Developing Disaster Risk Science
—Discussion on the Disaster Reduction Implementation Science—

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ABSTRACT

By reviewing the disaster reduction implementation science system, the necessity of developing disaster risk science is discussed and its preliminary framework is proposed in this paper. At the third IIASA-DPRI Forum on Integrated Disaster Risk Management, Okada (2003) presented the disaster reduction implementation science system, that is, the Networking of Vitae System, and expatiated on the structure, function, and system dynamic issues of integrated risk management. Influenced by the Vitae System of integrated risk management and based on the disaster system framework proposed by Shi in 1991, the authors examine the three basic components of disaster risk science, that is, disaster science, emergency technology, and risk management. Building upon these discussions, the structure, function, and dynamic system of integrated risk management are further explored, with the understanding that the core of integrated risk management is to optimize development and disaster reduction, to combine governmental and non-governmental disaster reduction actions, to integrate structural and non-structural countermeasures, and finally to form the regional integrated disaster reduction paradigm.

Keyword: Integrated risk governance, structure and function, system dynamics, regional disaster reduction paradigm, disaster reduction implementation science

The increase of global disaster risk is closely linked with global environmental changes (WMO, 2007). However, for decision making on integrated risk governance, further analyses and studies are needed to reveal the mechanisms and processes of such relationship. Recently, a great number of scholars in the disaster reduction field around the world have tried to explore the internal relationships between hazards and disasters from the complex processes of disaster formation and disaster risks, especially by focusing on the role of social systems, economic systems, and natural environments in these processes. Also, a large number of work on developing the theories and methodologies of integrated disaster risk research have been carried out. A new cross-disciplinary science, the disaster risk science, is coming into being (Shi, 2006).

At the third IIASA-DPRI Forum on Integrated Disaster Risk Management in 2003, Okada at the Disaster Prevention Research Institute of Kyoto University, Japan proposed the disaster reduction implementation science system to promote integrated disaster risk management, and the Vitae System, which has three basic cardinal functions: "to stay alive", "to live lively", and "to live together", as the new conceptual framework for integrated disaster risk management (Okada, 2003). Based on this theory, through the Pagoda Model, the Octopus Model, and the Case Station and Field Campus (CASiFiCA) paradigm, Okada had also expatiated on the theories and methodologies of disaster risk science. As a starting point, this paper provides a brief review of the schools of integrated risk governance, with a special focus on the disaster reduction implementation science system.

1. The Schools of Integrated Risk Governance

Since the United Nations carried out disaster reduction actions in the last decade of the 20th century, several terms, including disaster, disaster reduction, large-scale disaster risk governance, and integrated risk management, have frequently appeared in related journal papers, books, and governmental documents. Scholars in different research fields and practitioner with varied knowledge and backgrounds, from various points of view, all emphasized the importance of research on integrated risk governance and together, developed a large number of conceptual frameworks and models. In this paper, these frameworks and models are summarized into five schools of integrated risk governance as follows.

1.1 The Capacity School of Integrated Risk Governance

The UN/ISDR Secretariat published the *Hyogo Framework for Action 2005–2015: Building the Resilience of Nations and Communities to Disaster*, which was proposed at the International Disaster Reduction Conference on 18th–22nd, January, 2005 in Kobe of Hyogo, Japan. The core of the framework is "to ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation; to identify, assess and monitor disaster risks and enhance early warning; to use knowledge, innovation and education to build a culture of safety and resilience at all levels; to reduce the underlying risk factors; and to strengthen disaster preparedness for effective response at all levels" (UN/ISDR, 2007) (Figure 1). The framework emphasizes that capacity building of a commnity or a region is especially important for integrated disaster risk management.

1.2 The Policy School of Integrated Risk Governance

In 2005, the International Risk Governance Council (IRGC) released a framework for integrated risk governance. The key content of the framework is that integrated risk governance is composed of science based risk assessment, policy based risk management and risk communication, that is, interactive exchange of information and opinions concerning risks (IGRC, 2007) (Figure 2). In this framework, risk communication is the core serving as the bridge to integrate risk understanding and decision making (Figure 3). Besides disaster risks, terror, technology, and market risks are also focuses of this school. Policy issues and information sharing mechanism have been emphasized for risk analysis.

