# Foundations for Designing Global Emergency Response Systems (ERS)

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## ABSTRACT

Works on Emergency Response Systems (ERS) tend to set aside – or discuss peripherally – the global nature of catastrophes and the unique conditions under which these systems have to operate. Major disasters either affect more than one country or require the help of more than one nation. Designing ERS to manage global crisis situations pose great challenges due to incompatible technologies, language and cultural differences, variations in knowledge-level and management styles of decision makers, and resource limitations in individual countries. In this paper, we outline theoretical foundations for designing global ERS. We develop a path model that identifies the elements and their interactions needed to ensure quality of outcomes and processes of emergency response. We also prescribe a Global Information Network (GIN) architecture to provide decision-makers with timely response to crises involving global intervention.

### Keywords

Crisis management, emergency response systems, decision support

## INTRODUCTION

Large-scale crises and their impacts are becoming global. It is either a SARS outbreak, a bird flu epidemic that spreads across borders, or a tsunami in the middle of the Pacific that affects coastal nations. But the repercussions are almost the same. The lives of vast numbers of people of different nationalities are affected, and emergency response requires the involvement of not only multiple agencies within a country but hosts of other nations as well.

Lessons learned from recent disasters – the 2004 tsunami in the Pacific and the 2005 hurricane Katrina in the Central coast of the U.S. – have rekindled interest in crisis management and a better appreciation of the importance of preparedness, inter-organizational coordination, and particularly in creating an emergency response process that overcomes the difficulties in organizing and coordinating a large number of participating agencies (Raman et al., 2006). In the recent Restore Democracy operation in Haiti, for example, there were over 400 organizations in action. However, research on Emergency Response Systems (ERS) in the past has tended to set aside – or discuss only peripherally – the global nature of catastrophes and the unique conditions under which these systems have to operate. Designing systems to manage global crisis situations pose great challenges due to language and cultural differences, incompatible technologies, variations in knowledge-level and management styles of decision makers, political rivalries, and uneven resource limitations within affected countries.

In this global context, researchers in emergency management and even political scientists can no longer constrain their thinking to isolated locales in their effort to prepare and manage crises. The challenge is how such a vast effort can be coordinated to ensure the integrity and quality of the crisis management processes, and how quality of decision outcomes be assured. In this paper, we outline the theoretical foundations for designing global ERS from an inter-disciplinary perspective by integrating concepts from cognitive science, decision science and organization science. We then use a decision support engineering approach to analyze and design a general architecture for ERS in a global setting.

This paper is organized as follows. First, we briefly define crisis and describe its characteristics. Second, we highlight a number of critical problems facing global emergency response. Third, we propose a path model of global crisis management as the basis for understanding the design of effective ERS. We close by presenting some key features of a Global Information Network (GIN). The hope is the underlying concepts presented in this paper would lead to the development of decision support technologies at various access points of a global network for concerted Humanitarian Assistance/Disaster Relief (HA/DR) efforts in times of crises.

## GLOBAL CRISIS/EMERGENCY – DEFINITION, PERCEPTION AND COGNITION

A crisis is an event that has either occurred or impending to occur. It threatens life or property or both on a wide scale. It can be limited to a small locale or may extend over a large area, and is not necessarily limited within national boundaries. Under most emergencies, there is a time pressure for finding a solution.

A crisis is characterized by the fact that it occurs as a surprise, threatens one or more valued goals, and leaves little time for response (Hermann, 1972). The tsunami of 2004 in South-East Asia was never thought of as a possible natural disaster by the inhabitants or the governments in the region. Even governments with vast resources are victims of surprise when they fail in their intelligence and planning. In a global context, the process of intelligence gathering, information sharing and coordinated planning has proved to be of a close to insurmountable level of complexity.

One of the fundamental dictums all humans share is value of life. At the second level in our value systems is protection of property. Widespread destruction of property alone may lead to an emergency. Perceived values of life and property vary, however, significantly from one area of the world to another, and create divergence and conflicts in trade-off decisions.

Long physical distances between disaster areas and rescue centers severely hinder the ability to react swiftly. The ability to quickly react to unexpected events often is the key problem. While telecommunications technologies have helped speed up information flow across distant regions of the world, vast geographical distances and other social, political and economic realities are constraints that negatively affect expeditious response.

