborative relationships with non-profit sectors. The public sectors are categorized into the Committee of the Communist Party of China and its departments and mass organizations, jurisdictional governments and governmental sectors, and public institutions and state-owned enterprises. That highlights the need to attract non-profit sectors to participate in NPPA management. In addition, the organization list of each network shows that the involved public sectors affiliate to more than one government level. In the emergency management network of provincial and municipal governmental levels, the participating organizations includes jurisdictional management sectors and vertical management sectors affiliated with upper-level governments. That demonstrates multiple power sources and fragmentation of authorities in the NPPA network. The traditional hierarchical mechanism fails to coordinate all of the participants.

5.2 Evaluating the interorganizational relationships

NPPA management involves numerous tasks that are beyond the capability of an organization, and require collaboration and interaction among all the involved organizations. In this research, the interorganizational relationships represent interdependence, exchanges, and interactions among organizations during planning and responding to NPPAs, such as information reporting, command issue and commitment, emergency service, resource and expertise providing, information and resource sharing, and joint decision-making and implementation (Ansell, 2007). As discussed in Section 4, in this multiple organizational environment, an organization interact with others in vertical and horizontal dimension, and multiple governance mechanisms are used to regulate interactions among involved organizations to facilitate collaboration. Thus, the interorganizational relationships are

divided into hierarchical relationships and horizontal ones, representing different types of interactions. The NPPA management network consists of all the involved organizations and different relationships among them, which shape the interactions and collaboration across organizational boundaries in this specific field.

However, identifying the collaborative interorganizational relationships remains problematic (Robinson, 2012). In this research, the interorganizational relationships are formalized by the institutional arrangement. From the data source, the political-administrative structure in each level of government and between different levels of government are identified and presented by hierarchical relationships. In addition, the mandated or voluntary horizontal relationships are also identified by evaluating whether the interactions exist among the identified organizations. From the content analysis of emergency preparedness plans and interviews of key informants, 106 hierarchical relationships, and 286 horizontal relationships are identified. In fact, the entire NPPA management network is a composite network shaped by the interweaving of these two types of interorganizational relationships.

5.3 Visualizing the whole emergency management network

Figure 3 shows the intergovernmental and cross-sectoral network of NPPA management in the empirical context. In fact, it consists of two institutional networks in Guangdong Province and Shenzhen City, which are independent, but interact with each other. As shown in Figure 3, hierarchical and horizontal interorganizational relationships interweave with each other in the whole network, indicating that multiple governance mechanisms are utilized during NPPAs management. In the NPPA management network of Guangdong Province, the Department of Environmental Protection occupies the central position and acts as the NAO to manage the network operation. Meanwhile, the Emergency Management Office of Shenzhen City occupies the central position of the network in the municipal governmental level and coordinates the network actors. In the provincial and municipal networks, the NAOs rely on horizontal relationships to integrate the capabilities of vertical management public sectors, jurisdictional public sectors, and private sectors for addressing the fragmentation of administrative authority. Furthermore, between the organizations in provincial governmental level and those in municipal governmental level, the interorganizational interactions are mainly based on hierarchical relationships. That demonstrates the hierarchical mechanism is used to regulate intergovernmental interactions. In fact, the hierarchical mechanism provides capability to mobilize public organizations affiliating to different levels of jurisdictional governments and enhance rapid collaboration among them.

