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A Study on the Construction of Cross-Regional Emergency Management System From a Globalization Perspective

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Abstract
From a perspective of globalization, the dynamic network which is able to transfer the information of natural disasters and emergencies, command and deploy personnel and relief materials is a cross-regional system of systems. Since there are many systems in this field, it is necessary to build an emergency management system by reusing and integrating the existing systems. Firstly, we introduce the concept and features of system of systems; secondly, we elaborate that emergency management system can be regarded as a system of systems. Then, we put forward the concept of meta-structure for system-based communication, making the structure and functions of system of systems more understandable. Finally, based on the national information infrastructure platform, we build the logic model of China emergency management system of systems from a globalization perspective.

Key words: Emergency management; System of systems; Emergencies; Disasters

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INTRODUCTION
In recent years, great natural disasters broke out frequently in different parts of the world, causing incalculable damages to the social economy and people's lives of the affected countries or regions. Emergency refers to an event which took place suddenly, caused or may cause social instability and serious harms to public property and public health, having sudden, political, complex, harmful and urgent characteristics. Emergency management system is a set of management system which can ensure organized responses and recoveries to coordinate any or all emergencies. (Liu, Yu, Su, & Chen, 2010). Seeing from domestic and foreign relief processes, the inability to deliver the information of disasters and emergencies in a timely manner would resulting in unsuccessful implementation of the system of prevention, mitigation, preparation, response, recovery, and failure to share domestic and foreign resources. There is an urgent need to build an international dynamic network of emergency management system for large-scale natural disasters. In China, various ministries and industrial sectors have established good network infrastructures, including terminals, networks, storages and decision-making systems. Although most of these systems are independent and the network of each department is vertical, these pre-existing systems provide a good foundation for the lateral connections between the vertical systems (Wu, 2009). From a theoretical perspective, China's researches in emergency management system focus on city emergencies (Tan, Li, & Tian, 2013; Li, 2012), industrial prominent events (Li & Zhang, 2013; Zuo, 2011), specific regional natural disasters (Zhang, Zeng, Zhang, & Yu, 2013) and so on, but the researches in international cooperation-based emergency management system in the context of globalization are relatively less.

Meanwhile, in the field of emergency management, the numbers of various pre-existing disaster relief systems are increasing, so it is necessary to build a global emergency management system (EMS) by integrating and reusing the pre-existing systems and solutions. (Jamshidi, 2009; US Department of Defense, 2008). This paper introduces the theory of system of systems into emergency management system, aiming to build a global emergency management system or an infrastructure between domestic and international emergency management, which is referred to as cross-regional system of systems. It has a certain theoretical and practical significance for improving natural disaster and emergency management, preventing and reducing disasters based on the integration of domestic and foreign resources.

1. THEORY OF SYSTEM OF SYSTEMS

The concept of system of systems (SOS) was proposed quite late. In the early 1970s, the US Department of Defense applied the concept of SOS in the field of military management. Currently, there is no generally recognized definition for SOS (Kaplan, 2006). Some representative definitions are:

From a perspective of joint operations, Manthorpe (1996) believes that SOS focuses on the interoperability and synergies of command, control, computer, communication, information, and intelligence (C4I), intelligence, surveillance and reconnaissance (ISR) systems. According to Kaplan (2006), SOS project is a "cross-system and cross-community process which ensures the development and improvement of task-oriented abilities so as to meet the changing needs of multi-stakeholders. These evolutionary needs exceed the life cycle of a single system". The development from subsystems to systems, and eventually SOS shows a very strong integration capability. Jamshidi (2009) believes that SOS is an integration of finite, independent and operable systems which are connected and collaborated by network to achieve some higher goals. Luo and Luo (2014) holds that SOS is a large-scale integration of systems which are characterized by diversity, heterogeneity and independent working. They work together for a common goal and achieve an overall function which cannot be fulfilled by any individual system. Our study uses the definition.