Two similar events occurring in two areas of the world or at different times may generate different levels of responses. According to Billings (1980), the three factors influencing the extent of perceived crisis are (i) perceived value of possible loss (high importance), (ii) perceived probability of loss (high uncertainty), and (iii) perceived time pressure (immediacy). These three elements themselves are determined by technological, cultural, social, and of economical factors. They have imperative implications when dealing with a crisis of global proportion. It is possible that an untrained decision maker may misjudge an event and not pay adequate attention to the global aspect of an emergency. If the theater of a crisis is far away and the network systems to monitor the events are non-existent or rudimentary, the crisis management team may not fathom the seriousness of a situation.

Just as the individual perception of the viewer interferes with making an objective judgment of a crisis, so does the crisis itself on the decision-maker's cognitive abilities. Despite all the training, during a real emergency, team members may experience (i) reduced attention span both across time and space, (ii) loss of memory and abstract ability, (iii) diminished tolerance for ambiguity, (iv) deterioration of verbal performance and visual motor coordination, (v) regression to simpler and more primitive mode of responses, and (vi) increased stress leading to random behavior and rate of error. If the decision protocols are committee-based, they may be time consuming and ineffective.

The above problems get compounded when organizational infrastructures and procedures are weak, untested, and dealt with rescue operations involving international participation.

## EMERGENCY RESPONSE IN DEVELOPING COUNTRIES

The inadequate ability for developing countries to handle emergency response is perhaps one of the major issues in global HA/DR. About 95% of deaths caused by natural hazards occur in developing countries. For example, cyclones in Bangladesh have been responsible for taken large numbers of human lives. One half of a million people were killed by a 1970 cyclone and another 140,000 persons were killed by a 1991 cyclone (Schmidlin and Ono, 1999).

A number of economic and social factors explain why the developing countries are more vulnerable to disasters than developed countries. Some of the issues that are more amplified in a developing country setting are:

### Scarcity of economic resources and cultural fatalism lead to acceptance of a higher level of risk

Insufficient infrastructure often hinders the process of disaster relief. For example, after cyclones in Bangladesh, most people could not get proper medical treatment immediately. Some of the reasons include inadequate number of hospitals, lack of equipment, paved roads, transportation, and emergency electrical service (Long, 1999; Morrow, 1994).

Some developing countries do not invest in mitigation efforts on a continuous basis, but follow a "pay-the-price-later" philosophy, and choose to wait for the consequence of the adversity. The developed countries have a greater awareness and understanding of the importance of disaster management. They invest more in mitigation and prevention on an ongoing basis. They also have more resources available to enforce legislation that might reduce the vulnerability. Poverty increases a population's vulnerability. Lack of human and financial resources limit the implementation of mitigation and prevention measures (Taguchi, 1995). For example, fatalistic attitude toward nature also affected high death ratio during cyclone in Bangladesh. Citizens affected by the tornado in Bangladesh were deeply religious and considered the tornado an act of God. This fatalism could cause people to avoid taking an action to mitigate natural disasters (Schmidlin and Ono, 1999).

**Political and administrative instability, inferior technology and low level of education make it difficult to conduct emergency response operations**

Although warning and preparedness have been shown to be important in reducing tornado deaths in U.S., there were no warning systems and preparedness programs for tornadoes in Bangladesh. Inappropriate technology in Bangladesh is one of the reasons why so many people died (Carraro et al., 1994). In 1984, at a Union Carbide pesticide plant in Bhopal, India, there was a fatal leak of poisonous gas. Within a few days, there were more than 2,000 deaths and more than 200,000 injuries. A simple technique such as placing a wet cloth over the face could have prevented countless deaths (Hale, 1997).

Thus, emergency response in developing countries should be dealt with issues beyond immediate relief following the occurrence of a catastrophe. Developing countries try to increase their capacity and decrease their vulnerabilities through sustainable development. Sustainable development is the outcome of comprehensive planning that incorporates considerations of reducing hazards and vulnerability as well as strategies to protect the environment and to improve economic growth, level of education, and living conditions of the population (Stern, 1991).