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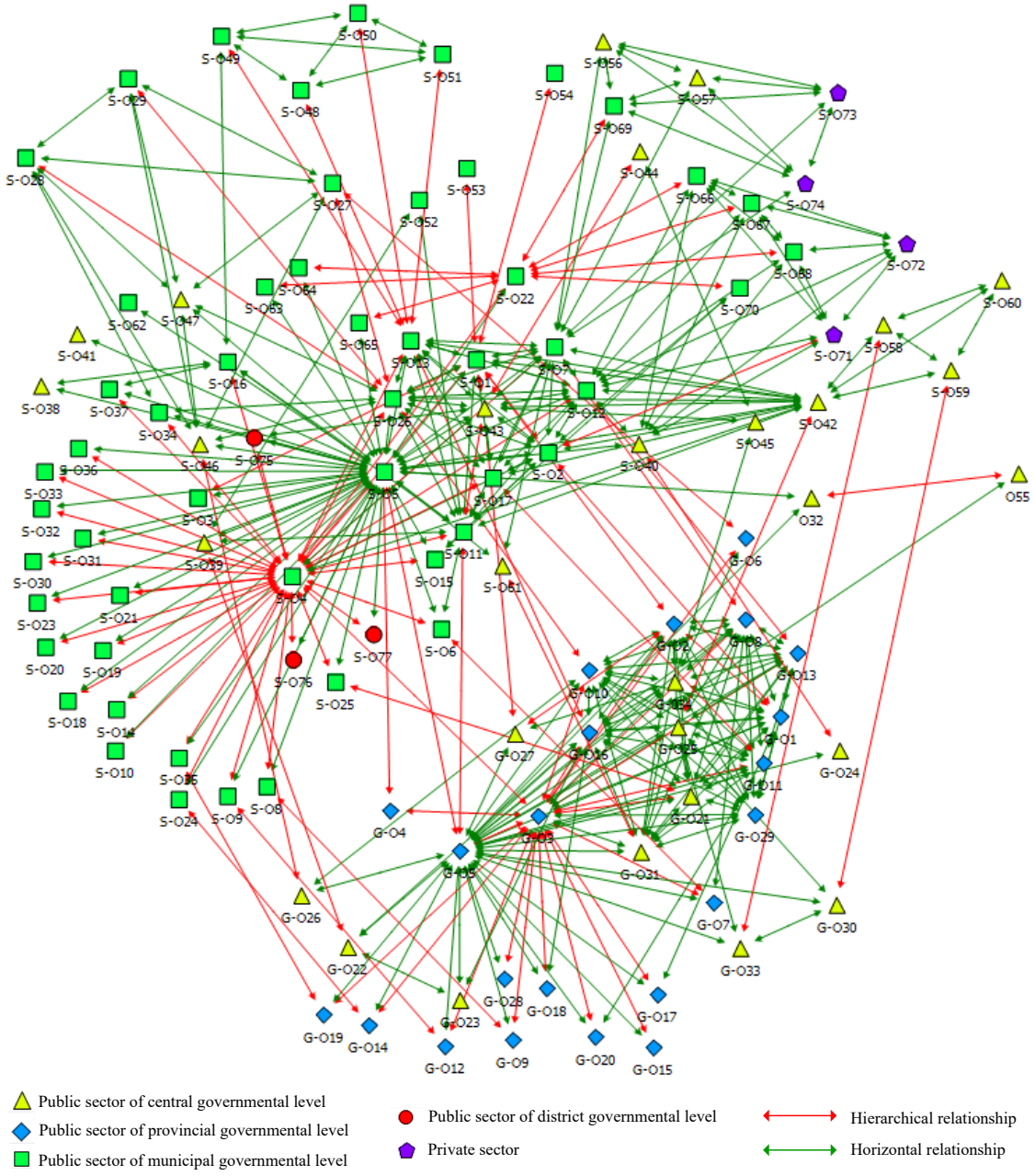

Figure 3. The intergovernmental and cross-sectoral network of NPPA management

5.4 Network analysis

In this section, the SNA tool NetMiner is used to analyze and measure structural characteristics of the emergency management network for NPPA management, at the levels of the node, the link, subset of nodes and the whole network. Network analysis results based on SNA provide an effective method to assess the level of collaboration within the network and understand operation process of the network in this specific field.

5.4.1 Characteristics of the whole network

In the whole emergency management network, there are 784 links among nodes, the average degree is 7.063, and the density of the network is 0.064. That indicates the whole network of NPPAs management is sparse. The mean distance between pairs of nodes is 2.549, indicating that one network actor can connect with another actor in a few steps; thus, information and resources can be shared easily in this designed institutional network.

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5.4.2 Node centrality analysis

(1) Degree centrality analysis

In this study, the maximum degree centrality is 0.473, the minimum degree centrality is 0.009, and the mean value is 0.064. Table 3 lists the top 12 organizations ranked by their degree centrality. Among these organizations, seven are public organizations at the municipal governmental level and the other five are from the provincial governmental level. In addition, the network degree centralization index of the whole network is 41.23%. It measures centralization of the network, and indicates that all the organizations concentrate only a few organizations in the central position of the whole network, such as Emergency Management Office of Shenzhen City and Environment Protection Department of Guangdong Province.

Table 3. The top 12 organizations ranked by degree centrality of organizations

No.	Organization name	Code	Degree Centrality
1	Emergency Management Office of Shenzhen City	S-O5	0.473
2	People's Government of Shenzhen	S-O4	0.345
3	Environment Protection Department of Guangdong Province	G-O5	0.309
4	People's Government of Guangdong Province	G-O3	0.236
5	Economic and Trade and Information Commission of Shenzhen	S-O7	0.164
6	Transportation Department of Shenzhen	S-O12	0.164
7	Public Security Bureau of Shenzhen	S-O26	0.164
8	Health and Family Planning Commission of Guangdong Province	G-O16	0.155
9	Communication Bureau of Guangdong Province	G-O25	0.145
10	Southern War Zone of Chinese People's Liberation Army	G-034	0.145
11	Environment Protection Department of Shenzhen	S-O11	0.145
12	Health and Family Planning Commission of Shenzhen	S-O13	0.145

(2) Betweenness centrality analysis

The betweenness centrality of node measures the extent to which a specific organization take on brokerage roles between pairs of organizations in the NPPA management network. The top 10 organizations with the highest betweenness centrality are listed in Table 4. These organizations with provide the shortest communication channel for other organizations and control the information in the NPPA management network. As shown, the Emergency Management Office of Shenzhen City and the Environment Protection Department of Guangdong Province have relatively higher node betweenness centrality. The Emergency Management Office of Shenzhen City is the highly centralized broker in the municipal NPPA management network, while the Environment Protection Department of Guangdong Province is the broker in the provincial network. In network of each government level, the governance mechanism is the NAO mode of network governance, and the above two organizations are set up specifically to govern the network and coordinate network activities. As a collaborative strategy of NPPA management, it emphasizes the directive connection to diversified partners and provides access to a wide range of resource and information for improving the broad collaboration.