1.3 The Sustainable Development School of Integrated Risk Governance

The Earth System Science Partnership (ESSP) focuses on the effects of global change on sustainable development, and the IGBP, IHDP, and WCRR emphasize implementing regional and global sustainable development by integrated risk governance. The Graduate School of Geography of Clark University,

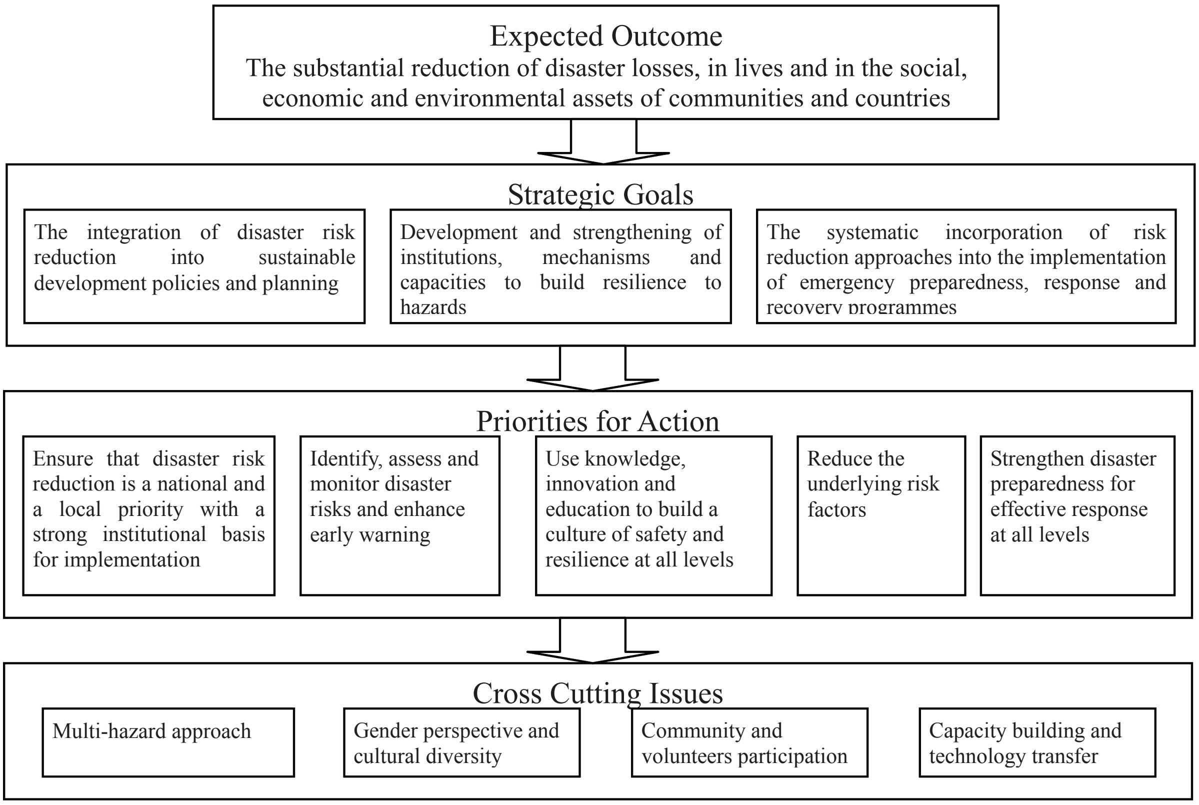

Figure 1 Summary of the Hyogo Framework for Action 2005–2015: Building the Resilience of Nations and Communities to Disasters (Hyogo Framework, modified)

Figure 2 Framework for integrated disaster risk analysis (IGRC)

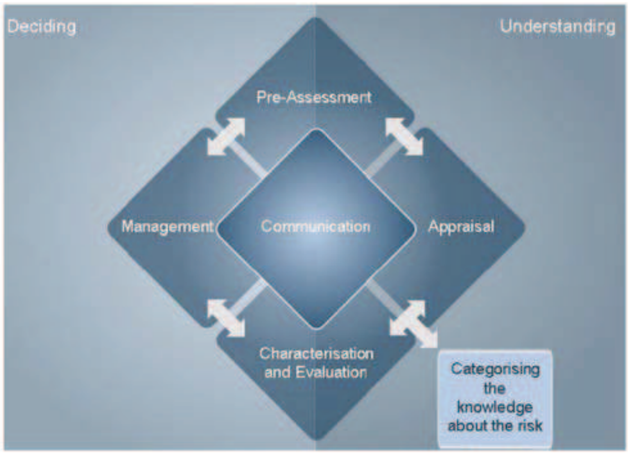

Figure 3 Framework for integrated risk governance (IRGC)

USA, and the Institute for Environment and Human Security of United Nations University, Japan are two typical organizations agreeing with this viewpoint. The core of this school is to establish the integrated assessment model system for vulnerability, resilience, and adaptation to disaster risks, to integrate risk governance and vulnerability reduction strategies into sustainable development, and to develop regional sustainability paradigm based on economic development, social equality, and ecological security (Serageldin, 1995) (Figure 4). Subsequently several models of