## A PATH MODEL FOR UNDERSTANDING AND DESIGNING GLOBAL ERS

Researchers have pondered over what variables come into play when designing and managing an ERS and how they lead to ultimate quality of outcomes through averting or minimizing loss of life and property during crises (e.g., Chen et al., 2005; Comfort, 1993; Jennex, 2004; Mak et al., 1999). The variables widely recognized as significant in ERS include: Technology (e.g., Calloway and Keen, 1996), Resources (e.g., National Research Council, 1999), Infrastructure (e.g., Georgakapoulos et al., 2000), and Culture (e.g., Coombs, 1999). We consider these variables to be fundamental requirements for building and successfully operating ERS in any economy. While there are other intermediary variables that impact on the quality of ERS, we argue that these are more basic to improving the quality of ERS decision outcomes and overall management of the relief efforts. In this paper, we call these variables as *Global Inducers*. To the above list of global inducers, based on our analysis of historical humanitarian relief efforts in developing countries discussed in the earlier section, we suggest additions such as education, administration stability, and politics – both nature of negotiations and climate. We agree with Turoff et al. (2006) that effective emergency response includes accurate prediction of disasters and timely and specific warning depends on the quality of emergency preparedness. The proposed path model seeks to identify intervening variables that help achieve the level of preparedness discussed by Bui et al. (2000) and Turoff et al (2006); these include the necessity to (i) change the mental models of those involved in emergency response; (ii) capture expert knowledge; (iv) train novices in crisis management, and (v) improve awareness of importance, immediacy, and uncertainty.

Researchers in Decision Support Systems have suggested relationships between decision quality and variables such as decision-maker's cognition (e.g., Farazmand, 2001, Sniezek et al., 2002), information quality (e.g., Liebowitz and Khosrowpour, 1999), organizational memory (e.g., Liebowitz, 2003) and problem formulation (e.g., Bui et al. 2000, Stern and Sundelius, 2002). We refer to these variables as *Intermediaries.* While they affect the decision quality, the global inducers mentioned earlier affect them themselves. While we believe the proposed path model to be rationally grounded in the literature mentioned above, due to limitations of space, detailed argumentations for the selected variables are not presented here.