Table 4. The top 10 organizations ranked by node betweenness centrality

No.	Organization name	Code	Betweenness Centrality
1	Emergency Management Office of Shenzhen City	S-O5	0.390
2	Environment Protection Department of Guangdong Province	G-O5	0.201
3	People's Government of Shenzhen City	S-O4	0.157
4	Economic and Trade and Information Commission of Shenzhen	S-O7	0.087
5	People's Government of Guangdong Province	G-O3	0.079
6	Health and Family Planning Commission of Shenzhen	S-O13	0.072
7	Transportation Department of Shenzhen City	S-O12	0.062
8	Communication Management Bureauof Shenzhen	S-O42	0.052
9	Public Security Bureau of Shenzhen	S-O26	0.051

10	Shenzhen Municipal Commission of Chinese Communist Party	S-O1	0.045

(3) Closeness centrality analysis

In closeness centrality analysis, the maximum value is 0.651, the minimum value is 0.331, the mean value is 0.399, and the standard deviation is 0.056. The mean value shows that the distances among organizations are very close, and the information can be communicated in the network. Moreover, the standard deviation indicates the minimal difference among the closeness centrality values of network actors. The closeness centrality analysis demonstrates that arranging the brokerage organizations in the network, such as Emergency Management Office of Shenzhen City and the Environment Protection Department of Guangdong Province, improves information, resources, and knowledge sharing in the NPPA management network effectively.

(4) Effect centrality analysis

In the effect centrality analysis, the strength of the transmitted effect of the node is set at 0.5. The concentric map of effect centrality is shown in Figure 4. The higher the effect centrality value of a node, it is closer to the center. The number beside each circle in the figure represents the effect analysis value of the nodes locating on the position of this circle. If a node locates at intermediate zone between two circles, its effect analysis value ranges between the numbers associating to them. As shown in Figure 4, only five of all the nodes have relatively higher effect centrality value, whereas most of the nodes have lower effect centrality values, and locates in the periphery of the map. The organizations with higher effect centrality value include the Emergency Management Office of Shenzhen City, the People's Government of Shenzhen City, the Environment Protection Department of Guangdong Province, the People's Government of Guangdong Province, and the Commission of Chinese Communist Party of Shenzhen City. Notably, three of these organizations are from the municipal governmental level, and the other two are public organizations from provincial governmental level. Establishing the interorgnizational collaborative platform for these organizations with higher effect centrality values will improve collaboration and coordination in the whole network, and reduce the cost of collaboration.

