Information Systems for Emergency Management

Edited by
Bartel Van De Walle, **Murray Turoff**
and **Starr Roxanne Hiltz**

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VLADIMIR ZWASS SERIES EDITOR

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Advances in Management Information Systems

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SERIES EDITOR'S INTRODUCTION

VLADIMIR ZWASS, EDITOR-IN-CHIEF

Some six decades after their invention, we are still learning how to develop computer-based information systems (IS) for the major categories of situations where their effective use can be of momentous benefit. Such is the domain of the emergency management information systems (EMIS). EMIS assist the people responding to crises, disasters, and catastrophes (characterized as major disasters). People who deal with emergencies need an appropriate informational and decisional support. This support has to be available at the right place—which means just about anywhere it may be needed. It has to come at the right time—preferably in real time, as the situation develops during a response. Most important, it also has to offer the complete information that is right for the individual and in the appropriate format—avoiding the overload and miscues. Far beyond that, EMIS need to support the coordination of efforts of a great number of organizations and individuals, many of them unfamiliar with the others, in the response situation of extreme urgency and under immense psychological and societal pressures.

The present AMIS volume is of true importance, as it brings together the research on EMIS foundations, development, and design with a major body of experience in the use of these systems from which general and specific lessons can be drawn. The value of the volume is thus vastly enhanced by its embedding in the actual practice, owing to a number of analytical field studies included here. It is further important that the volume's editors are the well-known authorities in this subfield of MIS. Murray Turoff is the father of this domain of research and practice, and his coeditors, Roxanne Starr Hiltz and Bartel Van de Walle, are major contributors to its development. Turoff's ground-breaking EMISARI system was developed at the Office of Emergency Preparedness of the President of the United States in the early 1970s and used for the management of emergency situations for some 15 years (EMISARI 1973). As the editors introduce to you the scope of the EMIS domain and its research methods, they simultaneously fulfill the AMIS objective of providing an integrated view of the MIS discipline.

In their most general role, EMIS help materially in coping with emergencies of various magnitudes, in particular, with the unprecedented and major events. The most stringent requirements for EMIS result from their use relating to disasters and catastrophes. Disasters come from natural sources, such as earthquakes, tsunamis, or floods. They may be a consequence of industrial, scientific, and technological hazards: a chemical spill, a virus escaping a research lab, or a cascading and lasting failure of the electric grid. Notable here are the potential consequences of the cyber hazards inherent in our networked computerized infrastructures. Infrastructures such as the Internet-Web compound display the scale-free property and thus highly enhanced vulnerability due to the presence of vastly connected hubs. The third category of disasters may result from a deliberate human action, such as terrorism or sabotage. With the mutually reinforcing effects of the growth of human population, technological advancements, and growing intercon-

nectedness of various infrastructures, accompanied by the eruptions of apocalyptic visions, our vulnerabilities grow apace and require a sustained effort on many levels of human affairs to contain them. These efforts need to be supported by tools that have a chance to target the threats. A comprehensive approach to the development of EMIS that can be realistically and effectively deployed to prepare for and to handle the situations of high individual and group stress is necessary. This is what the editors and the authors of this volume are after.

Although the deployment of EMIS during the response to an emergency is their most compelling use, these systems are expected to do much more: EMIS should provide a multifaceted assistance during the full cycle of emergency management. This includes identifying the risks and reducing vulnerability (mitigation), planning a response (emergency preparedness), the potentially very lengthy response itself (including early warning and alert), and the subsequent recovery (with various time horizons, some of them lasting years). The "management" of the recent catastrophes, such as the 9/11 attacks and Hurricane Katrina, in a highly advanced society, shows severe failures during all of these stages. The need to work on the development of far better EMIS, and that in the context of the overall sociotechnical system, cannot be underscored more starkly.

The advances in information and communication technologies (ICT) lead to the ever new capabilities that can be exploited in EMIS, along with the more established simulation, decision support systems, database management, visualization, or agent-based designs. Geographic information systems (GIS), global positioning systems (GPS), satellite imaging, and wireless mobile Internet are among technologies in common use today. Driven by Moore's law, new computationally intensive IT capabilities of near-real-time or even real-time data analysis and decision support emerge, along with the ancillary technologies, such as large-scale sensor networks, streaming databases, or enhanced virtual reality systems. Wearable computing, a form of pervasive IS, finds application in EMIS (Randell, 2008). Agile software development methods, such as extreme programming, are being studied with action research in the context of rapid development and fielding of response-oriented EMIS (Fruhling and de Vreede, 2006).

Grand projects are not always supportable and rarely desirable. Given the scope of EMIS, it is often the question of recognizing the value of the already existing systems, developed for a different purpose and in use, however fractured organizationally or nationally, and targeting them at the emergency management. It is also necessary, as the volume's editors and authors stress repeatedly, to recognize the limits of technology. The utopias of automation need to yield to the conceptualization of socio-technical systems where the action capacities of individuals can be fully exploited—and supported by ICT. Considering that the course of events during a disaster cannot be anticipated to a large degree, it is important to plan the response process, rather than a preset sequence of actions. Emergencies emerge—*nomen omen*. General organizing principles of EMIS have been derived from the practical experience and existing research literature by Turoff and his colleagues (2004), and their first premise is that "an emergency system that is not used on a regular basis before an emergency will never be of use in an actual emergency" (p. 10).

As in other areas of human endeavor since the arrival of the Web, there is an ongoing restructuring of the creation and production processes, with citizen volunteers taking an active role. Thus, citizen reporters gather and disseminate information in various formats during emergencies, for example uploading and tagging photos on Flickr (Liu et al., 2008). Citizen participation, supported by commonly available technologies, can become a significant contributor to emergency management. Actually, this is the newly empowered form of traditional involvement of compassionate bystanders and of survivors themselves (Palen and Liu, 2007). The growing mass acculturation to such technological artifacts as the Web-connected smart mobile phones, and the growing culture of short messaging, news sharing in various media, participation in online forums of different kinds

(e.g., wikis and blogs), social networking, and peer production can lead to new governance ideas for the preparation for and the handling of extreme events. These modes of work organization need to be actively researched. Rapidly emerging adhocracies (Mendonça, Jefferson, and Harrald, 2007) and swift trust that emerges precognitively in action in virtual temporary systems and enables cooperation (Xu et al., 2007) are just a couple of examples of the phenomena of interest. There is a need to adapt and adopt the tools aggregating the collective effort of volunteers. For example, Microsoft's Photosynth enables the construction of 3-D display formats from the multiple photos submitted by volunteers. The broadly participatory peer-production or crowdsourcing can augment the command-and-control model of disaster response. Since command and control are necessary in emergencies, the factors of the beneficial contribution of crowdsourcing, such as validation and aggregation, are a fruitful and important area of research. The appropriate support of various roles, such as first responders, command-and-control personnel, healthcare professionals, and various experts has to be studied. For example, time pressure decreases the performance levels of less experienced decision makers even in the presence of complete information (Ahituv, Igbaria, and Sella, 1998). To study EMIS as information systems within the larger sociotechnical systems on the most general level and thus to gain insights about their effective governance, adaptive structuration theory can be used (Bostrom, Gupta, and Thomas, 2009).

The volume brings home a very uncomfortable truth: much needs to be done to equip the people charged with disaster management with integrated IS before we can speak about "emergency management." The needs are particularly pressing in view of some of the more pessimistic assessments of threats (Smil, 2008). It is the very improbability of these events—combined with the magnitude of the harm they can produce—that deprives us of a rational response (Posner, 2004). Efforts to reduce our vulnerabilities have to be undertaken without delay (Perrow, 2007). Thus, beyond all said, IS should be deployed to start the other emergency management cycle with deconcentration, distribution of networks and control, decoupling, and redundancies. The scope and complexity of the tasks at hand militate the availability of multifaceted EMIS along with their continuing use in—we hope—simulation modes. The cumulative value of the design ideas and of the theory-informed experience gathered here is both of the moment and of lasting import.