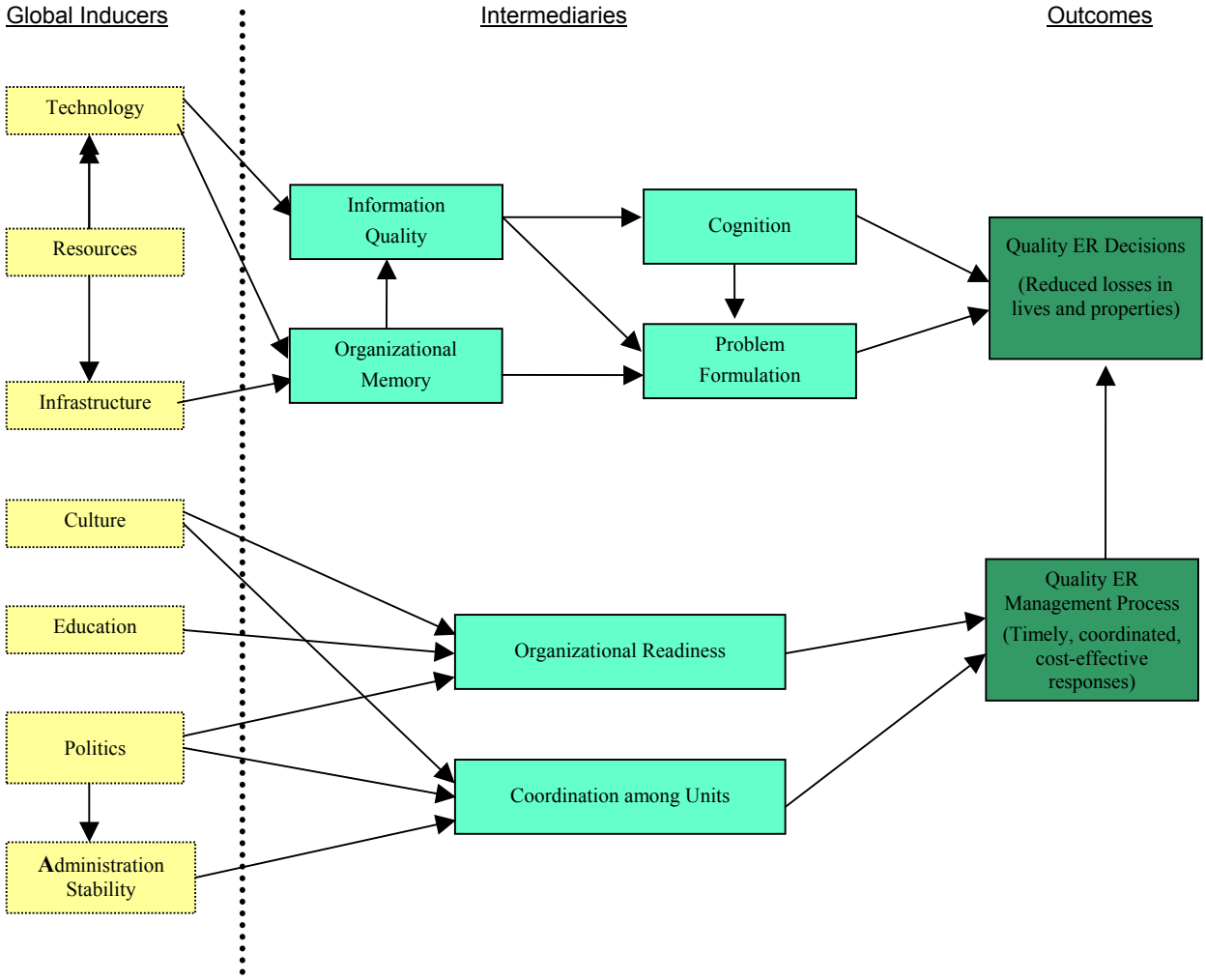


**Figure 1. Path Model for Effective ERS**

We do not claim the list of global inducers and intermediaries presented above to be complete although as explained earlier researchers have confirmed their prominence in disaster relief operations. We propose an integrated path model for quality assurance in emergency responses (Figure 1). We contend that, in order to build effective ERS, researchers need to discover all potential global inducers and intermediary variables and determine the path relationships among them.

The path model gives a meta view of the dynamics of quality assurance involved in preparing for and executing emergency responses. The left column in Figure 1 illustrates the *inducer variables*. An important purpose of the model is to help organizers of emergency response teams recognize that they vary from one country to another. For example, technology is not uniform across nations that may be coordinating their responses to the same global event. Countries with low technology levels may not even detect impending emergencies early enough to avert or mitigate them. Therefore, seeking compatible technologies would be a viable solution. Another inducer variable shown in the figure is infrastructure. Modeling transportation would require taking local constraints into account. Moving information, people and material is easier in countries with an advanced infrastructure. Available resources also vary among nations that can be used to adopt new technologies and improve infrastructure. Culture and belief systems also contribute to variations in how people in different parts of the world react to a set of circumstances. Similarly, education also plays an important part in emergency readiness levels. Another inducer is the political climate. Depending on the internal stability of political and administrative systems, governments may or not work cooperatively when emergency responses on a global scale have to be delivered.

The model also depicts six intermediary variables that link the inducers to the quality outcome variables. In the interest of brevity, we shall limit our discussion to three of these: (i) information, (ii) technology, and (iii) coordination.

### Information

A common denominator of all the activities in connection with a crisis prevention and response is information. Information exchange needs to be interoperable, standardized and secure. During a complex emergency situation, whether by natural or technological disaster, an accurate timely description of the event, its consequences, the needs, the response requirements, and the gaps in national capacity to handle the crisis are required (Harrald et al., 1992). A major problem can arise if various national agencies participating in the decision have conflicting information about the crisis.

During an emergency, information is likely to get distorted. If too much information flows into a few decision-makers, the information overload may lead decision-makers to focus only on selected sources. Another cause of distortion is loss of information over long distance.

Media usually provide breaking news. Local media tend to be nation-centric, focusing on national priorities and community interests. They can be short on analysis and tend to fail to provide all the data required for executive decision. A disaster assessment team should try to provide analysis based on a sound understanding of the facts so as to influence the strategic decision and the use of resources.

Emergency response operations should be transparent to everyone, including the local populace. Authorities involved in a disaster are reluctant to release information they deem critical to national security (Sovereign, 1997). The lack of sharing security information can threaten the lives of those who work among the local populace. As an example, in a recent rescue operation in Rwanda and Chechnya, emergency workers have been targeted and killed by rebel troops without proper protection or even awareness of the threat. These events have led to more efforts for better coordination on security issue.

### Technology

Information technologies that work well during normal times may get overloaded and become incapacitated of meeting the high volume of information processing. Incompatible communication devices represent a particularly serious problem. The use of widely accepted commercial communication systems, such as cellular telephone, could ease these problems. But the need for securing up-to-date information still exists. Thus, information age is a double-edged sword for an organization that is under siege.