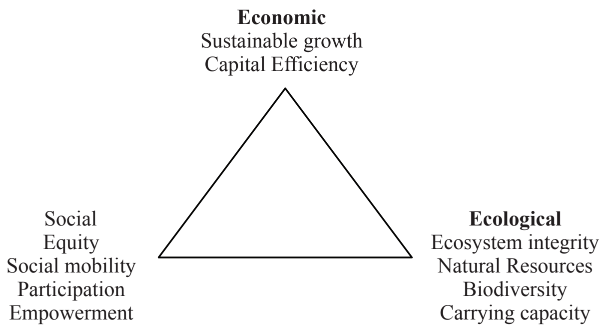

Figure 4 Serageldin's triangle of sustainability

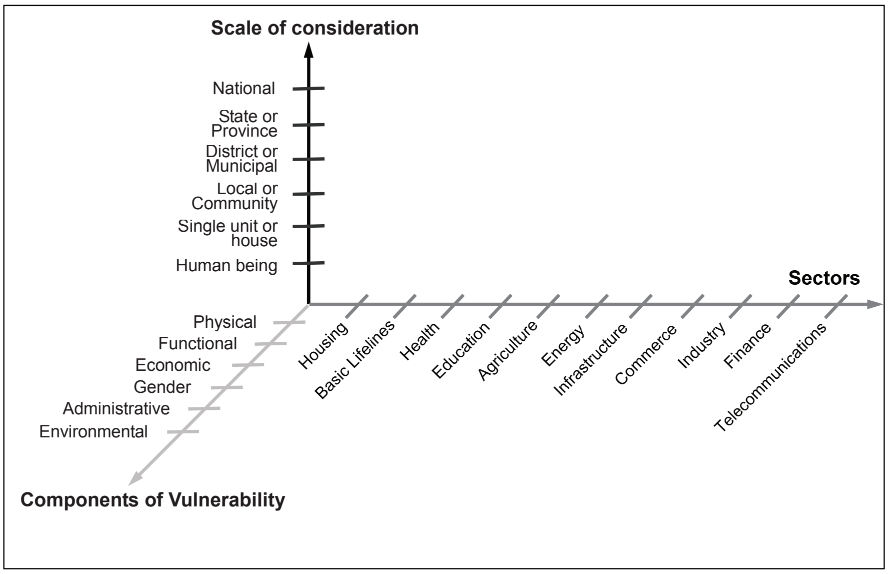

Figure 5 Framework for vulnerability introducing the notion of independent dimensions of scale of consideration, components, and sectors

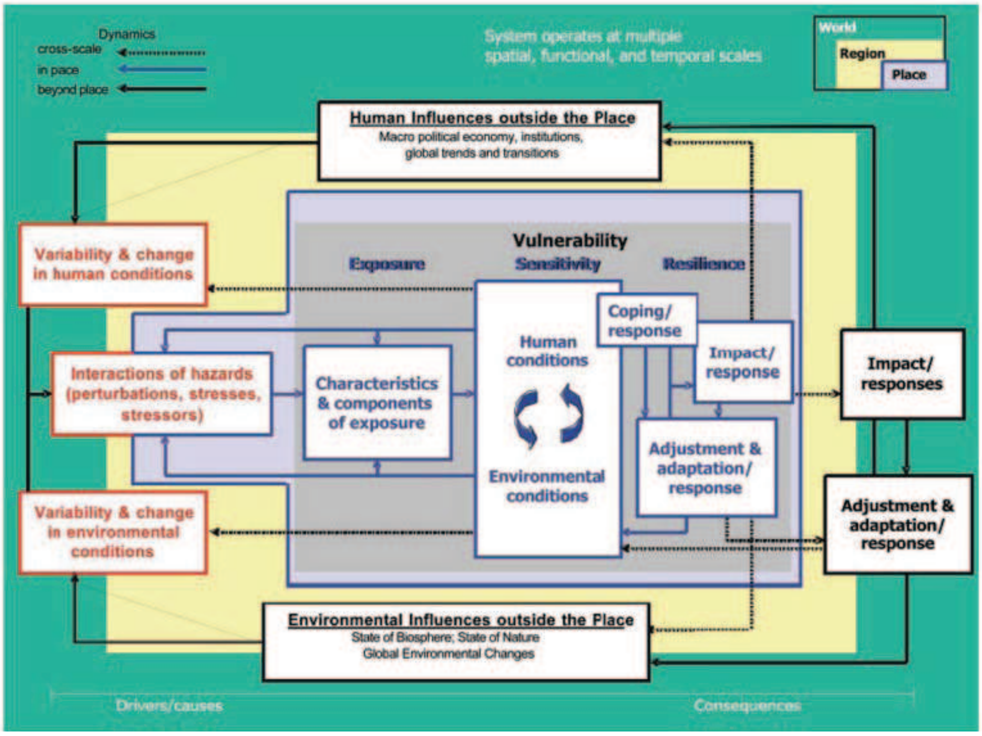

Figure 6 The vulnerability framework (Turner et al, 2003)

vulnerability by integrating sustainability into disaster risk governance have been proposed (e.g., Figure 5 and Figure 6) (UNU-EHS, 2006; Turner et al., 2003). Overall, this school emphasizes on balancing disaster risk management and sustainable development.