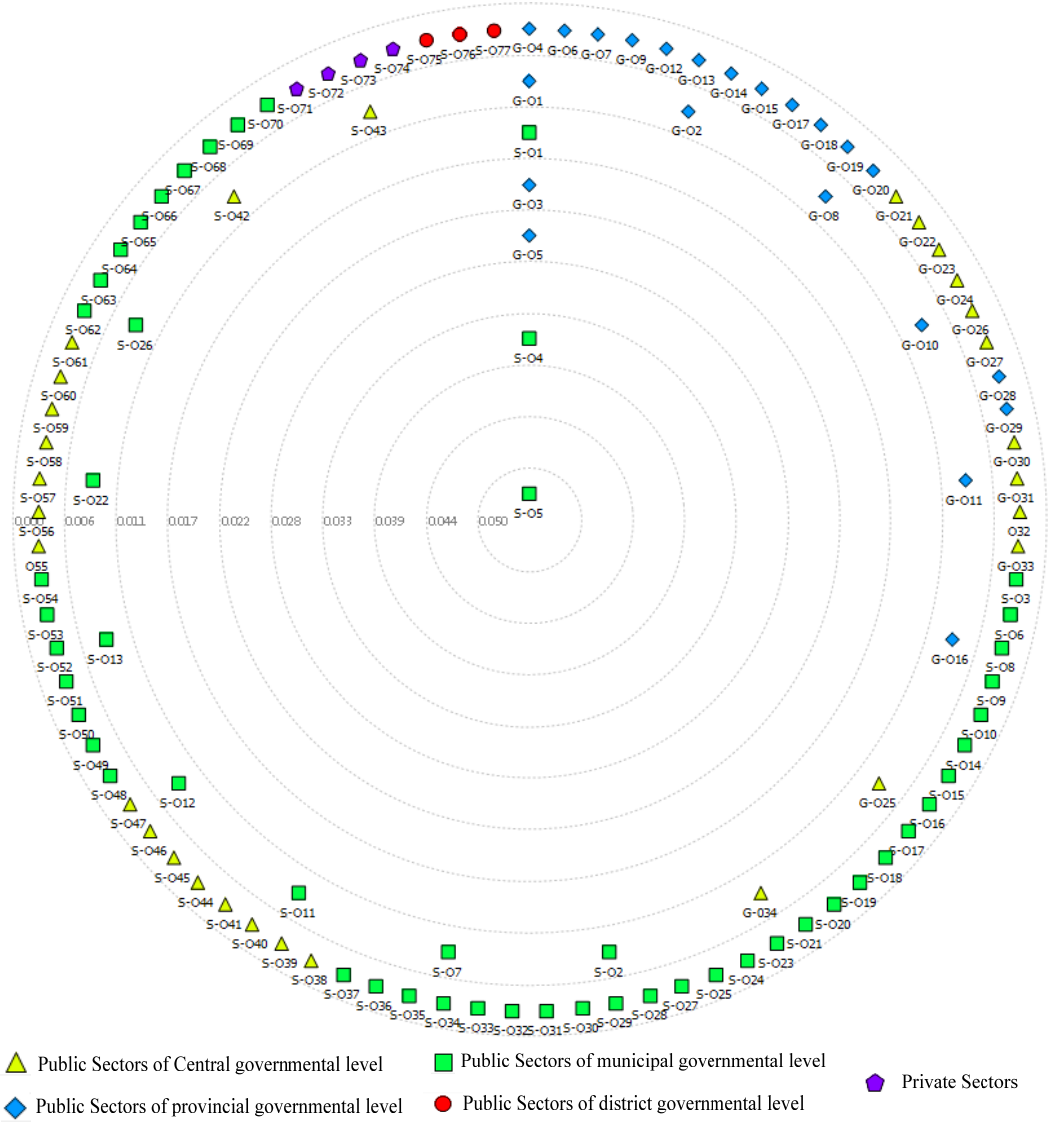

Figure 4. The concentric map of effect centrality analysis

5.4.3 Link betweenness centrality analysis

In the whole NPPA management network of management, link betweenness centrality analysis can help identify the most important interorganizational relationships for information communication. Table 5 lists the top 10 links in the whole network ranked by link betweenness centrality. Designing and sustaining such links play essential roles in improving the effectiveness of the whole network. Thus, more attentions should be played to sustain interorganizational relationships with higher value of link betweenness centrality. The most important identified links are the link between Environment Protection Department of Guangdong Province (G-O5) and Emergency Management Office of Shenzhen City (S-O5) and link between the People's Government of Guangdong Province (G-O3) and People's Government of Shenzhen (S-O4). These links are intergovernmental relationships and serve as the most important information conduits in the whole network. This analysis result indicates that these hierarchical relationships that occur between provincial governmental level and municipal level play more important role for coordinating network operation process.

Table 5. The lists of the top 10 links in the network ranked by link betweenness centrality

No.	Description of interorganizational links	Node BC
1	Link between Environment Protection Department of Guangdong Province (G-O5) and Emergency Management Office of Shenzhen City (S-O5)	631.328
2	Link between People's Government of Guangdong Province (G-O3) and People's Government of Shenzhen City (S-O4)	303.796

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4	Link between Emergency Management Office of Shenzhen City (S-O5) and Economic and Trade and Information Commission of Shenzhen City (S-O7)	155.057
3	Link between Environment Protection Department of Guangdong Province (G-O5) and Environment Protection Department of Shenzhen City(S-O11)	153.066
5	Link between Emergency Management Office of Shenzhen City (S-O5) and Marine Bureau of Shenzhen City(S-O40)	150.362
8	Link between Emergency Management Office of Shenzhen City (S-O5) and Health and Family Planning Commission of Shenzhen City (S-O13)	133.038
6	Link between Health and Family Planning Commission of Guangdong Province (G-O16) and Health and Family Planning Commission of Shenzhen City(S-O13)	128.172
7	Link between Economic and Trade and Information Commission of Guangdong Province (G-O8) and Economic and Trade and Information Commission of Shenzhen City(S-O7)	126.919
9	Link between Emergency Management Office of Shenzhen (S-O5) and Shenzhen Team of Chinese Armed Police (S-O46)	125.398
10	Link between Emergency Management Office of Shenzhen (S-O5) and Shenzhen Border Team of Chinese Armed Police (S-O47)	113.837