Even if all the emergency response participants try to do their best in exchanging information among themselves, cultural and technical incompatibilities constitute considerable barriers for a free information flow. They may use different languages and incompatible communication equipment (Carlson and Davis, 1998). At the inter-agency level, incompatibilities related to organizational structures also hinder the quality of information processing (Hammainen et al., 1990). When military organizations are called in for help, their rigid communication hierarchy may clash with their non-military counterparts that are relatively free of rank. The movement of relief supplies depends on transport arrangement made by particular organization. Backlogs in port are common. If possible, just-in-time supply of equipment will reduce the needs for inventory and loss due to looting and spoilage (Quarantelli, 1988; Sovereign, 1997).

In order to achieve total asset visibility, extensive monitoring and tracking capability is required. Although much of these capabilities can be brought through international assistance, raising the region's own permanent capability will improve the chances the country joining the global network of transportation and communication in the long run.

### Coordination

Another key issue is searching for a way to achieve unity of efforts and better coordination across the variety of organizations in emergency response operations (Morrow, 1994; Nunamaker et al., 1989). Coordination theory has proved to be useful in reducing time delay, from crisis planning, recognition, mobilization and response.

There can be significant differences in perspectives between organizations involved in relief efforts during the emergency response process. For example, one organization may be more concerned about short-term rescue activities while another may be focused on long-term infra structural development. It can lead to loss of coordination

especially when short-term emergency response operations disrupt the long-term self-reliance of a specific region. Although minor disruptions are inevitable, if emergency response operations can be accomplished in a relatively short time before local situation is distorted, the disruptions can be minimized.

When quick and massive responses are required, no single organization has all the resources to alleviate the effects of a disaster. Supra-nationals, local government, military units-all must find some way to cooperate or at least not to disrupt others' activity. Because of the high number of participating agencies, command structure is often hard to achieve. The ad-hoc mixture of participants is likely to lead to a situation where no one is in charge. Coordination should be planned prior to the occurrence of a crisis.

Putting together, the path model suggests that, to improve the quality of decision outcome and processes, the Global ERS should be designed to enhance information, cognition, collaboration and decisionmaking. Andriole advocates that the GIN architecture should have three constituents: (i) system components, (ii) products, and (iii) processes to make these products (1996). The ERS should be enabled by a Global Information Network (GIN) that consists of information technologies for information, communications and surveillance, and should be able to support the Command, Control, Consultation and Coordination processes (see Figure 2)