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INFORMATION SYSTEMS FOR EMERGENCY MANAGEMENT

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CHAPTER 1

THE DOMAIN OF EMERGENCY MANAGEMENT INFORMATION

STARR ROXANNE HILTZ, BARTEL VAN DE WALLE, AND MURRAY TUROFF

Abstract: *This chapter provides an introduction to this volume, structures the different contributions, and provides a summary of each of the chapters, highlighting what we consider to be the most important contributions and issues. The phases of emergency preparedness and response are reviewed, as is the issue of appropriate research methodology for evaluating new types of emergency management information systems.*

Keywords: *Emergency Response, Emergency Management Information Systems (EMIS)*

Technology that provides the right information, at the right time, and in the right place has the potential to reduce disaster impacts. It enables managers to plan more effectively for a wide range of hazards and to react more quickly and effectively when the unexpected inevitably happens.

—Etien L. Koua, Alan M. MacEachren, Ian Turton, Scott Pezanowski, Brian Tomaszewski, and Tim Frazier (chapter 11, this volume)

SCOPE AND PHASES OF EMERGENCY MANAGEMENT AND THEIR INFORMATION SYSTEMS SUPPORT

Disaster, crisis, catastrophe, and emergency management are sometimes used synonymously and sometimes with slight differences, by scholars and practitioners. We use "emergency management" in the title of this book primarily to refer not to small-scale emergencies such as a traffic accident or a house fire, but rather to disasters and catastrophes (whether from natural causes or from human actions such as terrorist activities). A *disaster* is defined by the United Nations (UN) as a serious disruption of the functioning of a society, and *catastrophes* refer to disasters causing such widespread human, material, or environmental losses that they exceed the ability of the affected part of society to cope adequately using only its own resources. Both disasters and catastrophes create a crisis situation: emergency managers must intervene to save and preserve human lives, infrastructure, and the environment. The design, assessment, and impacts of emergency management information systems (EMIS), including information and communication technologies to coordinate and support this intervention, are the subjects of this volume.

Quarantelli (2006) has reviewed how community disasters (used generically to also include the more serious "catastrophes") are qualitatively and quantitatively different from routine emergencies. When a disaster is declared, at the organizational level alone there are at least four differences:

1. In disasters, compared to everyday emergencies, organizations have to relate quickly to far more and unfamiliar entities, often involving hundreds of different organizations. Coordinating information and actions becomes very complex.
2. Since community crisis needs take precedence over everyday ones, all groups may be monitored and given orders by disaster management entities that may not even exist in routine times.
3. Different performance standards are applied; for example, triage at emergency sites has the goal of saving the maximum number of lives given only the medical resources that are immediately available or expected before there is a significant probability that a casualty will die.
4. The dividing line between "public" and "private" property disappears; private goods, equipment, personnel, and facilities may be appropriated without due process or normal organizational procedures.

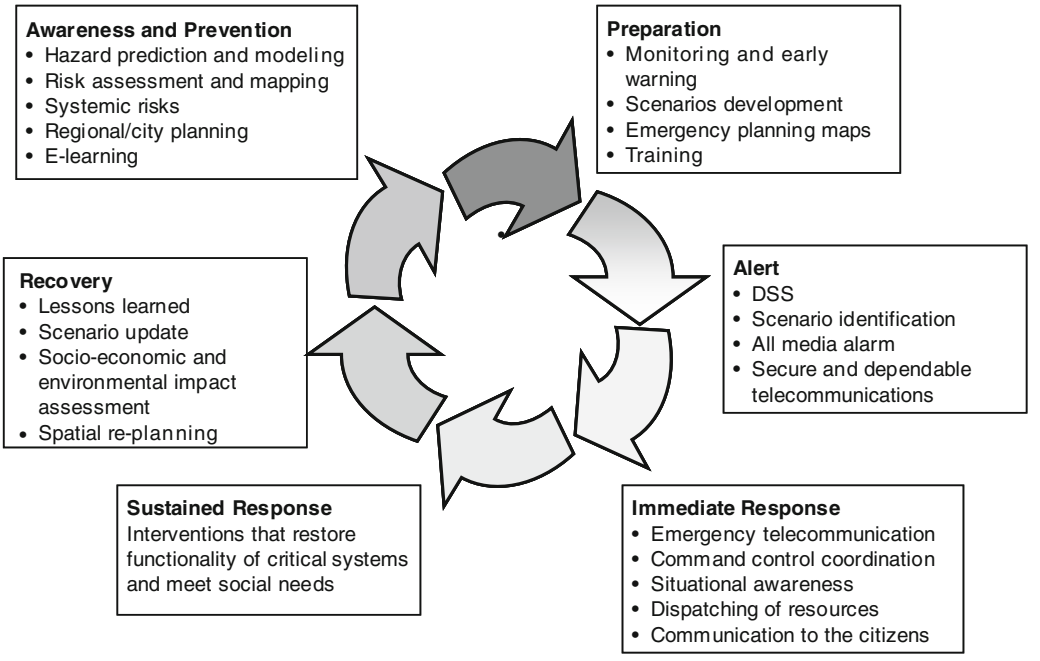
A catastrophe is a disaster with a much more severe and widespread level of devastation. In a catastrophe, much of the housing is unusable, most if not all places of work, recreation, worship, and education such as schools totally shut down. The infrastructures are so badly disrupted that there will be stoppages or extensive shortages of electricity, water, mail or phone services, as well as other means of communication and transportation (Quarantelli, 2006). Local organizations, including the emergency response organizations, cannot function normally, since they lack facilities, and the scope of the catastrophe means that nearby communities that had been counted on to provide assistance are also not available. Thus, "outsiders" such as federal or international organizations must take over.

The literature on disaster management typically identifies four to eight phases of the emergency management process (Turoff et al., 2009). Almost all classifications include four basic phases: *mitigation* (which involves risk assessment as a first step)*, preparedness, response* (also called *emergency management*), and *recovery.* Some add identification and planning as the first phase, and/or "early warning" as a separate phase between preparedness and response. Other possible phases that overlap with these main phases include training, immediate preparedness, and evacuation. Planning encompasses all these areas, and many of these functions go on simultaneously depending on conditions and locality within the disaster area. Within the European Union research framework, the European Commission's Directorate General on the Information Society and Media (DG INFSO) strongly supports the view of an "integrated disaster management cycle," as shown in Figure 1.1.

Regardless of the specific definition of the various phases, information systems are increasingly important to support the personnel involved. This is particularly true given new types of information systems and technology, for example, wireless mobile Internet that can provide worldwide connectivity to distributed teams for disaster planning and response, and geographical information systems that can integrate up-to-date satellite photos and maps of affected areas with tagging and reporting and uploading of real-time data by citizens. Examples of the use of information systems in each phase are given in the various chapters in this volume; we will also review a few here.

Mitigation refers to pre-disaster actions taken to identify risks, reduce them, and thus reduce the negative effects of the identified type of disaster event on human life and personal property. For example, geographical information systems can be used to identify floodplains for rivers or likely wind patterns that might bring fires to areas such as the canyons of Southern California. Once a geographic area at risk is identified, steps can be taken to decrease these risks, such as new zoning to prevent construction in a floodplain, or fireproof roofs being required for new construction in a wildfire-prone area.

Figure 1.1 **The Integrated Disaster Management Cycle**



Source: Senior EU project officers from DG INFSO have presented Figure 1.1 at numerous EU project and public information meetings. It is reproduced here with permission from its original author, Guy Weets at DG INFSO.

Preparedness refers to the actions taken prior to a possible disaster that enable the emergency managers and the public to be able to respond adequately when a disaster actually occurs. For example, personnel can be trained using computer-generated or -supported simulations or exercises. Web sites can be created to direct citizens about what to do in different disaster circumstances and how to prepare their families, for example, by having a two-week supply of water, food, medicines, and other necessary materials stored in their homes, or map-based indications of evacuation routes for events such as floods or fires. Preparedness also includes having adequate information systems up and running and practicing with them so that they can be used for command and control to coordinate emergency personnel and locate resources and keep track of the location of evacuees, for instance.

The *response* phase includes actions taken immediately prior to a foretold event, as well as during and after the disaster event, that help to reduce human and property losses. Examples of such actions include placing emergency supplies and personnel; searching for, rescuing, and treating victims, and housing them in a temporary, relatively safe place. Information systems are crucial for coordinating the efforts to distribute rescue workers and supplies and materials (e.g., water, food, medical supplies, and ambulances) to the locations where they are most needed. Increasingly, citizens are supplying information to online systems that are helpful in this phase, such as by uploading photos of the unfolding disaster or supplying information about missing or injured people.