5.4.4 Clique analysis

All of the cliques identified in the NPPAs emergency management network are shown in Table 6. Clique analysis provide an effective way to study the cohesion structure and identify the interorganizational integration in the NPPAs emergency management network. The clique analysis results indicates there are a total of 66 cliques in the whole network. Only five cliques are composed of more than four organizations. Most cliques consist of three and four organizations. The majority of the cliques are composed of organizations from the same levels of government. That shows the designed NPPA management network demonstrates the characteristic of selective integration. Some organizations are members of a tightly connected clique, whereas others are completely isolated from this clique. This network structure characteristic proves that the closure approach is extensively applied in NPPAs management for improving interorganizational collaboration. In addition, from the clique analysis result, multiple cliques have common member organizations. The Emergency Management Office of Shenzhen City (S-O5) is the common member of 38 cliques, and the Environment Protection Department of Guangdong Province (G-O5) is the common member of 18 cliques. In fact, these organizations act as the boundary spanners that provide an information channel among different cliques. The main tasks of these organizations are to collect information and share information with other member organizations. It plays a significant role during information communication in NPPA management network.

Table 6. The cliques identified in the NPPA management network

No.	Members	Size	Cohesion index	No.	Members	Size	Cohesion index
1	S-O5, S-O4, S-O11, S-O2, S-O7, S-O1, S-O12, S-O13, S-O17, S-O26, S-O42, S-O43	12	10.241	34	S-O5, S-O46, S-O26, S-O47	4	6.028
2	S-O5, S-O4, S-O11, S-O6	4	4.367	35	S-O5, S-O61, S-O7	3	4.836
3	S-O5, S-O4, S-O11, S-O16	4	4.28	36	S-O5, S-O63, S-O22	3	5.586
4	S-O5, S-O4, S-O8	3	3.724	37	S-O5, S-O64, S-O22	3	5.586
5	S-O5, S-O4, S-O9	3	3.724	38	S-O5, S-O65, S-O22	3	5.586
6	S-O5, S-O4, S-O10	3	3.767	39	G-O2, G-O5, G-034, G-O8, G-O10, G-O11, G-O13, G-O16, G-O21, G-O25, G-O29, G-O31, G-O3, G-O1	14	23.825
7	S-O5, S-O4, S-O14	3	3.767	40	G-O2, G-O5, G-034, G-O27	4	7.509
8	S-O5, S-O4, S-O15, S-O2	4	4.412	41	G-O3, G-O5, G-O8, G-O7	4	6.388
9	S-O5, S-O4, S-O18	3	3.767	42	G-O3, G-O5, G-O9	3	5.684
10	S-O5, S-O4, S-O19	3	3.767	43	G-O3, G-O5, G-O12	3	5.684
11	S-O5, S-O4, S-O20	3	3.767	44	G-O3, G-O5, G-O14	3	5.684
12	S-O5, S-O4, S-O21	3	3.767	45	G-O3, G-O5, G-O15	3	5.786
13	S-O5, S-O4, S-O22	3	3.447	46	G-O3, G-O5, G-O17, G-O1	4	6.485
14	S-O5, S-O4, S-O23	3	3.767	47	G-O3, G-O5, G-O18, G-O16	4	6.294
15	S-O5, S-O4, S-O24	3	3.724	48	G-O3, G-O5, G-O19	3	5.684
16	S-O5, S-O4, S-O25	3	3.724	49	G-O3, G-O5, G-O20, G-O11	4	6.485
17	S-O5, S-O4, S-O30	3	3.767	50	G-O3, G-O5, G-O28	3	5.786
18	S-O5, S-O4, S-O31	3	3.767	51	G-O3, G-O6, G-034	3	8.308
19	S-O5, S-O4, S-O32	3	3.767	52	G-O10, G-O5, G-O26	3	7.043
20	S-O5, S-O4, S-O33	3	3.767	53	G-O16, G-O5, G-O23, G-O22	4	9.304
21	S-O5, S-O4, S-O34, S-O26	4	4.28	54	G-O25, G-O5, G-O33, G-O30	4	9.304
22	S-O5, S-O4, S-O35	3	3.724	55	S-O27, S-O26, S-O28, S-O29,	6	35

					S-O46, S-O47		
23	S-O5, S-O4, S-O36	3	3.767	56	S-O28, S-O26, S-O34	3	14.727
24	S-O5, S-O4, S-O37, S-O16	4	4.92	57	S-O44, S-O43, S-O45	3	23.143
25	S-O5, S-O4, S-O75, S-O43	4	4.458	58	S-O48, S-O13, S-O49, S-O50, S-O51	5	40.769
26	S-O5, S-O4, S-O76	3	3.767	59	S-O52, S-O11, S-O39	3	20.25
27	S-O5, S-O4, S-O77	3	3.767	60	O55, G-O5, O32	3	9.818
28	S-O5, G-O5, O32	3	3.904	61	S-O56, S-O7, S-O57, S-O69, S-O73, S-O74	6	45
29	S-O5, G-O5, S-O11	3	3.375	62	S-O58, S-O42, S-O59, S-O60	4	30.571
30	S-O5, S-O3, S-O1	3	5.143	63	S-O66, S-O67, S-O68, S-O12, S-O40, S-O71, S-O72	7	40.444
31	S-O5, S-O38, S-O16	3	6	64	S-O66, S-O67, S-O68, S-O22	4	22.526
32	S-O5, S-O39, S-O11	3	4.909	65	S-O70, S-O2, S-O15	3	20.25
33	S-O5, S-O40, S-O12	3	4.5	66	S-O71, S-O12, S-O2	3	9.529