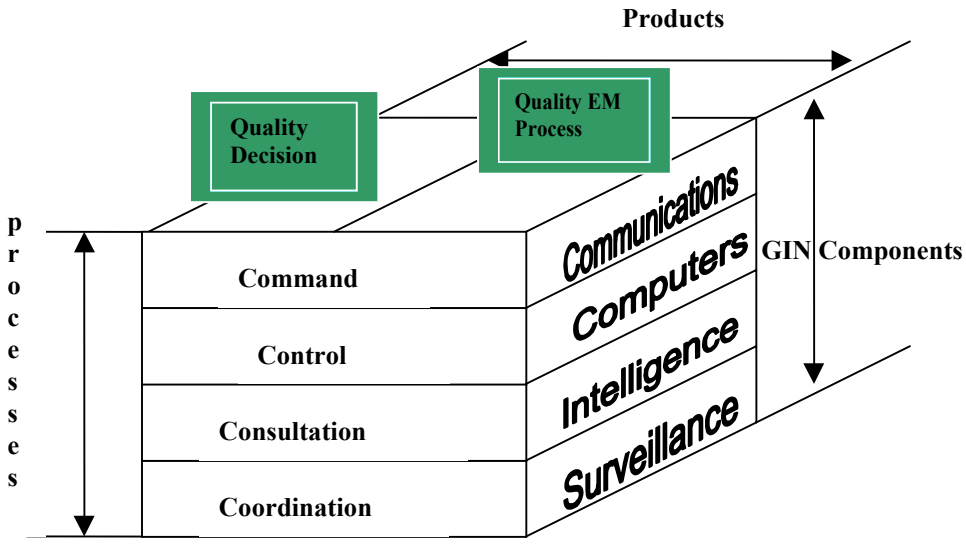


**Figure 2. Structure of a ERS (based on Andriole, 1996)**

## GLOBAL INFORMATION NETWORK IMPLEMENTATION AND EXPECTED FUNCTIONALITIES

The benefits of the path model can best be realized by a net-centric Global Crisis Management Support System (GCMSS). First, such a system can assist the automation of functions described by the intermediary variables. This is important because of the global character of the emergency and not everyone involved in dealing with a crisis would be sufficiently familiar with the geographic areas and the populace affected. Second, it can support seamless flow of information and team collaboration among the decision-makers. This may involve language translations and presenting data in alternative formats. It can provide these not only during crisis-response phase, but pre and post crisis phases as well (see Table 1). Third, the system can help integrate data and expert knowledge through globally distributed data and knowledge bases. Finally, the system can serve as a collection of massively distributed information processors with real-time modeling, simulation, fusion, data mining and warehousing capabilities. In short, an ERS designed based on the path model should lead to the desired outcomes – enhanced quality in emergency response decisions, and overall management of crisis.

ERS for global response requires a worldwide network connecting databases, experts in disaster relief, and other tools available in cyberspace. The system components are made up of the physical computer hardware at the local nodes of the global network, knowledge bases storing intelligence, communication hookups from fiber optics to satellites, and surveillance mechanisms to perform continuous information gathering as well as maintain security.

The processes that these components can transact involve command, control and communication (Aisbett and Srikanth, 1999). The net result of the interaction between GIN system components and processes are two products consisting of high-quality crisis decisions from the GCMSS and high quality in the overall handling of the global crisis at hand. Figure 2 shows the linkage between the path model's functionalities with the GIN architecture. Figure 3 illustrates the agencies typically involved in global operation in the GIN concept.

The GIN framework has been applied to two "Virtual Information Centers" (VIC) located in the East and West sides of the U.S (Bui et al., 2000). These VICs include a command center that physically houses all members of the disaster management team with telecommunication lines connecting to expert advice groups from around the world. The GIN maintains an array of data and knowledge base warehouses covering the range of information required in disaster situations. The databases continually update factual data on geography, population, past disasters as well as current events as they evolve. Field sensors are connected to the network bringing the latest information. The knowledge bases would have information on the social/cultural/organizational characteristics of the agencies involved and the system would have the ability to initiate and manage interactive sessions among the agencies in a manner that fosters productive communication, negotiation and faster conflict resolution. More information on the VIC architecture can be found in Bui, et al. (2001).

The capability to collect, analyze and disseminate information effectively is a critical success factor for emergency operations in modern age. Multimedia capabilities are incorporated so that information in any form - voice, data, graphics, or streaming video - could be sent over the network. The overall implementation emphasizes on the GIN's functional capabilities, ease of use, compatibility and maintainability. Some of the desirable capabilities in emergency response operations are shown in Table 1.

## SUMMARY

There is an urgent need for emergency response planners to identify factors that affect the quality of management process and decision outcomes and explore system architectures that can support emergency responses in a global setting. Major disasters such as SARS, bird-flu virus epidemic and tsunamis tend to affect beyond national borders. Any relief effort must involve swift and coordinated actions by national agencies, non-governmental organizations, and in some situations, the militaries. Designing systems to resolve global crisis situations pose a much greater challenge than those limited within a nation.

We propose in this paper a path model that identifies key components and elements that are critical to the design of an effective global Emergency Response System. Engaging each other in a cooperative undertaking to overcome crises is increasingly becoming the hallmark of emergency management of tomorrow. The growing global element involved in modern emergencies demand a new breed of functionalities in future decision-support systems designed to support quality in both outcomes and management processes. The purpose of this paper is to lay a multi-disciplinary perspective in approaching this massive and challenging task. The proposed model also lays a theoretical framework to conduct empirical studies on the effectiveness of emergency management.