1.4 The Vitae School of Integrated Risk Governance

Okada (2003) proposed the disaster reduction implementation science system from the viewpoints of the structure and function of disaster system. The core of the Vitae System School is to develop the Vitae System for enhancing community's coping capacity, through integrating the Pagoda Model (Figure 7) and the Octopus Model (Figure 8), and to enhance implementation of the disaster reduction implementation science through the Case Station and Field Campus (CASiFiCA) paradigm. A detailed discussion of this school's approaches is provided in the second part of this paper.

Figure 7 Pagoda Model

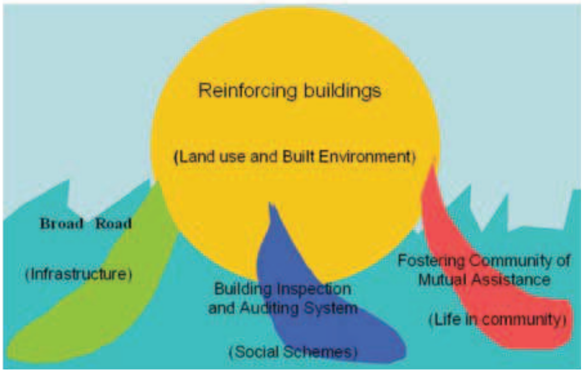

Figure 8 Octopus Model

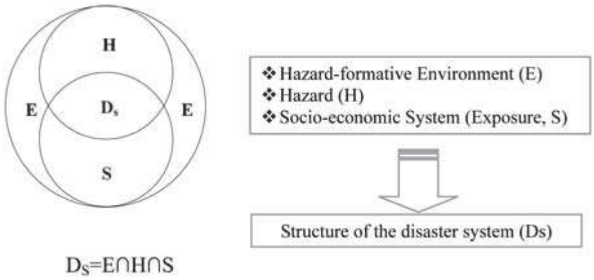

Figure 9a Structure of a disaster system

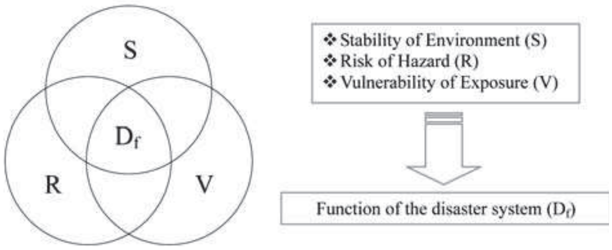

Figure 9b Function of a disaster system

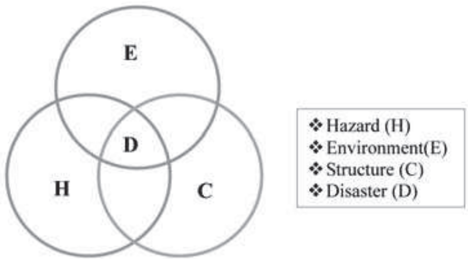

Figure 10 Structure of the disaster system by Mileti

1.5 The System School of Integrated Risk Governance

In 1991, Shi attempted to find an effective way for integrated risk governance from the viewpoint of disaster system (Figure 9) (Shi, 1991). In this system, disaster risk is closely related to the stability of the environment, the intensity and frequency of the hazard, and the vulnerability of the exposure. In 1999, Mileti also addressed the issue of integrated disaster risk from this viewpoint (Figure 10) (Mileti, 1999). In this system, disaster risk is closely related to the stability of the environment (atmosphere, hydrosphere, biosphere and lithosphere), the vulnerability of human system (demographics, culture, economic and technology, etc.) and structure system (the structure of built environment). The main focus of this school is on the structure and function of disaster systems as well as their dynamic and non-dynamic activities, and the dynamic and non-dynamic models of these systems.

Scholars in these schools of integrated risk governance have different backgrounds, viewpoints, and focuses, but all agree that development and disaster reduction need to be synchronized, technology and management need to be integrated, and research and implementation need to go hand in hand.

2. Understanding the Disaster Reduction Implementation Science

From a multi-disciplinary perspective, Okada and his group in the Kyoto University have carried out in-depth studies on integrated risk governance. Recently, DPRI and IIASA have made fruitful cooperation and advanced the disaster reduction implementation science system research by jointly organizing the Forum on Integrated Disaster Risk Management.