5.4.5 Brokerage analysis

In this analysis process, all the involved organizations are classified according to the emergency functions detailed in Section 4.1. If a given organization performs more than one emergency function, it is considered to be the member of each block representing those emergency function groups. Consequently, the whole NPPA management network consists of a number of overlapping blocks. Each block consists of organizations performing the same emergency function. Counting the number of tied triads connecting nodes within same block from triads connecting nodes in different blocks is possible. Table 5 shows the brokerage analysis results of the top 10 organizations with the highest total scores. All of these organizations should utilize various information communication technologies to help organizations share information, establish communication relationships with the partner organizations. As shown, the role liaison is the most remarkable role for the Emergency Management Office of Shenzhen City (S-O5), the People's Government of Shenzhen City (S-O4), and the Environment Protection Department of Guangdong Province (G-O5) in each emergency function group. The organizations acting as liaison receive information from one block and send it to a different block, and it belongs to another block. That indicates their main brokerage role is to communicate information and coordinate other organizations in different emergency function groups. In addition, the brokerage role of consultant for the Emergency Management Office of Shenzhen City (S-O5) and the People's Government of Shenzhen City (S-O4) is also distinguishable. That demonstrates these organizations in the same emergency function group also rely on them to transmit information. For all of the other organizations in Table 7, the liaison role is more remarkable than other brokerage roles, and none assumed the consultant role.

Table 7. The brokerage analysis results of the whole NPPA management network

Node code	Function group	Gatekeeper	Representative	Consultant	Liaison	Total
S-O5	M-OnSiteEC	100	98	775	2,528	3,501
	M-EOC	432	421	775	1,873	3,501
S-O4	M-EOC	275	275	460	894	1,904
G-O5	P-F1	106	106	56	1,296	1,564
	P-EOC	278	278	56	952	1,564
G-O3	P-EOC	154	154	42	418	768
S-O26	M-F2	120	120	0	130	370
	M-EOC	84	84	0	202	370
S-O12	M-F4	140	140	0	88	368
	M-EOC	86	86	0	196	368
S-O7	M-F8	120	120	0	126	366
	M-F7	26	26	0	314	366
	M-EOC	87	87	0	192	366
S-O13	M-F1	100	100	0	132	332
	M-EOC	77	77	0	178	332
S-O11	M-F9	50	50	2	164	266
	M-EOC	59	59	2	146	266
G-O16	P-F1	52	52	0	138	242
	P-F3	25	25	0	192	242
	P-EOC	61	61	0	120	242

5.4.6 Block analysis

In the block analysis, all the organizations are also divided into multiple subsets called blocks according to emergency function group as the brokerage analysis. The block analysis present the interactive relationships among these emergency function group, provide the insight to the NPPA management network. The SNA tool Netminer is utilized to analyze the relationships among these blocks. The map of block analysis is shown in Figure 5. As shown, P-EOC block (representing the emergency

command group at the provincial governmental level) and M-EOC block (representing the emergency command group at the municipal governmental level) occupy the central position in the provincial and municipal NPPA management networks. Second, the M-OnSite block (representing the on-site emergency command group) connects with the M-EOC block, and no link exists between the M-OnSite block and the P-EOC block. The organizations in the provincial NPPA management network dispatch responders to the scene of this accident. Moreover, the onsite emergency command group represented by M-OnSite should interact with organizations from provincial governmental level to report information, obtain resource. Thus, the absence of interactive relationship between M-OnSite block and the P-EOC block poses barriers for collaboration in NPPA management. Third, there is not link between the M-EOC block and the In-SiteM block, which represent the group of organizations responding to the NPPAs in the area of the nuclear power plants. That leads to the municipal government cannot obtain the situation information of the accident timely, and cannot collaborate with the operational enterprise of nuclear power plants belong to the In-SiteM block. Finally, no direct interactive relationship exists between the blocks performing the same types of emergency function in the provincial and municipal government levels. For example, P-F10 block and M-F8 block are the same emergency function groups providing electricity, and should interact and collaborate with each other in NPPA management. However, the absence of interactive relationship between them makes that it is difficult to provide emergency services collaboratively.