| Support type | PHASES OF ASSISTANCE AND RELIEF OPERATION | | |
|---|---|---|---|
| | PRE-CRISIS | CRISIS RESPONSE | POST-CRISIS |
| **Information** | -Needs assessment (local and global)<br>*-Information collection, compilation, filtering, analysis and storage (Global remote sensing & warning, document management)*<br>*-Integration of infrastructure system databases (Data standardization and interoperability)*<br>*- Translation and certification*<br>*- Adaptation to national information management policies* | -Real-time Interactive Information center (access, share, exchange)<br>- Real-time GPS-supported location information<br>*- Global authentication of data*<br>-Data security and standardization<br>-Push-approach to information dissemination using voice communications (VoiP and multi-media) | -Dissemination of activity results<br>-Dissemination of lessons learned |
| **Communication** | -Electronic discussion group<br>-Satellite network<br>-Dissemination of help request to expert group world wide | -Knowledge based information filtering<br>-Teleconferencing | - Evaluation of communication bottlenecks<br>- Search for alternate technologies |
| **Collaboration/ coordination** | -Group/event scheduling<br>*-Coordination with regional/national network*<br>*-Transnational scenario development (planned emergency responses)*<br>*-Trust building among international agencies/teams* | -Computer assisted logistics (tracking, monitoring)<br>-Just-in-time support<br>-Group/event scheduling and Coordination of planning<br>-Security (VPN)<br>*-Language translation*<br>*- Special assistance to international rescue staff* | *- International briefing of coordination*<br>- Exchanging of lessons learned |
| **Medical support** | -Public health education<br>-Information about major diseases<br>*-Planning, training, stockpiling, and transportation of medical supplies* | *-Remote diagnosis/patient monitoring*<br>*-Information network to support healthcare teams* | *-Review of international coordination procedures*<br>-Follow-up on on-going medical situations |
| **Decision focus** | - Intelligence gathering, interpretation<br>- Continuous update of directory of experts<br>*- Universal visualization and multi-media* | *-Supply Chain Management Support (sequencing of responses)*<br>*- Global response tracking support*<br>*-Distributed group decision support system*<br>-Computer assisted project management (modularity and scalability) | - Review of effectiveness of decision outcomes<br>- Update organization memory<br>*- Assessment and improvement of global emergency management processes* |

**Table 1. Mapping Path Modeling to a Global ERS Requirements**

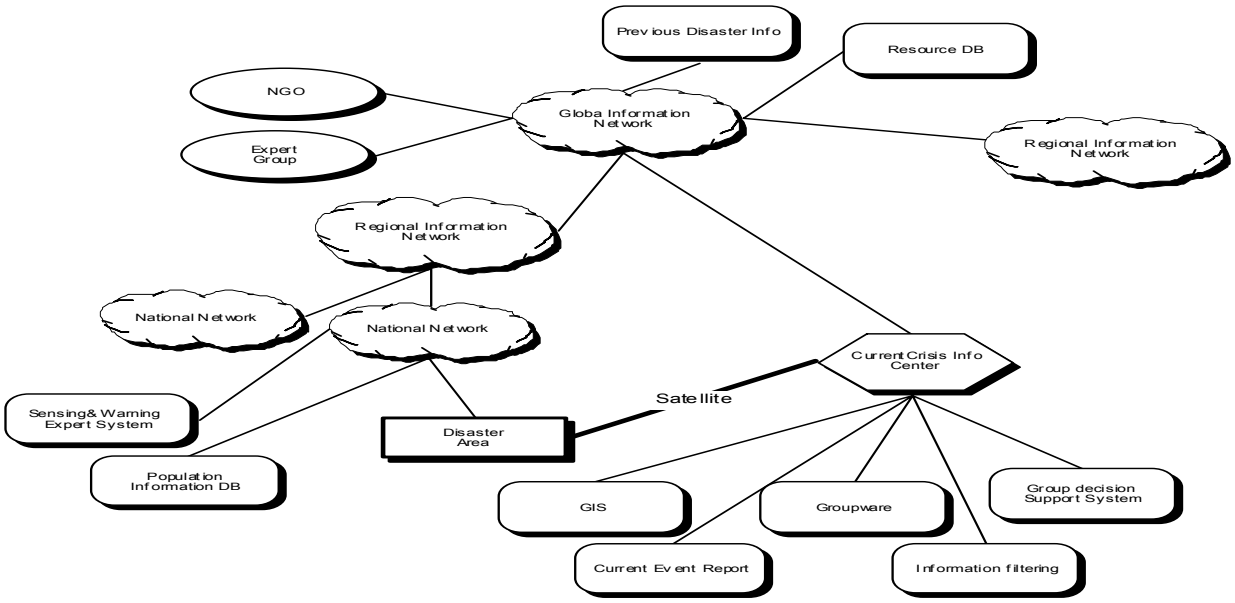


**Figure 3. An Illustration of Agencies involved in the Global Information Network (GIN) for ERS**

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