The *recovery* phase is sometimes never completed; its objective is to enable the population

affected to return to their "normal" social and economic activities. So, for example, recovery would include replacing a destroyed bridge or other missing infrastructure, as well as rebuilding permanent housing that was lost in the disaster. The maps and models included in geographical information systems are important aids in the planning and management of a recovery process.

However, despite the recognition that information systems are crucial components of emergency management, there has been surprisingly little research published that facilitates understanding of how they are actually used in emergencies. There have been a few short overview articles about EMIS (e.g., Van de Walle and Turoff, 2007, 2008), but there are no comprehensive overviews of the field. Our aim is to fill this gap in this volume of studies that will be of interest and value for researchers, practitioners, and students. In the chapters invited for this book, the emphasis was on case studies and data on systems that not only exist but also have been studied in use, so that others can benefit from the lessons learned.

The following section covers the topic of research methods appropriate for documenting and assessing the effectiveness of the use of EMIS, a topic that is not explicitly covered in any of the chapters of this volume. It is meant to sensitize readers to this issue. Then we summarize the chapters in the book, organized according to the divisions we arrived at of foundational chapters relevant to any type of EMIS, chapters related to the characteristics of individuals and organizations that provide the context within which EMIS are designed and studied, case studies of specific types of EMIS, and systems design guidelines. After looking at the summaries, the reader may decide to peruse chapters in a different order or jump to a chapter that seems particularly relevant. The summaries are also meant to highlight what we think are the most important issues and contributions in each chapter.

METHODS OF RESEARCH ON EMIS: REFLECTIONS AND AN EXAMPLE STUDY OF EARTH OBSERVATION TECHNOLOGIES

One of the emphases of this volume is the importance of assessing the usefulness of new information systems for supporting emergency preparedness and response, when applied in practice, rather than just drawing conclusions from a theoretical understanding of the potential benefits of new technologies. This is particularly important in the case of crisis response applications, the use of which is embedded in complex socio-technical systems that often cross many national and organizational boundaries.

Case and field studies that include qualitative research methods are especially appropriate for both formative and summative evaluation of new and evolving systems that do not yet have a large number of users. By formative evaluation is meant research that is designed to provide feedback to further improve the usability and usefulness of a tool. By summative evaluation is meant an overall measure of "how good is this system," particularly as compared to other alternatives, including manual methods. No one method of data collection is likely to be sufficient for system evaluation; a combination is likely to be necessary. All of the authors of chapters in this volume about specific systems were asked to include a discussion of the methods and findings of evaluation research on their systems. Some chapters provide more information than others do about research methods; in this section, we highlight one chapter that used a variety of assessment methods.

Qualitative research methods used during a large-scale simulation and recognition of how the use of information systems during crises is part of a socio-technical system are important aspects of "Do Expert Teams in Rapid Crisis Response Use Their Tools Efficiently?" (by European scholars Jiri Trnka, Thomas Kemper, and Stefan Schneiderbauer). This chapter reviews experiences and

lessons learned from a simulation of operational deployment of earth observation technologies by expert teams in rapid crisis response. By "earth observation technologies" [EOT] is meant advanced geospatial technologies, such as space-based sensors, unmanned aerial vehicles, high volume data processing tools, and integrated geospatial databases which can be used in detailed real-time mapping to obtain a fast and reliable situation assessment when crises occur.

The research focus of this chapter is thus laid on gaining knowledge of operational deployment of EOT by expert teams in rapid crisis response. In many situations, simulations, as a methodological means of studying human systems or their parts, are the only way for the research and development community and the prospective users to confront and analyze these situations and systems. The simulations that are relevant in the emergency context are those with humans in the loop—interactive multi-person settings reproducing reality or its parts (Crookall and Saunders, 1989). They replicate situations and processes, where simulation participants (humans) try to solve a problem or overcome various obstacles in a collaborative manner. This type of simulation has been widely used in the military and crisis management domain. In these simulations, participants act based upon hypothetical conditions (defined via scenarios), while using real and simulated resources. The simulations described in Trnka et al.'s study were executed in real time, but are referred to by the authors as "low-control" simulations in the form of case studies. The focus of data collection and analysis is given primarily to qualitative data and qualitative analysis on how different interactions and processes took place.

The scenario created for the study reported in Trnka and colleagues' chapter was an incident in a nuclear power plant followed by a release of radioactive gasses. Each team had one predefined coordinating organization operating at a coordination point; the simulation was executed at fourteen different locations in nine countries over a period of thirty-three hours. There were three independent expert teams with an average of twenty-one members in each team. In the simulation, the three expert teams worked in parallel on identical tasks related to rapid mapping tasks in a crisis response context. Four data collection procedures were used: participant observation, an after-action review, expert evaluation, and follow-up workshops.

1. *Participant Observation*—was the main data collection technique. Each team was assigned two observers who were located at the main coordination point. There was an observation guide containing detailed specification of the observation areas and examples of questions of interest. The guide also included a time schedule for regular status reports, which the observers had to send to the simulation managers three times a day, approximately every three to four hours. A status report form with specific questions for every scheduled reporting occasion was developed and used by the observers during the simulation. Such detailed plans and forms for observation greatly increase the probability that comparable and rich data will be collected at all sites, so that conclusions can be drawn.
2. *After-Action Review*—provided the simulation participants with immediate feedback.
3. *Expert Evaluation*—all the outcomes delivered by the teams were evaluated by experts from the remote sensing domain, focusing on the assessment of the products and the EOT used in the simulation.
4. *Workshops*—a sample of simulation participants and observers took part in two half-day follow-up workshops. During these workshops, outcomes of the simulation were presented, followed by an informal discussion, with recording of the discussions.

With this combination of methods, the research team was able to identify what problems occurred and to explain why some teams did much better than others.

Note that a similar multi-method was adopted by Schooley and his colleagues in their study of an incident reporting system, which will be described in the next section.

On the other hand, more quantitative methods will be necessary for large-scale systems with many users and installations. However, we lack standard scales that can be used to compare across studies. For example, a recent review of instruments used to assess public health preparedness concluded that there was a great deal of overlap but little consistency in what constitutes "preparedness" or how it should be measured (Asch et al., 2005). The American CDC (Centers for Disease Control and Prevention) has issued guidance on public health surveillance and detection capabilities for agencies that urges assessment, at least annually, of the timeliness and completeness of their reportable disease surveillance system. However, few studies have published quantitative measures of reporting timeliness and these studies do not evaluate it in a standard manner (Jajosky and Groseclose, 2004). The chapter by Ann Fruhling on evaluation of a medical emergency response system gives an example of the development and fielding of a survey instrument.

CHAPTER SUMMARIES AND OVERVIEWS

Foundations: EMIS Design Framework and Ethical Guidelines

The two chapters described in this section provide general guidelines that are applicable to the design and use of EMIS in any phase of the emergency management cycle.

A Design Framework

In "Structuring the Problem Space of User Interface Design for Disaster Response Technologies," Susanne Jul uses sociological theories of disasters to develop a systematic description of the design problem space for user interfaces for response technology. This is an example of EMIS as "sociotechnical" systems—technical systems that must respond to social needs and the social context of use. Examination of three sociological dimensions of events, focusing on implications for response, reveals a twelve-dimensional framework for describing users, tasks, and contexts of response technology that could be used to help guide the design for any type of EMIS. The three dimensions are *scale* (a measure of the extent of the effects of an event), *kind* (an indicator of the types of effects of an event), and *anticipability* (a description of the possibilities for preparedness for an event).

Scale reflects the power of the causal agent(s), the success of mitigative measures, and the effectiveness of the response system. Sociologists commonly discuss three measures of scale: magnitude, scope, and duration of impact (Kreps, 1998). *Magnitude* indicates the severity of social disruption and physical harm, or in other words, the extent to which the lives of those affected have been interrupted or altered. *Scope* indicates the extent or total size of the affected geographic and social area that has been exposed to social disruption and physical harm. *Duration* is the total elapsed time between the onset of social disruption and physical harm and when the disaster is no longer defined as producing these effects. Further developing the dimension of scale, Jul uses Quarantelli's (2006) separation of magnitude into disruption of community infrastructure and resources (physical and human), disruption of response infrastructure and resources, and the adequacy of established response measures.

The typology also identifies four types of organizations (Dynes, 1998). *Established organizations* normally engage in response activities, and their operational structure is unchanged during responses. *Expanding organizations* routinely engage in response activities, however, they must

expand their operational structure to do so, typically by recruiting volunteers. *Extending organizations* do not normally perform response activities, but are able to do so using their existing organizational structure. *Emergent organizations* likewise do not normally participate in response, but must create a new organizational structure to do so, and are often formed spontaneously.