2.1 The Vitae System

At the third IIASA-DPRI Forum in 2003, Okada proposed the Vitae System for integrated disaster risk management. This model takes cities, regions and communities as living (vital) integrity (or living body) with robustness and resilience in its coping capacity. Each living body has three cardinal functions, that is, (i) "Survivability" (to live through or become alive), (ii) "Vitality" (to live lively), and (iii) Conviviality (to live together or communicate).

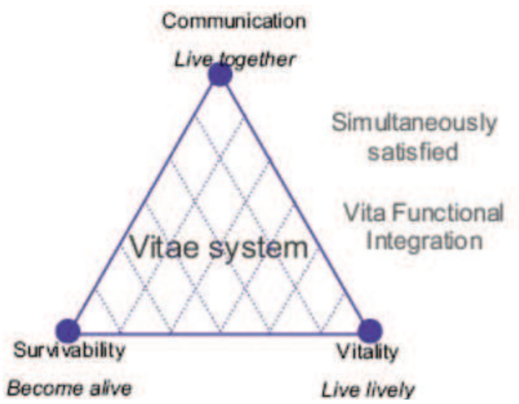

Figure 11 The Vitae System

As Figure 11 shows, the model is depicted as a triangule with three nodes representing fundamental functions of any living body. The area of the triangle represents the degree of viability, a property characterizing the range of coping capacity. The Vitae System has the properties of "holism", "biorhythm" and "communalism".

2.2 The Pagoda Model

Okada proposed this conceptual model to broaden the scope of disaster management. The point was to envision the region (land, city, and community) as a vital (living) common space represented by a five-storied pagoda model as depicted in Figure 7 (Okada, 2002). The top layer corresponds to "living activities," the second to "land-use and built-environment," the third to "infrastructure," the fourth to "social environment," and the fifth (bottom) to "natural environment." Much of disaster risk is commonly latent and spatially/temporally distributed across a region. Moreover social hazards may lie in ambush over niches between different layers in the spatial/temporal system of the pagoda.

2.3 Octopus Model

Since disasters are complex systems, disaster risk management needs to systematize and link any particular, specialized knowledge and technology to relevant policy concerns and governance issues. Okada depicted such multidisciplinary approach using an Octopus Model as shown in Figure 8 (Okada 2003), and stated that disaster risk management needs multiple legs (polyped) that cling to other interconnected areas.

2.4 PDCA cycle and urban diagnosis

The PDCA cycle (Figure 12), with the continuous improvement cycle of "Plan", "Do", "Check" and "Act" was advocated by Shewhart and Deming after the World War II (Aguayo, 1991), and used for production management and quality control in industries.

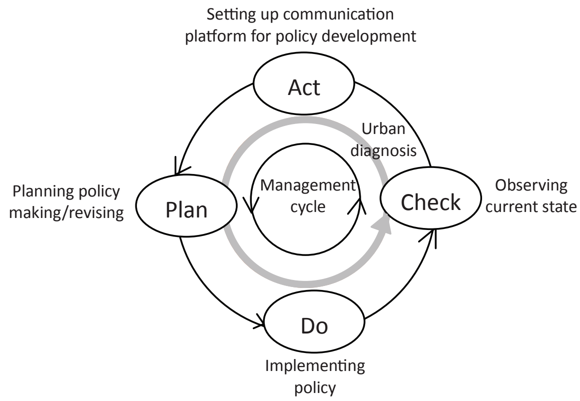

Figure 12 PDCA Cycle

This cycle fits well with the evolving perspective of participatory disaster planning and management. In the cases of participatory community planning, all stakeholders (local government, local people, NGOs/NPOs, and/or experts) need to share information on the status quo and their knowledge in the community before they start the planning. Okada (2002) introduced this PDCA cycle into urban risk management tasks called "urban diagnosis", which emphasizes the diagnosis of the status quo based on the practice of "Check" and "Act" before "Plan". Thus the cycle is aslo called CAPD cycle in the fields of disaster risk management. This management method is also suggested to help participating agents to share the current condition and to provide a communication platform for disaster preparedness policy making.

2.5 CASiFiCA

Due to the very complex nature of natural disasters and risks, risk reduction research erequires that researchers from relevant fields work together to affect a change towards a safer society. Such an interdisciplinary research has largely been difficult owing to the very nature of the problems and their solutions. Case Stations and Field Campus, proposed by Okada in 2005, has proven to be an excellent tool for assessing the feasibility of implementing scientific and policy advancements in the field of disaster risk reduction research. These methodologies effectively integrate various disaster risk reduction technologies, principles, practices, and policies at a pilot location and try to study their net impact on ultimate reduction of risk and fostering sustainable development.