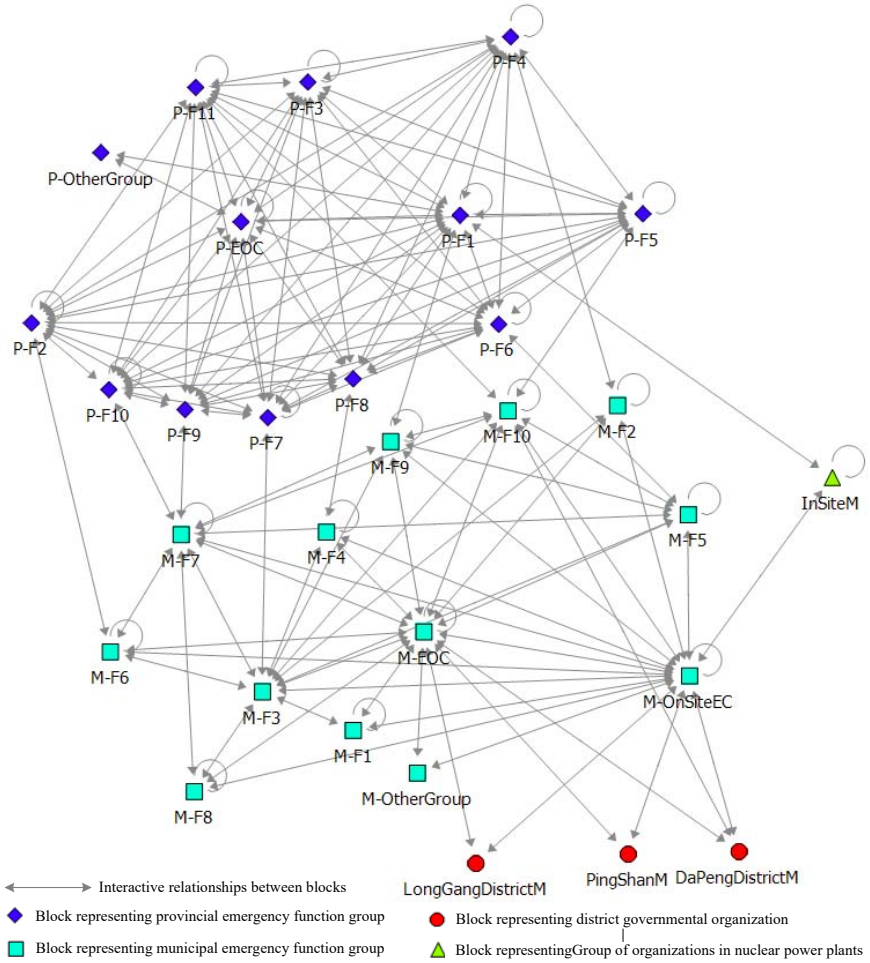

Figure 5. The map of block analysis of the emergency function groups

6. Discussions and implications

In the current time, the number of nuclear power plants increases rapidly, and how to address the disastrous situation caused by NPPAs is an existing problem in China. From the empirical research of the earliest nuclear power plants in China, this study investigates and conceptualizes the governance mechanisms for improving inter-organizational collaboration in the Chinese political-administrative context. The intergovernmental and cross-sectoral network structure of NPPAs management are examined and analyzed based on SNA. From the network perspective, the characteristic of NPPAs

management network are examined and the obstacles of effective collaboration are discovered in Section 5. In this section, how to improve interorganizational collaboration in NPPAs management is presented and discussed in China.

As mentioned in Section 5.1, the current emergency management system of NPPAs in China mainly relies on the resources and capabilities of public sectors. Only a few private organizations are involved in the municipal NPPAs management network, and non-profit organizations are absent in the network. However, private and non-profit sectors can provide diversified resources and capabilities beyond the public sectors. That is essential for satisfying requirements of NPPAs management. Especially, private sectors and non-profit can provide emergency services with lower cost and higher quality, such as transportation, logistics support, communication support, evacuation and settlement. Therefore, public sectors in emergency function groups, such as transportation group, communication group, hidden, evacuation, and settlement group, logistics supporting group, should establish collaborative relationships with private and non-profit organizations, and integrating their resources and capabilities for providing the emergency services together.

Secondly, unlike the other network in most of the existing literatures (Kapucu, 2010; Mandell, 2003), the NPPAs management network is a hybrid network (Moynihan, 2007) shaped by the interweaving of the hierarchical and horizontal interorganizational relationships. Especially, in Chinese centralized political-administrative structure, NPPA management networks add one or more layers of horizontal relationships for employing multiple governance mechanisms on the hierarchical structure of public organizations. In each level of jurisdictional government, the hierarchy mechanism is still the traditional tool for achieving rapid coordinated response (Moynihan, 2007). That is crucial in NPPAs management. In particular, collaboration among multiple levels of jurisdictional governments are mainly achieved by established and sustained the interorganizational hierarchies. Meanwhile, the network governance mechanism is required along with the hierarchy mechanism to address the fragmentation of authorities and to enhance collaboration. This empirical research proves that the hierarchy mechanism and the network mechanism based on trust are not mutually exclusive; instead, they complement each other in the NPPA management context. In fact, a hybrid governance mode, which is the combination of hierarchical, market, and network governance mechanism, takes into effects for improving collaboration among public, private and non-profit organizations in NPPAs management.