Sociologists have also found that event *kind* affects response characteristics. One aspect of kind is *affect,* which is an indication of the diversity of the effects of the event. Dynes (1998) separates *community disasters*—events that affect a broad range of physical and human resources (e.g., earthquakes)—from *sector disasters*—events that primarily affect a specialized segment of the community (e.g., computer viruses).

The final dimension of disaster considered, *anticipability,* captures event characteristics that determine what preparedness is possible. It comprises two measures, predictability and influenceability. An event is *predictable* if it is within the realm of imagination of the times and its occurrence is perceived as sufficiently likely to be believable. An event is *influenceable* if means of reducing damage are known and can realistically be implemented given the resources and sociopolitical environment of the time and place. For example, although many measures had been proposed that would have reduced the impact of Hurricane Katrina, they were considered "too expensive" and the levees were not rebuilt to prevent failure. Thus, available technology made the Katrina Hurricane disaster both predictable and influenceable, but the political structure did not act on the information.

To illustrate analytic use of the framework, it was applied to an actual response to a conventional local disaster (an apartment-building fire). The framework offers a foundation for a design theory of user interfaces for response technology, and can accelerate individual design processes by helping designers develop accurate problem spaces more quickly. It can also help designers and researchers to identify unexplored design problems and solutions, and can lead to new and innovative designs.

Ethical Considerations

Irene Anne Jillson, in her chapter, "Protecting the Public, Addressing Individual Rights: Ethical Issues in Emergency Management Information Systems for Public Health Emergencies," includes a review of nine design principles from the foundation paper by Turoff and associates (2004) on "Dynamic Emergency Response Information Systems" (DERMIS). In emergency response and in creating information systems to support emergency response, the key ethical issue is the distribution of needed basic resources. Basic resources can be defined as those supplies necessary to sustain life in a public health emergency, including food, potable water, medication, blankets, and temporary shelters. Current public health emergency planning efforts, although extensive, have inadequately addressed basic resource distribution and, in particular, related ethical issues. Both of these can and should be considered in the design of EMIS. However, a review of emergency planning and policy documents shows that there is very little if any attention paid to ethical issues in emergency response planning, which includes the design of information systems to manage that response. The concepts and principles reviewed in this chapter can be applied to most types of emergencies, not just medically related ones such as pandemics or bioterrorism.

Jillson also reviews the historical and cross-cultural bases of ethical principles, including:

1. Beneficence (e.g., do not harm; maximize possible benefits and minimize possible harm in the delivery of care and conduct of research).
2. Respect for persons/human dignity (acknowledgment of autonomy—individuality; protection of those with diminished autonomy—meeting needs of vulnerable populations).
3. Justice—distributive justice, assurance of equal access to healthcare services.

In particular, there is a lack of consensus on distributive justice principles. For example, the prospect of an avian flu pandemic and an associated vaccine shortage has sparked heated discussions about resource allocation, namely, who should receive the vaccine when roughly only 10 percent of the American population will be able to be vaccinated in the first year of an avian flu pandemic. The United States Department of Health and Human Services (US HHS) has issued a proposed vaccine rationing plan, giving first priority to health care workers, people involved in vaccine manufacturing, and those at highest risk of severe disease (e.g., senior citizens), on the basis that this scheme will result in the greatest number of saved lives (US HHS, 2005). However, the amount of vaccine would not be sufficient to cover all in these categories, even if nobody else were vaccinated. Others have argued that a "fair innings" approach should be used and priority should be given to younger people who have not yet experienced a full life. If younger people, who in fact are at great risk in such an epidemic, were to be given priority, what is the definition of "younger people," for example, under six? Under eighteen? Under thirty? Moreover, what is the ethical or practical basis for making such decisions?

The chapter ends with an explicit consideration of the extent to which an EMIS adequately incorporates issues of social justice. In particular, how does the EMIS contribute to assurances that marginalized and particularly vulnerable populations are reached? And to what extent are privacy issues addressed and how are they balanced with the *need to know* in order to protect the social good?

Individual and Organizational Context

In designing EMIS, it is necessary to take into account the decision-making qualities of the individuals and groups that will become the users. Humans are not rational machines, especially when under stress.

The Threat Rigidity Syndrome

Suppose while you are in the wilderness, walking a trail, you turn a corner and come face to face with a ten-foot-tall, 1,000-pound grizzly bear. You, or anyone, would have an immediate mental reaction of fear that could be quite severe. Such fear produces one of three very different responses:

- A loss of clear thinking, a mental rigidity due to the obvious threat, and an instinctive reaction to turn and run from the bear ("flight"). (Note that this would turn you into "prey," and the bear would probably eat you.)
- A loss of clear thinking, an instinctive reaction to "fight" the bear by hitting it with a rock or your hiking pole (note that you would quite probably lose.)
- A calmer thought process to try to recall what one might know about this situation and think through, quickly, alternative reactions, as well as rapidly examining the surroundings or assets being carried for anything that might help. (This might lead to recalling that experts say you should yell, wave your hands over your head to appear to be bigger, and slowly back away while looking down so as not to "challenge" the bear for territory. If all goes well, the bear will not follow. If the bear does follow, you are well prepared and remember that you have pepper spray on your belt. And you squirt it at the bear instead of at yourself.)

The syndrome of what is called "threat rigidity" of individuals dealing with emergencies is well established in the literature. Linda Plotnick and Murray Turoff's chapter on "Mitigating Maladaptive Threat Rigidity Responses to Crisis" reviews this syndrome. The literature shows

that "mindfulness" for individuals and groups is very much an underutilized alternative compared to instinctive or habitual reaction choices that may not fit the emergency situation at all.

Individuals in command and control or in decision-making positions in emergency situations are just as prone to this phenomenon as underprepared hikers, or firefighters inside a burning building. However, the factors that drive a person toward a state of threat rigidity as opposed to a state of mindfulness are numerous and in some cases cumulative over time. For example, if a person does not trust others to take over their responsibilities, they may stay in their role for a long continuous period of time creating a severe degree of fatigue, possible increasing errors due to ignoring some critical information, and getting negative feedback on results that threatens their confidence in the results of their actions or decisions.

Depending upon what is taking place over an extended period of time, the emergency responder is continually subjected to changes in a number of factors that may drive him or her to better or worse decision making. These factors are due to a wide variety of causes: what is happening in the environment, administrative practices, policies, the design of the systems being used, and interactions with others. This chapter reviews how each of the factors influences the potential occurrence of threat rigidity. It points out the concerns one must have for the design of systems and the environment in which they operate. The objective is to be able to ensure that professionals do not reach a state of threat rigidity while handling their role and responsibilities in a given emergency.

The chapter provides solutions to the problem of how to design human processes and information systems in an optimal configuration to avoid any possibility that threat rigidity will occur. However, it should provide awareness of making better tradeoffs in the design of the processes and the supporting system for any type of EMIS application. There is also the important consideration of how to become aware that threat rigidity potential is increasing and what actions to take to reduce its occurrence.

Using Tools Efficiently

The chapter by Jiri Trnka, Thomas Kemper, and Stefan Schneiderbauer, "Do Expert Teams in Rapid Crisis Response Use Their Tools Efficiently?" which covers some of the group dynamics considerations, was already summarized above as part of the section on evaluation methodology, since it includes the most complete discussion of methodology in the set of case studies. Attention is given to expert teams that provide remote support to various decision makers, in the form of analytical products and services based on earth observation data. The teams' tasks concern work on digital satellite imagery, such as data collection, fusion, analysis, and visualization, and are accomplished with the aid of various computer-based tools. The chapter describes experience and lessons learned from an exploratory study of three expert teams deploying earth observation technology in a simulated crisis response scenario. It demonstrates how team configuration is tightly related to communication and has an essential impact on team interaction, how work is performed, and whether or not a collaborative task is accomplished successfully in a field as challenging as crisis response.

Case Studies

This section, consisting of four chapters, is the heart of the volume. Each chapter describes in considerable detail the design of specific EMIS and how they have been used, and reports the results of evaluation of this use.