SOS is composed of systems which mutually interact. This kind of system is called as component system. Therefore, SOS has different characteristics with system. Maier and Rechtin (2002), and Maier (1998) proposed five key features of SOS:

(1) Independent operation. If SOS is decomposed to component systems, the component systems must be able to run independently and effectively. SOS is composed by the systems which run independently in accordance with their own goals; (2) Independent management. Component system can not only operate independently but also manage independently. Each component system joins SOS separately for an integration, but each of them still works normally without being subject to the control of SOS; (3) Evolution. SOS cannot be completely formed. Its existence and development is an evolutionary process whose functions and intentions are constantly added, deleted and adjusted; (4) Emergence. SOS's functions and purposes cannot be achieved by any component individually. The main purpose of SOS is to achieve emergence; (5) Geographic distribution. Component systems are widely distributed in geography. Due to increased communication capability, wide range becomes a vague and relative concept, but at least it means that various components can easily exchange a great deal of information instead of a lot of materials or energies.

2. CROSS-REGIONAL EMERGENCY MANAGEMENT SYSTEM OF SYSTEMS

This paper applies the theory of SOS into emergency management system. Emergency Network is the foundation for emergency management system, and in order to build an effective information system of public emergency we must have a basic network which is capable of carrying a variety of businesses and going through numerous departments. All of these basic networks are the component systems for a SOS and can run across several regions or countries. We can say that the activities and evolution of emergency management system determine a country's ability and efficiency to respond to emergencies (Xue, 2010).

This section describes the characteristics of emergency management SOS and its component systems. Emergency management SOS is a technical means to promote the effectiveness of disaster management by coordinating the communications between the parties involved in disasters (Public Safety Canada, 2010). EMS can be used in all stages of emergency management: prevention, mitigation, preparation, response and recovery.

Emergency management system of systems (EMSOS) is a large, complex, dynamic, pre-existing, heterogeneous, autonomous, independent and physically distributed system, and presents meaningful emergent behaviors and features. Cross-regional emergency management system is a SOS with the general characteristics of SOS.

EMS is a technological tool to improve emergency management process. There is a four-step cycle for emergency management: prevention, mitigation, preparation, response and recovery. Many technological tools can be used in disaster prevention and mitigation, such as inventory system, tracking, testing, driver identification and route planning software. Advanced automatic crash notification system (Advanced ACN) and telemedicine can be used in disaster preparation. Emergency management subsystems (such as scheduling and coordination software, early warning system, evacuation and re-entry management, response management and emergency traveler information system) are conductive to disaster response and recovery.

The characteristics of the component systems of cross-regional emergency management SOS are as below:

(1) Autonomy: Component systems are automatic, but collaborate with each other to form a synergistic symbiotic

relationship; (2) Governance: emergency management is a common responsibility of many stakeholders: governments, NGO, regional and international organizations/donor agencies, local governments, national/local organization (women's committees, youth groups, schools, etc.), community workers, trainers, disaster management personnel (local and national) and policy-makers. Each stakeholder takes charge of some subsystems. EMS, as a collaborative system, cannot be developed from scratch; (3) Heterogeneity: the subsystems of EMS are built independently. They use different development techniques and belong to different application domains (i.e. medicine, fire protection, communication and transport). Similarly, subsystems are different due to their attributions to different types, such as whether a subsystem includes data, hardware, software, equipment and personnel, or institution, facility and manual program; (4) Physical distribution: because of very large scale and a number of subsystems, some of very large scale systems are physically distributed. EMS is a very large scale system, and many of its subsystems are physically distributed, such as the subsystems of geographic information system.

3. CONSTRUCTION OF EMERGENCY MANAGEMENT SOS

Now we introduce with an example of China's cross-regional emergency management system.

3.1 Meta-structure of EMSOS

In the background of SOS, component systems have pre-existing, heterogeneous, autonomous, and distributed and independently features. Component systems achieve cooperation through exchange of information, rather than exchange of materials and energies. Therefore, SOS is a connective/relationship-oriented structure responsible for information dissemination (Dagli & Kilcay-Ergin, 2009). The SOS architecture design focuses on connecting component systems and global communication infrastructure. Therefore, the key of cross-regional EMS design is to build the meta-structure of information dissemination.