Thirdly, NPPAs management network demonstrates the characteristics of selective integration. From the evidences of network analysis, both brokerage and closure strategies are employed for improving interorganizational collaboration. The brokerage strategy emphasizes the use of diverse participating organizations to provide access to a wide range of information and resources. The organizations acting as bridges provide access to novel resources and new information for other partner organizations. In this research, the Emergency Management Office of Shenzhen City (S-O5) and the Environment Protection Department of Guangdong Province (G-O5) are the core of the network of each governmental level respectively, and prioritize the creation of new partnerships with other organizations. In this research, such organizations are list in Table 4, whose communication infrastructures and capacities should be paid attention to. Moreover, a forum for coordinating efforts of numerous responsible organizations should be established to build and sustain relationships among them in the practices. On the other hand, the closure strategy emphasizes collaboration only with those organizations with similar capacities to overcome communication barriers and cultural conflicts. Such strategy allows these organizations to increase repeated interactions and trust building within designed emergency function groups, which is effective for developing common operational picture and cognition (Comfort, 2007). This strategy typically focuses on creating and maintaining network ties by designing and using exercises in NPPAs management practice. However, building and sustaining the interorganizational collaborative relationship is costly. Therefore, only a small number of organizations participates in an emergency function group, and the involved organization takes considerable time and efforts to build and maintain such relationships. In addition, the existing inter-organizational relationships takes on different levels of importance in the communication process of the NPPAs management network. The relationships listed in Table 5 have higher link betweenness centrality, and play more important roles in NPPAs management. Therefore, those interorganizational relationships should be paid more attention to be sustained.

Finally, from the block analysis in Section 5.4.6, there doesn't exist interactive relationships between several pairs of emergency function groups providing the same functions in provincial and municipal governmental level. That inhibits the

integration of emergency services and resources of the same type and reduces intergovernmental collaboration. Therefore, organizations in the same emergency function groups at different governmental levels, such as logistics supporting groups in municipal and provincial governmental level (represented by P-F10 and M-F8), should build and sustain relationships with each other for improving collaboration. In addition, the on-site emergency command group (represent by M-OnsiteEC) is responsible for coordinating responders and resources affiliating to organizations from different government level at the accident site. It should establish collaborative relationships with the emergency command group in the provincial governmental level (represent by P-EOC). In the current institutional NPPA management network, the directive interaction between the operation enterprise of the nuclear power plant and municipal government doesn't exist. The NPPAs management regulation should be reformed to allow the operation enterprise of the nuclear power plant to report to the Emergency Management Office of Shenzhen City directly for achieving coordinated operations between the in-site response and the off-site response around the nuclear power plant, which is mainly performed by the municipal jurisdictional government.

7. Conclusions and future work

NPPAs management involves responsibilities of multiple jurisdictional governments and requires complex interaction and coordinated efforts of numerous organizations. The intergovernmental and cross-sectoral network provides an arrangement to enable multiple organizations with diversified capabilities to work together effectively toward the common objective of addressing NPPAs. This research investigates and conceptualizes governance mechanisms and associated interorganizational relationships involving in each governmental level and between multiple jurisdictional governments in the field of NPPAs management. The developed political-administrative structure are deemed to improve collaboration among involved organizations. Unlike most of the existing literature, in which the network mechanism are explained via a contrast with hierarchical mechanism; instead, they are discovered to play essential roles together and complement with each other. For intergovernmental relationships, the hierarchical mechanism is the main role to improve collaboration, and the network mechanism is its auxiliary. NPPAs management network is a hybrid network consisting of hierarchical and horizontal relationships, which provides the flexibility and achieve rapid coordination in the time-critical context. Another contribution of this research is to construct the inter-governmental and cross-sectoral network in an empirical case, and employ SNA to analyze of the network structure at the levels of the node, link, subset of the node, and entire network. The network structural characteristics and their impact on interorganizational interactions are examined and discussed. A number of managerial implications for improving inter-organizational collaboration in the NPPA management network are present in this field.

The network in this research is formed through mandate and are defined by the regulations; thus, a lack of consideration exist regarding emergent participating organizations and interorganizational relationships in NPPAs management. The formal emergency management network, which disregards how emergent relationships typically form and how they are sustained, may not operate as intended. The gap between the formal network and the actual emergency response network provides a future research direction.

Acknowledgment

The work was supported by National Science Foundation Grant of China (Project No. 71303093), Hong Kong Scholar Program, Humanities and Social Science Youth Fund of the Ministry of Education in China (Project No. 13YJC630145) and the Fundamental Research Funds for the Central Universities of China (Project No. 21612301).

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