Emergency Identification/Diagnosis: An Example for Contagious Diseases

Feedback from first responders is key to making emergency response systems (ERS) effective and scalable should the need arise. Ann Fruhling's chapter, "STATPack™: An Emergency Response System for Microbiology Laboratory Diagnostics and Consultation," examines a particular case on how well a newly developed ERS performed and the lessons learned from the actual users of the ERS during emergencies.

The Secure Telecommunications Application Terminal Package (STATPack™) system is a secure, patient privacy–compliant, Web-based network system that supports video telemedicine and connectivity among clinical health laboratories. The overarching goal of this public health emergency response system was to establish an electronic infrastructure, largely using Web technology, to allow secure communication among state public health hub and spoke laboratory networks in emergency situations. The smaller "sentinel" laboratories (referred to as "spoke" hospital laboratories) are linked to larger hospital laboratories (referred to as regional "hubs"), which provide expertise and consultation when a potentially dangerous pathogen needs identification. The network supported by STATPack utilizes the multistate Public Health Laboratories' state-of-the-art approaches to identifying emerging infectious diseases, tracking sources of antibiotic resistance, and detecting bioterrorism agents to further support the rural public health infrastructure in states with large rural geographical areas.

The research methods challenge in this project was to formulate questions to measure the perceived usefulness of a system that is not expected to be used very often and that may not directly benefit the laboratory user. With forty-one laboratories participating at the time of the study, there were far too many to rely on personal visits for participant observation and interviews. For the purposes of developing a survey, the technology acceptance model (TAM) (Davis, 1989) constructs of perceived usefulness and perceived ease of use were envisioned as the perceived costs and benefits of using STATPack. Perceived usefulness might be measured in terms of the perceived benefits to public health, and the costs to the user in terms of the level of effort (ease of use) required to perform the tasks necessary for distance consultation with the National Public Health Laboratory.

The results of the survey were favorable; for example, 82.2 percent of respondents either agreed or strongly agreed with the statement, "I feel that the STATPack is a useful system to have in my laboratory," and 88.9 percent of respondents either agreed or strongly agreed with the statement, "Overall, I am satisfied with how easy it is to use the system." Use of the system has been expanding. However, it is still only a regional special purpose system. Political support and funding are necessary to create the kind of national, multithreat diagnosis system that STATPack demonstrates is possible.

Coordination of Emergency Response

Rui Chen and his colleagues from SUNY Buffalo (Raj Sharman, H. Raghav Rao, Shambhu J. Upadhyaya, and Catherine P. Cook-Cottone) present a case study of a severe October snowstorm to chronicle the "Coordination of Emergency Response: An Examination of the Roles of People, Process, and Information Technology." Information technology (IT) itself is not enough. They conclude that "members of the emergency response community must improve their practices before they can fully leverage the potential benefits of advanced emergency response systems."

While snowstorms may not seem to be major emergencies, that depends on how much snow, when, and where. Even though the Lake Erie region is very prepared for winter snowstorms, an

unseasonable lake-effect snowstorm that hit the western New York area with record-breaking snowfalls while leaves were still on the trees in October downed thousands of tree limbs and toppled power lines, leaving about one million people without electricity in western New York for up to ten days. This in turn knocked out much of the infrastructure of the region, closed government and other offices and highways, and required large-scale sheltering of residents. This case study of Erie County's attempt to coordinate a response shows how difficult it is when regions do not have adequate plans and trained personnel to deal with large-scale emergencies.

The advanced information system used was off-the-shelf software made available to all the municipalities. It was supposed to replace the conventional paper-and-pencil–based management approach by digitalizing information flow and semiautomating decision support. Key functions included a call center service, incident status board, integrated message broadcasting system, asset management tool, contact management tool, and numerous reporting and task management tools. The objective was a collaborative platform for distributed individuals/groups/organizations to share information, make decisions, and consequently to synergize response capabilities.

Each of these modules could have provided highly useful information and decision support. However, the authors document that the intended users had adaptation problems with each of the modules.

The authors summarize by stating that "future improvements are needed in organizational process/policy design, infrastructure support, system maintenance, ease of use, and user adoption," and of course, user training of prospective responders.

Challenges Facing Humanitarian Management Information Systems (MIS)

Humanitarian operations in disaster-struck areas require substantial communication and coordination support amid damaged human, technological, and societal infrastructures, as described in "The Challenges Facing A Humanitarian MIS: A Study of the Information Management System for Mine Action in Iraq." The chapter concerns the Iraqi Mine Action Program (MAP), a humanitarian demining initiative started in the country in 2003. Humanitarian consultant Daniel Eriksson presents his experiences on the use of the Information Management System for Mine Action (IMSMA) within the complex humanitarian context of Iraq. IMSMA is the UN-approved standard for information systems supporting humanitarian demining activities and has been put to use in demining programs around the globe.

IMSMA is a distributed multiuser system providing a geographic information system (GIS) interface to a relational database containing mine-related data and provides several decision-support functions. The system supports production of geographical maps, demining task lists based on these maps (showing the location of minefields, past accidents, nearby hospitals), and historical or statistical reports. In addition, on-site survey teams can input local information into IMSMA to calculate a "community impact score," enabling monitoring of the progress (or lack thereof) of local mine-related actions.

Daniel Eriksson describes his approach as "participatory observation," and his observations are based on his extensive field experience in the Iraqi humanitarian mine action. From these observations, he derives seven challenges that prevent the successful adoption of IMSMA in Iraq, among which are the security situation, the lack of central governance, staff retention, user understanding of the MIS, and the lack of decision support functionality for the operational decision makers working on the ground. The latter two challenges, poor user understanding and insufficient or inadequate user support, are symptomatic of a failure to design a useful and usable information system. As happens all too often, systems are designed "in splendid isolation," in this case by a

renowned European university, ignorant of the needs in the field—in this instance those of the struggling humanitarian workers.

The contextual challenges of a failing government and deteriorating security situation are symptomatic of most humanitarian operations. These factors are mutually reinforcing, and contribute to a high turnover of local and international staff, who usually leave without transferring their knowledge and expertise to their successors, causing widespread demotivation among those who are there to help. Eriksson accurately describes this vicious circle:

> The deteriorating security situation has forced a reduction in the data collection and resulted in decreased on-site support by expatriate information management experts. This factor plays a role in dragging the mine action community into the vicious circle of reduced data collection leading to reduced data quality, which results in a reduced interest in collecting data.

Daniel Eriksson concludes his participatory observation report by suggesting concrete measures and solutions to meet the above challenges. These solutions are within the realm of the international community of which we are all part and can only be successful if all of us contribute our knowledge, our expertise, and, above all, our undivided attention.

Minnesota Interorganizational Mayday Information System

In "User Perspectives on the Minnesota Interorganizational Mayday Information System," Benjamin L. Schooley, Thomas A. Horan, and Michael J. Marich present a case study of a Minnesota information system that automatically creates incident reports. It pushes select General Motors (GM) OnStar emergency data (such as crashes recorded by sensors) to preauthorized emergency response and transportation stakeholders (dispatch centers, law enforcement, ambulance providers, health care facilities, and traffic management centers). The purpose of the Mayday project was to develop and demonstrate a method for reducing the time required to notify emergency response providers of a stranded or disabled vehicle by relaying vehicle location and other critical information about the event to a wide range of EMS and transportation stakeholders.

In general, participants in the Mayday study noted how their ability to visualize and see emergency and transportation resources enabled more effective communications (as compared with the voice-oriented, manual sequential system for emergency notification and dispatch), more informed decision making, and a higher degree of perceived service performance. Though the system is based on input from individual automobiles, in a larger scale emergency, the flow of information from many end users could serve to indicate the scope of injuries and need for help across a wide area.

While an overview of the Mayday operational system is provided, the focus of this chapter is on the perspectives of the users that were affected by the system. In this sense, the chapter focuses on the relationship between the operational Mayday system and the behavior of emergency responders and participating organizations. The need to design information systems to "fit" both organizational and interorganizational performance goals is emphasized.

The end-user evaluation utilized on-site visits with each participating organization as well as individual interviews and roundtable discussions with participants. Participants were personnel from both management and nonmanagement positions and included call center operators, medical dispatchers, State Patrol officers, paramedics, physicians, hospital administrators, and nurses.

The evaluation was conducted in two overlapping phases. The first phase sought to understand the operational Mayday system as described by documentation and users. The analysis utilized

business process documentation, Mayday performance data for the year, technical information system documentation, management reports, performance reports, and interorganizational agreements, including formal and informal contracts, as well as field notes and supplemental interviews. The data were collected through field visits on location at each participating organization as well as through follow-up phone and e-mail conversations.