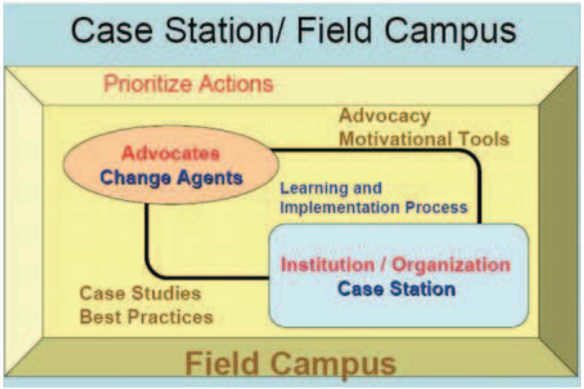

Figure 13 CASiFiCA

Together, the Vitae System, the Pagoda Model, the Octopus Model, the "Plan-Do-Check-Act" Model, and the Case Station and Field Campus paradigm, which are mutually interdependent, describe the driving force, structure, function, response, and paradigm of disaster systems in the disaster reduction implementation science.

3. Developing Disaster Risk Science

Continuous and in-depth research on integrated disaster risk management promotes the formation of disaster risk science. The studies on disasters can be divided into three schools, namely, hazard school, exposure school, and hazard-formative environment school (Shi, 1996). Likewise, the studies on integrated risk governance have been summarized into five schools as discussed in the first part of this paper. Illuminated and influenced by the ideas of disaster reduction implementation science, this paper proposes to further develop the disaster risk science. Our view is that the disaster risk science system should have three components, that is, disaster science, emergency technology, and risk management.

3.1 Disaster Risk Science System

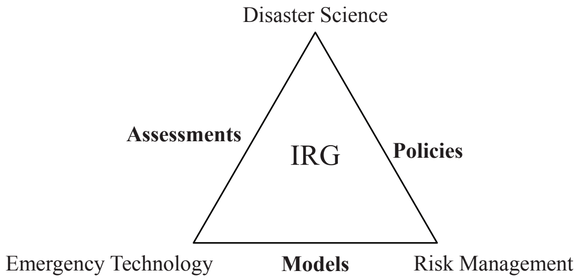

Figure 14 Disaster Risk Science

Figure 14 shows the three components of the disaster risk science. Disaster science is the complex science concerning the formation mechanisms and change processes of disaster systemes, as well as disaster reduction countermeasures (Shi, 2002). A disaster system is a complex system of the earth surface (Shi, 1991) and an interactive and integral entity of human beings and the nature. It is composed of the structure system consisting of hazard, exposure, and hazard-formative environment, and the function system consisting of vulnerability, complexity, and adaptation (Shi, 2002, 2005) (Figure 9a and Figure 9b). The change of the disaster system is determined by its dynamic and non-dynamic processes (Shi, 2005). The countermeasures of disaster reduction mainly include preparedness, emergency response, and restoration and reconstruction, which are referred to as disaster prevention, disaster resistance, and disaster relief in the Chinese disaster reduction actions.

Emergency technology is the technology set used in emergency response planning, action, and command for disaster emergency management. Emergency plans include general principles, institutions, the organization of operations, emergency response support, and monitoring and management for local or central government to deal with disasters. Generally, emergency response plans can be categorized into six types: general plans, special plans, sectoral, local plans, plans for enterprises and organizations, and plans for large-scale activities. Emergency response action is a series of countermeasures including forecast, early warming, emergency handling, restoration and reconstruction, and information dissemination by following the emergency response plans. Emergency response command is the institution and organization (the leading groups, operational groups, working groups, and expert groups), emergency response support system (human resources, financial supports, public facilities, science and technology supports, and so on), and emergency response monitoring and management (drills, propaganda and trainings, and a responsibility and reward system) corresponding to different disaster levels as stipulated in emergency response plans.

Risk management is a part of public administration that consists of disaster risk identification, risk classification and assessment, modeling, response, and adaptation. Disaster risk identification is to examine hidden risks of a region, an enterprise, or an organization according to corresponding criteria. Risk classification is to determine risk types and risk levels based oncertain indicators. Risk assessment is to assess risk levels using models and certain standards. Risk modeling is to simulate potential disaster risks of the above mentioned entities. Risk response is the preventative measures to disaster risks taken by these entities following the results of risk assessment. And risk adaptation is a series of adjustments made to the plans and actions of these entities in accordance with estimated disaster risks.

3.2 Integrated Risk Governance

Disaster systems are characterized by uncertainty, complexity, and diversity and are global and integrative in nature. Therefore, disaster risk governance, integrated disaster reduction, and emergency management need to be carried out in an integrated way. Scholars and practitioners have attempted to answer the questions of "what to integrate" and "how to integrate" in integrated disaster risk management. However, these still remain open questions. Based on our long-term study and understanding of disaster risk management, the authors put forward the following viewpoints for discussion.