The researches in SOS architecture are concentrated in the interface of subsystem, aiming to achieve communications among subsystems. System architecture relates to the interface of a system's internal structure and external structure, and the latter reflects the observable characteristics of the system. SOS architecture is a connective/relationship-oriented architecture emphasizing the compromises among interface, communication protocol and component. (Wang, Wang, Zhu, & Li, 2011)

System architecture design is a design of meta-structure. Meta-structure has a high degree of interoperability and some evolution promoters. Thus, meta-structure can support the cooperation among stakeholders on the programmatic and constructive level, and help understand and analyze the integration of component systems.

On the programmatic level, SOS mainly deals with the collaboration among physical organizations. In the context of SOS, many organizations can only achieve their goals through cooperation and coordination. Map of interoperability (Brownsword, Fisher, Morris, Smith, & Kirwan, 2006) can make joint decisions based on combining decision matrix and social selection theory. Map of interoperability acts to reflect the relationships between components and determine stakeholders. Video conference can be applied in a distributed background. Distribution is a core feature of SOS.

On a constructive level, an information-based meta-architecture emphasizing the interface between shared repository and subsystems is to be built. The process of architecture design consists of two steps: database construction and interface development.

3.2 EMS Logical Model Based on Information Infrastructure Platform

3.2.1 Design Principles and Mechanisms of Information Infrastructure

Hanseth and Lyytinen (2010) pointed out that large-scale information infrastructure has a complexity beyond traditional system designs. They proposed a complete theory for designing information infrastructure, which focuses on promoting growth in base installation and developing theories of network economy and complexity. They proposed five design principles and related mechanisms as shown in Table 1.

Table 1
Design Principles and Mechanisms

Design principle	Mechanism
1. Originally designed uses	The immediate and short-term effectiveness will guide small target groups to later use
2. Draw on existing installation bases	Expanding the existing structures will allow users to adopt new services more easily
3. Expand the installation bases with persuasive tactics	Constructing users' community and developing technologies will increase uses
4. Make them simple and practical	New users and partners will enjoy easier services
5. Modularization will be achieved by building the main functions, practical layering and gateways of each infrastructure	Modularization and hierarchical structure will make infrastructure expand more easily

3.2.2 Information Infrastructure

The term of information infrastructure is well known by Clinton/Gore's announcement on the national information infrastructure. In Webster's dictionary, the definition of infrastructure includes "substructure or a fundamental base".

Information infrastructure is the material base supporting distributive innovative flowing space. In general, information infrastructure refers to the information processing platform of enterprise, including basic structure, information processing and the network elements completing a variety of information processing functions (including information acquisition, transformation, transmission, storage, retrieval, etc.) In addition to system equipment, software and hardware components, information infrastructure also includes the people, organizations and processes transmitting and processing information.

Information infrastructure can be broadly classified into global information infrastructure (GII), national information infrastructure (NII) and enterprise information infrastructure (EII). Information infrastructure crosses the boundaries of countries, regions and innovation units.

3.2.3 EMS Logic Model

The three infrastructures form a global emergency management information platform through interconnection, or EMS logic model as shown in Figure 1. Network access devices include laptops, cell phones, fax machines, telephones and other communication equipment. Throughout the emergency experience of the world, it is not difficult to conclude that there is only governments having the abilities to build emergency systems throughout the networks of all sectors of society. Therefore, government network is bound to become the core network bearing emergency response system, and government's emergency command center is bound to become the center for information gathering, storage and computation (Wu, 2009).