The second research phase examined contextual issues about the Mayday operational processes and information exchanges. Semistructured interview questions sought to understand what conditions inhibit or prohibit information sharing across organizations, the role information sharing (and technology) plays in the delivery of public services, and the role of information sharing to manage interorganizational service performance. Researchers took detailed field notes and summarized observations.

The overall study methodology and research process, including the coding of interviews, was guided by the time-critical information services model (Horan and Schooley, 2007). This framework was developed as a way to distinguish between different simultaneously ongoing streams of phenomena, some of which are organizational, and some of which are performance-based, technological, time-dependent, and so on, and frame them into an analytical lens for interorganizational systems analysis.

EMIS Design and Technology

This section contains six chapters that provide in-depth discussion of EMIS application areas (simulation and geocollaborative environments), implementations (both in the humanitarian domain), and standards (in the resource management and risk management domains, respectively).

Simulation in Emergency Management

Simulation and modeling have a rich history in emergency management, but up to now, they have been applied mostly to very sophisticated problems such as the spread of hazardous materials in gaseous or liquid form, planning major evacuations, nuclear accident implications, and so on. New technological developments in sensors, data fusion, and emergency communications, coupled with increasingly complex and extreme disaster situations, are causing a growing requirement for the direct incorporation of better models in all phases of emergency preparedness and management. The need to improve training with the use of asynchronous models and virtual reality systems, the growing use of sensors for the detection of emergencies and the monitoring of ongoing disasters, on-site medial sensors, major logistic complexities, and the like have all led to increasing demands and requirements for interactive models and simulations that can be integrated into real-time information systems. These topics are covered in the chapter on "Simulation and Emergency Management," by Julie Dugdale, Narjès Bellamine-Ben Saoud, Bernard Pavard, and Nico Pallamin.

An interesting example of the future promise of this area is recent work in creating three-dimensional representations of two-dimensional satellite scans taken at different angles before and after an earthquake, flood, or severe storm. The resulting contrast (before and after) provides instant visualizations of the resulting conditions that can be used to guide both short-term response and longer-term recovery. This area is rapidly developing, and this chapter provides a set of fundamentals that leads the reader to an understanding of the potentials of this field for emergency preparedness and management as well as the common pitfalls that have plagued past efforts.

Geographical Information Systems

While the term "earth observation technologies" was used by Jiri Trnka and colleagues, a more general term for this class of systems is "geographic information systems" (GIS). The chapter by Etien L. Koua, Alan M. MacEachren, Ian Turton, Scott Pezanowski, Brian Tomaszewski, and Tim Frazier on "Conceptualizing a User-Support Task Structure for Geocollaborative Disaster Management Environments" provides a framework for the design of geocollaborative environments. These environments are intended to support group interaction and collaboration during disaster management activities, by providing access to relevant geographic information (e.g., maps of many different types) and communication tools.

Most crisis management activities require geospatial information—to determine where events have occurred, who is at risk, and how the risk varies geographically, and such factors as what routes are available to ship supplies, where to set up medical facilities and shelters, what the impacts might be on surrounding places (e.g., due to disruption of power, housing of refugees, disappearance of jobs, etc.). As a result, as pointed out in the chapter by Koua and his colleagues at Penn State, geographic information systems have the potential to make a substantial positive impact on our ability to plan for and cope with crises of many kinds, especially when they include remote sensing from satellites to provide near-real-time maps that can be shared among disaster managers to understand the location and scope of damage.

Most large-scale disasters have fundamental geographic components related to the geographic distribution of vulnerability and impacts, location of facilities at risk and those with resources, evacuation of people and routing of supplies, and others. A GIS has the potential to enable crisis managers to gather, store, integrate, analyze, share, and apply geospatial information to evaluate and manage a crisis efficiently. However, geographic information systems are currently not used to full potential in disaster management. Some of the reasons include: data needed to support the required tasks are not always available (and if available are not always accessible where and when they are needed); current GIS involve complex technology that requires substantial training for users to be operational; and interoperability problems with both data and other software tools critical to crisis management impede incorporation of GIS in typical workflows. Some of these problems may be solved by "distributed" GIS, which is defined as geographic information services provided though the Internet (both wired and wireless networks) that allow people to access geographic information, spatial analytical tools, and GIS-based Web services without having a GIS and data on their own computer.

The Geocollaborative Web Portal (GWP) system created by the Penn State group is a set of geographically aware information access and analysis tools that are an example of a distributed GIS, especially constructed to support collaboration between people in the "field" during an emergency, and their remote GIS support team.

Two field studies were used to assess the GWP; one took place during an Indonesian earthquake, and the second was a simulated emergency on the Penn State campus. The international collaboration trial pointed out some serious shortcomings, such as slow response time on an annotation tool when limited to the relatively low Internet speeds in the disaster area; this led to many improvements in the tool. These types of results show how important it is to test new emergency response systems under "real" conditions as well as in exercises or simulations.

Space Technologies in Humanitarian Emergency Response

Earlier contributions in this volume have illustrated the increasing importance of satellite imagery for emergency response, and satellite phones often are the only available communication tools for

emergency responders operating in areas where the basic communication infrastructure has broken down. In establishing UNOSAT in 2001 as an operational entity committed to making satellite solutions and geographic information easily and quickly accessible to UN organizations, the UN wanted to exploit the potential offered by these new space technologies. The United Nations Institute for Training and Research (UNITAR) Operational Satellite Applications (UNOSAT) core team consists of UN fieldworkers as well as satellite imagery experts, geographers, geologists, development experts, database programmers, and Internet communication specialists. This gives UNOSAT the ability to better understand the needs of their users and to provide them with suitable, tailored solutions anywhere at any time.

In "Operational Applications of Space Technologies in International Humanitarian Emergency Response," UNOSAT's Einar Bjorgo and Olivier Senegas provide a comprehensive overview of the diverse contributions space technologies are making to twenty-first-century international humanitarian emergency response. Perhaps surprisingly, they not only discuss space technology applications and use for earthquakes, tsunamis, flooding, and fire disasters but also illustrate the technology's application in case of armed conflicts such as the recent Lebanon crisis in the Middle East and violence in Timor-Leste. For both crises, satellite imagery was used to assess the damage that had resulted from the violence, and to support the reconstruction and redevelopment of the affected areas.

The authors conclude their review of existing applications by pointing toward several promising new technologies looming at—or more accurately, high above—the horizon, such as global navigation satellite systems for locating refugees or on-site verification of satellite image assessments, unmanned aerial vehicles (UAVs) for low-cost and continuous aerial monitoring, and grid computing for faster processing and distribution of satellite imagery.

Global Disaster Impact Analysis

Information on humanitarian disasters is increasingly—and often increasingly rapidly—available from a wide range of sources, ranging from local information sources (government, local emergency responders) to information provided by the international UN OCHA (the Office for the Coordination of Humanitarian Affairs), as well as the international media. As the UN organization with the formal international mandate to coordinate humanitarian response, OCHA disseminates response information such as situation reports (sitreps), maps, data, and news from different sources through its ReliefWeb Web site.

Together with the UN, the European Commission's Joint Research Center in Ispra (Italy) has developed the Global Disaster Alert and Communication System (GDACS), an information system that constantly monitors these various sources. Alerts are issued when their data indicate that an earthquake, flood, or other natural disaster has occurred. Alerts are sent out through e-mail and SMS to registered users—currently several thousand people are registered—and the information harvested from the different sources is collected and published online at the GDACS Web site.

In their chapter, "Near Real-Time Global Disaster Impact Analysis," the authors (Tom De Groeve, Alessandro Annunziato, Zsofia Kugler, and Luca Vernaccini), who are also the developers, focus on a critically important and distinctive feature of the Global Disaster Alert and Coordination System (GDACS): the automatically calculated prognosis of the natural disaster's impact on the local communities. The impact prognosis is color-coded in the alert messages GDACS sends out, ranging from green (no impact), to orange (medium impact), to red (high impact). The impact of an event depends not only on the magnitude of the hazard but also on the extent to which the population or critical infrastructure is exposed to the impact, and on the vulnerability or resilience of the population or infrastructure with respect to that specific hazard. GDACS integrates

information on each of these contributing factors, as the system is equipped to "read" a variety of file types. Perhaps even more important, GDACS publishes this information using well-defined standards, in fact turning heterogeneous input data into homogeneous standard feeds. As a specific case in point, De Groeve and coauthors illustrate the information-integration challenges in flood detection and tsunami forecasts.