3.2.1 What should be integrated?

Disaster system is a complex system of the surface of the earth as mentioned above, therefore two principles should be adhered to in integrated risk governance. The first is to deepen our understanding and to carry out integration from a multi-disciplinary perspective, that is, to discuss integration from the science, technology, and management fields of integrated risk governance. The second is to deepen our understanding and to carry out integration crossing scales, that is, to integrate from the macro, meso and micro scales of integrated risk governance. Based on these, it is recognized that: (1) multiple stakeholders including the government, communities, organizations, households, and individuals all need to be involved; (2) multiple actions such as structural (hard) and non-structural (soft) countermeasures need be coordinated; (3) multiple stages of activities, that is, activities before, during, and after a disaster need be integrated; and (4) given the multiple system characteristic, it is necessary to optimize the integration of systems by integrating the multi-stakeholder, multi-action, and multi-stages of activity systems (Figure 15) (Shi, 2007).

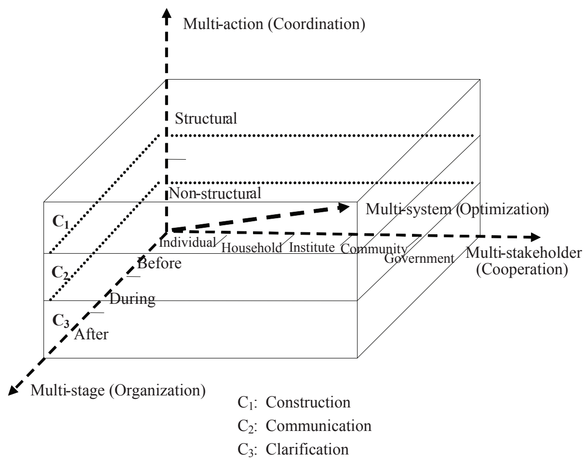

Figure 15 Three Dimensional Paradigm of Integrated Risk Governance

3.2.2 How to integrate?

After the contents for integration are determined, the next question is how to integrate in disaster risk governance. Recently, the question of how to integrate has generated a large amount of discussions by scholars from various traditions. Generally, there are four approaches having been proposed. The first is to organize workshops (conferences or forums) involving multi-disciplinary, multi-field and multi-departmental participants to explore the ways to carry out integrated risk governance through brainstorming. Discussions on integrated risk governance at the annual meetings (conference or forum) of Internatonal Disaster and Risk Conference (IDRC), World Conference on Disaster Reduction (WCDR), International Risk Governance Council (IGRC) and IIASA-DPRI are evidences of such attempts. The second is to develop information sharing network to speed up the process of risk information sharing. For example, the UN/ISDR secretariat is setting up the Global Platform for Disaster Risk Reduction (GP/DRR); the Disaster Reduction Hyperbase-Asian (DRH-Asian) is under construction in Japan; and the Integrated Risk Governance Network (iRiskNet|IRG-China) is being developed in China. The third is to develop integrated risk mapping, for example, the map of Hotspots of Global Disaster Risk jointly developed by the UNDP and the World Bank, and the national first generation integrated disaster risk map in China. The fourth is to develop various models to simulate the evolution of disaster risks. Such examples are the Alliance for Global Open Risk Analysis developed by the Kyoto University of Japan, the System of System developed by the Old Dominion University of USA, and the Integrated Risk Governance System Dynamics developed by the Beijing Normal University of China.

3.3 Integrated Risk Governance Paradigms

To affect integrated risk governance requires to develop exemplary cases that can be replicated elsewhere, that is, the integrated risk governance paradigm, taking into account regional political, cultural, economic, and social characteristics. For example, Roger Kasperson and his colleagues at Clark University, USA have studied the critical zone with nine typical case study areas (Kasperson, 1995), Norio Okada and his colleagues at the Kyoto University, Japan have proposed the Case Station and Field Campus (CASiFiCA) methods (Okada, 2005), and Peijun Shi and his colleagues have developed the Paradigm of Integrated Disaster Risk Reduction of China (PIDRR) (Shi, 2005). The core purpose of these activities is to implement integrated risk governance, and to enhance and improve regional integrated disaster reduction capacity and risk governance level for large-scale disasters by cooperation, integration, coordination, and optimization in a given region. Achieving these goals will help to lay the foundation for building safer communities, regions, countries, and a safer world, and to ensure a sustainable development of the world.

The essence of these paradigms is to implement the integrated risk governance appropriate for the regional political, economic and cultural systems of concern by (1) cooperation among different stakeholders such as the government, communities, organizations, households, and individuals; (2) coordination of structural countermeasures with non-structural countermeasures; (3) integration of preparedness, emergency response, restoration and reconstruction; and (4) optimization of such multi-stakeholder, multi-action and multi-stage activities. That is to say, it is to integrate the coordination institutions between central and local level activities, the cooperation mechanisms among different stakeholders, and the legal system governing such coordination and cooperation.