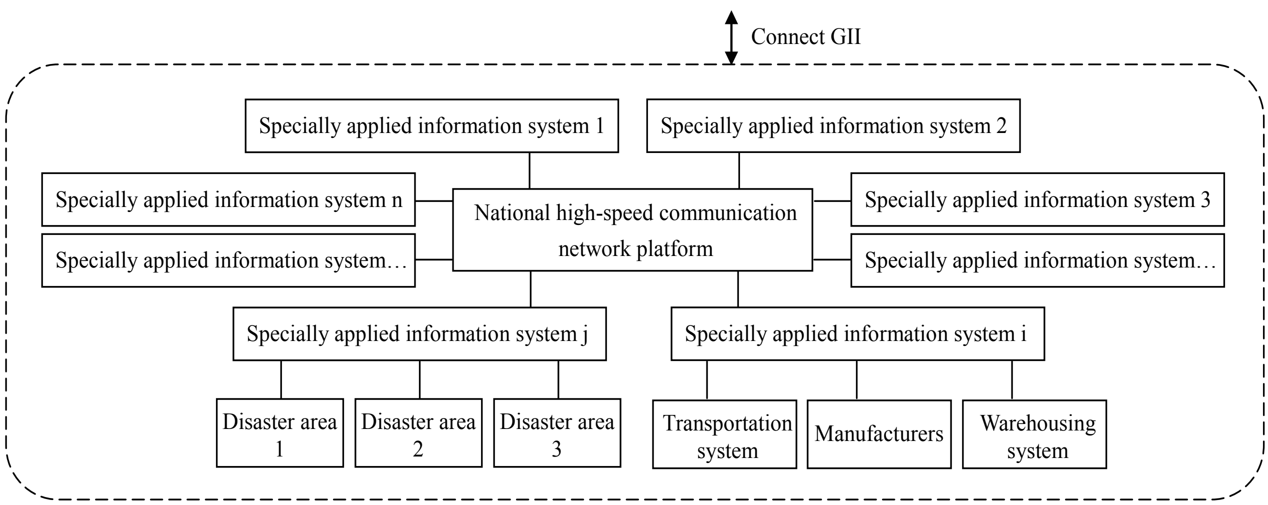

Figure 1
CNII Overall Logic Model

GII can connect a variety of users at different locations across the earth, provide a huge amount of information to them, including videos, data, multimedia images or entertainments, and have a profound impact on our social, economic development and political life.

China national information infrastructure (CNII) is the complete information network which ensures the citizens to obtain their required resources in the simplest way anywhere and anytime. This network is characterized by: (1) The national optical network is the backbone network to transfer information; (2) Various types of applied information systems should access to this network to build an integrated information network platform; (3) End users can quickly get multimedia and other forms of information services. CNII can access GII.

Enterprise information infrastructure (EII) is the foundation for enterprise informatization. In general, it includes a hardware platform (such as computers, data storage equipment, enterprise internal networks and communication equipment, etc.), a software environment (such as operating systems, database systems and application software, etc.), and a service environment (such as end-user computing environment, assistance and service environment, and application development environment, etc.). EII is the basic tool for an organization to release data, information and knowledge to people and processes.

In Figure 1, the "specially applied information systems" includes the information system providing specialized information services to the whole society, such as videotext referral information system, public voice information system, public data referral information system, production system and public health care system; some production and management information systems for the internal use of a particular department or industry, such as the national government office automation system, and railway traffic control system, etc.

CONCLUSION

The theory of SOS effectively explains the interactions among many independent systems on a higher level, and provides a new perspective for the construction of emergency management system.

The first is the SOS with the features of global emergency management system. SOS architecture is a connective/relationship-oriented architecture, emphasizing the compromises among interfaces, communication protocols and components. The key to build an emergency management SOS is architecture design.

The second is to put forward the concept of meta-structure to help construct emergency management SOS.

Meta-structure supports the cooperation among stakeholders on the programmatic and constructive level, and can help understand and analyze the integration of component systems. On the programmatic level, SOS mainly deals with the collaboration among physical organizations. In the context of SOS, many organizations can only achieve the goals of SOS by cooperation and coordination. Map of interoperability acts to reflect the relationships among components and determine stakeholders. On the constructive level, an information-based meta-architecture emphasizing the interface between shared repository and subsystems is to be built.

The last is to put forward the EMS logical model based on information infrastructure platform. The model is a globally open architecture which can access to disaster prevention and mitigation resources at different locations across the earth, achieve a great deal of information exchange in a timely manner, and provide effective technical supports and information security for emergency management.

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