While a single tsunami can cause the death of hundreds of thousands of people, as we have learned from the horrific Boxing Day tsunami in Southeast Asia in 2004, floods are the most frequent of all natural disasters. Although floods are less lethal than tsunamis, they affect more people than any other disaster: according to estimates, 20,000 people are affected for every person killed in a flood. While sophisticated flood-prediction systems using real-time reporting of extreme precipitation and other surface meteorological variables from in situ, radar, or satellite observations exist, such systems are rarely available in developing countries that are the most affected by natural disasters. As prediction models are hence simply unavailable, local communities in these countries can be warned only through early detection. The authors illustrate a new approach they have developed to use microwave satellite observations for flooding detection and discuss the reliability of their results, which is currently being improved. A prototype system in which their approach has been implemented is available online.

We anticipate that this chapter will provide the reader with a compelling illustration of how a variety of data sources and data formats can be successfully integrated into an effective and efficient emergency warning and response system. This will benefit not only the humanitarian community, but, most important, will provide the relief needed by members of affected local communities who critically depend on fast, effective, and efficient response operations.

Standards-Based Resource Emergency Management Systems

For any emergency operation, there must be a combination of information and communications technology and a resource management system to support those involved in any phase of emergency preparedness, response, and recovery. In "Toward Standards-Based Resource Management Systems for Emergency Management," Karen Henricksen and Renato Iannella examine the state of the art of current commercial systems, various attempts to arrive at standards, and some of the differences and similarities across different countries. There is, as yet, no single set of agreed-upon functional requirements supporting this area. While some standards have been imposed in certain areas for exchanging information and interfacing equipment, the general problem of interoperability and integration across different systems is still a major challenge. Perhaps the United States is farther behind than other countries in tackling this problem. From one point of view, this has its benefits in that requirements are still evolving and changing. Some of the newer systems that cut across the political and geographical boundaries that disasters do not recognize are actually making use of the Web as a de facto standard to bring support to wherever the Web can be accessed. In this category, for example, are the systems supporting community involvement in emergency preparedness and cooperation and collaboration between humanitarian and local volunteer organizations. As the authors point out, the current atmosphere is a push to more open systems where there are clear interface standards that allow different products from different sources to be integrated.

Environmental Risk Management Information Systems

While many of the contributions in this volume are dedicated to information systems designed for the emergency response phase, "Requirements and Open Architecture for Environmental Risk

Management Information Systems," by Thomas Usländer and Ralf Denzer reminds us that the management of risks—that is, their identification, analysis, and mitigation—is of critical importance to avoid emergencies happening in the first place. The data that may enable the identification of risks, however, typically reside in specific or proprietary organizational systems, restricting the data's accessibility and wider use outside the organization's realm—let alone across state or country borders. Realizing the risk management limitations imposed by the diversity of systems used, the authors propose a generic and open service-oriented architecture based on established standards. This architecture was developed in the five-year-long European research project ORCHESTRA, the objective of which was to design a future "ideal" IT infrastructure for (environmental) risk management. The developed infrastructure had to provide the foundation for a risk management system dealing with risks independent of the risks' nature (fire risks or flood risks, for example), and independent of the organizational setting—that is, regardless of whether the risks were managed, for example, in Sweden or in Belgium.

The authors present in detail the requirements that form the basis of the ORCHESTRA architecture, and the technical reference model. ORCHESTRA may also be seen as a first major effort in harmonizing various relevant standards proposed by international bodies such as the Open Geospatial Consortium (OCG), International Organization for Standardization (ISO), the World Wide Web Consortium (W3C), and the Organization for the Advancement of Structured Information Standards (OASIS). The ORCHESTRA platform has been used in the development of different pilots across Europe: floods and fire risk prevention in Catalonia, risks of roadblocks on the French–Italian border, environmental risks due to ship traffic, and one integrated pilot on pan-European risk management. As the ORCHESTRA architecture is currently being used in various follow-up European research projects, we can only be relieved to see that the harmonization of risk management systems is not suffering from the problems that today characterize European political harmonization!

CONCLUSION

The typical journal article or conference paper has length limitations that make it impossible to describe thoroughly the context of a system implementation, its features, evaluation methods and results, and future plans. We explicitly encouraged the authors of this volume to take as much space as they needed to cover these topics adequately. The result, we feel, is a set of very rich accounts of current EMIS. Nevertheless, not all types of systems could be covered in the limited number of chapters in this volume. In the last chapter, we describe a few types of systems that are not covered here, particularly the use of "social computing" systems for citizen participation, and we assess the state of the field and of "hot" topics for future research and development.

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PART I

FOUNDATIONS

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CHAPTER 2

STRUCTURING THE PROBLEM SPACE OF USER INTERFACE DESIGN FOR DISASTER RESPONSE TECHNOLOGIES

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Abstract: *This chapter develops a systematic description of the design problem space for the design of user interfaces for disaster response technology. The description is derived from examination of three sociological dimensions of events (scale, kind, and anticipability), focusing on their implications for response characteristics. The resulting twelve-dimensional framework provides designers with a conceptual tool for understanding the users, tasks, and contexts of a given response technology. Use of the framework is illustrated in the analysis of the American Red Cross component of the response to a conventional local disaster (an apartment-building fire), which reveals a surprising complexity of designing response technology even for a small conventional disaster. The conceptual framework developed offers the beginnings of a theoretical foundation for a design-oriented discipline of response technology.*

Keywords: *Response Technology, User Interface, Design Space, Design Theory, Disaster Management, Disaster Response, User, Task, Context Analysis, Requirements Analysis*

In order to solve a problem, a problem solver must develop what cognitive scientists call the *problem space*—a mental representation of the problem (Newell and Simon, 1972; Simon, 1999). If the problem is to be solved successfully, the problem space must contain those problem features that are relevant to solutions and omit those that are irrelevant (Simon, 1999). It is often difficult to decide whether a given feature is relevant, but in design problems, even knowing what constitutes a feature can be challenging. Experienced designers have, over time, developed an understanding of the problem features that tend to dominate problems and solutions in their domain of expertise, along with a set of common configurations (schemata) of relevant and irrelevant features. This knowledge allows them to develop problem spaces and understand new problems quickly and accurately.

Experience, however, is not the only means of gaining systematic knowledge of a design domain. Informed analysis of typical and atypical design problems can identify problem features and relationships among them that are critical to their solution. Organized systematically, descriptions of the critical and characteristic differences among individual design problems reveal the structure of the *design problem space*—the set of problem spaces that are meaningful in the domain and from which problem spaces for specific design problems must be drawn. This structure represents a map of the design domain that exposes critical differences among

different designs. It can be used to analyze and understand existing design challenges and to guide exploration of new ones.

This chapter develops a theoretical framework for structuring the design problem space for user interfaces for *response technology*—technologies expressly intended for use in the response phase of emergency and disaster management. "Response" is used here to refer to deliberate efforts aimed at expedient mitigation or immediate relief rather than in a general sense of reaction to events. The framework focuses on three categories of problem features, related to users, tasks, and contexts, respectively. These are key categories of problem features in any user interface design problem, and the framework concentrates on characteristics that are peculiar to disaster response, including responder procedural and declarative knowledge, task generalizability and structure, physical and informational resources offered by the working context. While applicable to any technology used in response, the framework is aimed primarily at information technologies.

In the absence of a sociological theory of response, the framework is based on sociological theories of crises, emergencies, and disasters, as these theories of events often include extensive discussion of and evidence for their relationships to response. Analysis of the sociological literature centers on three dimensions of events that have been documented to correlate with response characteristics: *scale* (a measure of the extent of the effects of an event), *kind* (an indicator of the types of effects of an event), and *anticipability* (a description of the possibilities for preparedness for an event). The analysis reveals systematic variations in the individuals and organizations that participate in response, the kinds of tasks and skills required, the amount of preparedness possible, and what resources may be available.