4. Conclusion

This paper has summarized the schools of integrated risk governance, discussed the disaster reduction implementation science, and put forward a preliminary framework of disaster risk science. We have found that there are five schools of integrated risk governance, namely, the Capacity School, the Policy School, the Sustainable Development School, the Vitae School, and the System School. The Vitae System, the Pagoda Model, the Octopus Model, the “Plan-Do-Check-Act” Model, and the Case Station and Field Campus” paradigm describe the driving force, structure, function, response, and paradigm of disaster systems in the disaster reduction implementation science. Disaster risk science is composed of the disaster science to understand the structure, function, and driving force of disaster systems; emergency technology to improve disaster handling; and risk management to standardize disaster responses. To complete the disaster risk science system and to improve and enhance regional or industrial integrated risk governance capacity, establishing typical cases and integrated disaster reduction paradigms would be necessary in future research.

REFERENCE

Aguayo R, 1991. Dr. Deming: The American Who Taught the Japanese about Quality, Fireside,.

IRGC, White Paper No.1, Risk Governance – Towards an Integrative Approach. Available: http://www.irgc.org

IRGC, 2007. Available: http://www.irgc.org

Kasperson JX, Kasperson RE, and Turner BL, 1995. Region at Risk. United Nations University Press, Tokyo – New York – Paris.

Mileti D S, 1999. Natural Hazards and Disasters – Disasters by Design, Washington: Joseph Henry Press.

Okada N, 2002. Disaster Mitigative Urban Diagnosis (DiMUDnosis) Viewed as Process of Risk Management, 2nd Japan China Joint EQTAP Meeting on Urban Disaster Risk Management, Beijing, China, 2002.

Okada N, 2003. Integrated Disaster Risk Management. 3rd IIASA-DPRI Forum, Kyoto, Japan, 3-5 July.

Okada N, 2005. Placing the Research Stream of Integrated Disaster Risk Management (IDRiM) In Retrospect and Prospect, 5th IIASA-DPRI Forum, Beijing, China, 14-18 September.

Serageldin I, 1995. Promoting Sustainable Development: Towards a New Paradigm, in Serageldin I, and Steer A eds, Valuing the Environment: Proceedings of the First Annual International Conference on Environmentally Sustainable Development, Washington D.C.: World Bank, pp.13-21.

Shi P, 1991. Theory and Practice on Disaster System. Journal of Nanjing University (Natural Sciences), Special Issue for Natural Disaster, pp.37-41(in Chinese).

Shi P, 1996. Theory and Practice of Disaster Study. Journal of Natural Disasters, Vol.4, No.4, pp.6-15 (in Chinese).

Shi P, 2002. Theory on Disaster Science and Disaster Dynamics. Journal of Natural Disasters, Vol.11, No.3, pp.1-9 (in Chinese).

Shi P, 2005. Theory and Practice on Disaster System Research in a Fourth Time, Journal of Natural Disasters, Vol.14, No.6, pp.1-7 (in Chinese).

Shi P, 2007. Regional Integrated Disaster Risk Management. In: Li L. et al. eds., Disaster Emergency Treatment and Integrated Disaster Reduction, Peking University Press, pp.274-288 (in Chinese).

Shi P, Guo W, and Li B, et at., 2005. Disaster Reduction and Sustainable Development: Adjustment of Disaster Reduction Strategies of China based on "The 2nd World Conference on Disaster Reduction, 2005". Journal of Natural Disasters, Vol.14, No.3, pp.1-7 (in Chinese).

Shi P, Li N, and Liu J, et al., 2006. Discussion on Harmonization Way of Development and Disaster Reduction: Harmonization Strategies of Development and Disaster Reduction in China based on "The International Disaster Reduction Conference, Davos, 2006". Journal of Natural Disasters, Vol.15, No.6, pp.1-8 (in Chinese).

Shi P, Shao L, and Zhao Z, et al, 2007. On Integrated Disaster Risk Governance: Seeking for Adaptive Strategies for Global Change. Earth Science Frontiers, Vol.14, No.14(in print and in Chinese).

Turner B L, Kasperson R E, and Matson D A, et al., 2003. A Framework for Vulnerability Analysis in Sustainable Science, Proceedings of the National Academy of Science, 100(14): 8074-8079.

UN/EHS, 2006. Vulnerability – A Conceptual and Methodological Review (Juan Carlos Villagrán de León), No. 4.

UN/ISDR, 2007. Available: http://www.unisdr.org

WMO, 2007. Climate Changes, 2007. The Physical Science Basis, Summary for Policy Makers, IPCC WGI Forth Assessment Report, Paris, February, 2007.