Analytic use of the framework is illustrated in a case study that examines the users, tasks, and contexts observed in an actual response. This case study examines the experiences of thirty individuals who participated in the American Red Cross response to an apartment-building fire in Mountain View, California, in 2006. In addition to identifying the characteristics of users, tasks, and contexts in this particular situation, the analysis shows that a design to meet the needs of the response would have been required to accommodate inexpert and expert users equally, allow for multitasking, and provide portability, if not functionality, at least of key data or information.

The framework offers a foundation for a design theory of user interfaces for response technology and can accelerate individual design processes by helping designers develop accurate problem spaces more quickly. It can also help designers and researchers to identify unexplored design problems and solutions, and lead to new and innovative designs. Finally, an organizing design theory provides a basis for communication of ideas and is essential to the advancement of a design-oriented professional or academic discipline.

STRUCTURING PROBLEM SPACES

Cognitive scientists talk about structuring and structure of problem spaces at the level of the individual problem solver. The present approach of analyzing and structuring problem spaces at the domain level is adapted from software engineering, where *domain analysis* is used to identify the objects and operations that are common across a domain of software applications, for example, document preparation or telecommunications applications (Prieto-Dìaz, 1990). Conventionally, domain analysis focuses on problem features that pertain to the problem solution, that is, the architecture and design of the software.

Features that arise from properties of solutions are *defining*—they define the solution and offer distinctions between solutions. *Constraining* features, in contrast, arise from properties of the problem situation, constrain what constitutes a solution, and determine what qualities a solution

must exhibit to be a "good" solution. Faulty representation of either constraining or defining features in the designer's problem space can doom design efforts.

The present approach is to expose the design problem space structure of a domain by developing a systematic description of constraining features based on analysis of characteristic design problems. Similar analysis of design solutions could be used to expose the structure of a *design solution space*—the set of viable designs in the domain. Combining specifications of design problem and design solution spaces with analysis of the relationships between them would reveal the structure of the *domain design space*—the (abstract) set of solutions that address (real) domain problems.

Users, tasks, and contexts are three major sources of constraining features in user interface design, and user, task, and context analysis are widely accepted techniques for improving the utility and usability of information technologies (Beyer and Holtzblatt, 1998; Hackos and Redish, 1998; Schraagen et al., 2000). These techniques aim to identify design requirements related to the user (the individuals who are expected to work with the tool directly), their task (the goals and activities they are trying to accomplish), and their context (the setting and circumstances under which they are expected to use the tool). User, task, and context analyses are typically performed at the individual application level but have been applied to understanding the design problem spaces of creativity (Hewett, 2005) and navigation (Jul, 2004), and in developing domain-specific style guides (Gulliksen and Sandblad, 1995).

The present work complements the efforts of Chakrabarti and Mendonça (2005), who outline a domain-level analysis of stakeholder requirements for information systems for critical infrastructure management. In contrast to the work of Zimmerman (2006), who suggests ways of increasing the effectiveness of existing general-purpose technologies during response, the present work focuses on specialized response technologies.

DIMENSIONS OF DISASTER

Sociologists have found that differences in disaster events can be linked to qualitative differences in the ensuing responses (Quarantelli, 1998). This section examines three dimensions describing sociologically significant differences among crisis, emergency, and disasters with a view toward identifying distinctions and variables that represent problem features in the design of user interfaces for response technologies. The dimensions examined are *scale* (a measure of the extent of the effects of an event), *kind* (an indicator of the types of effects of an event), and "*anticipability*" (a description of the possibilities for preparedness for an event). These three dimensions were selected because of the evidence they present for characteristic differences in response, specifically differences that pertain to potential users, tasks, and contexts of response technology, that is, *who* participates in responses, *what* they are trying to accomplish, the *circumstances* under which they are working, and the relationships among these.

The present examination is undertaken in the absence of a sociological theory of response. It is not intended to contribute to sociological debate, but rather to lay a foundation for a theory of design. As a consequence, differences that are important to a sociological understanding of events but do not create new dimensions of response may not be upheld. For instance, definitional distinctions between crises, emergencies, and disasters are diffused by similarities and variations in response.

The dimensions derive from empirical studies of disasters and disaster responses, as reported in survey and synthesizing literature. The discussions of scale and kind of disaster are based on the work of Quarantelli (1993, 1998, 2005), Dynes (1998), and Kreps (1998), all of whom develop sociological theory from extensive field studies. Discussion of scale also relies on reviews

of studies of emergent social phenomena (Drabek and McEntire, 2002, 2003). The dimension of anticipability is the work of Gundel (2005), which rests on reports and analyses of actual disasters and responses.

It should be noted that most of the studies underlying the literature reviewed were conducted in North America. They, and consequently the present work, reflect American disaster management culture and practices, and should not be assumed to generalize to other cultures without question. In particular, American disaster management has evolved a complex intergovernmental system in which different levels of government (federal, state, tribal, local) have different responsibilities, authorities, resources, and capabilities. These separations have direct repercussions on who is involved in responses and how they are involved (Donahue and Joyce, 2001).

The studies cited in the literature were focused primarily on direct response activities, that is, on activities in the affected area. This results in an emphasis on individuals and organizations involved in local coordination and management, downplaying regional, national, or international endeavors. The studies were also focused on responses to consensus-type events—typically, natural hazard occurrences, rather than civil conflicts or humanitarian relief efforts. The present work should thus not be assumed to apply to remote response activities, the remaining phases of disaster management—prevention, mitigation, preparedness, and recovery—or to conflict-type events (such as civil conflicts or riots) without further consideration.

Scale

Scale is a measure of the extent of the effects of an event and reflects the power of the causal agent(s), the success of mitigative measures, and the effectiveness of the response system. Sociologists commonly discuss three measures of scale: magnitude, scope, and duration of impact (Kreps, 1998). *Magnitude* indicates "the severity of social disruption and physical harm" (ibid., p. 34), in other words, the extent to which the lives of those affected have been interrupted or altered. *Scope* indicates "the social and geographic boundaries of social disruption and physical harm" (ibid.), that is, the size of the sociogeographic area affected. *Duration* is "the time lag between the onset of social disruption and physical harm and when the disaster is no longer defined as producing these effects" (ibid.), that is, how long it takes for things to stop breaking.

Scope and duration are fairly straightforward (albeit difficult to measure), but Quarantelli (2005) separates magnitude into disruption of community infrastructure and resources (physical and human), disruption of response infrastructure and resources, and the adequacy of established response measures. Quarantelli (2005) integrates these three measures with scope and duration to define three distinct categories of scale (see Table 2.1): An *emergency* is a short-lived event whose effects are localized within a single community. The community as a whole and its response infrastructure remain fully functional, and its internal capacity is sufficient to manage the response.

A *disaster* is a longer-lived event that affects an entire community, but leaves both community and response infrastructure largely intact. However, because so much of the community is affected, it is not able to manage the response on its own and must rely on aid from neighboring communities (typically through mutual aid agreements). A *catastrophe* is a long-lived event that affects multiple communities, destroying much of their infrastructures, and severely damaging or overwhelming response systems. Communities cannot manage the response on their own and often compete with neighboring communities for external assistance rather than benefiting from mutual aid agreements.

Responses to differently scaled events differ in the amount of and dependence on emergent behaviors and organizations (spontaneous responses by individuals and organizations not normally

Table 2.1

Measures of Scale

	Local emergency	Local disaster	Disaster	Catastrophic disaster
Examples	1997 Paris traffic accident	2006 Mountain View apartment complex fire	9/11 terrorist attack, 1989 Loma Prieta earthquake	1918 U.S. flu epidemic, 2004 U.S. hurricane season, 2005 Hurricane Katrina
Impact on community infrastructure		Localized effects, if any	Localized damage or loss	Extensive damage or destruction
Impact on response infrastructure		Largely unaffected	Localized damage or loss	Extensive damage or destruction, and/or completely overwhelmed
Adequacy of response measures		Within local planning	Exceeds local capacity but within greater response capacity	Exceeds all planning and capacity
Organizational emergence	Only established organizations mobilized	Established and expanding organizations mobilized	All types of organizations mobilized	
Scope	Only part of single community and official jurisdiction affected		Single community and official jurisdiction affected	Multiple communities and official jurisdictions affected
Duration	Hours–weeks		Weeks–months	Months–years
Terms adopted here	Local emergency	Local disaster	Regional disaster	Catastrophic disaster

Sources: Quarantelli (2005) and Dynes (1998).

Table 2.2

DRC Typology of Organizations Participating in Response

		Tasks	
		Routine	Nonroutine
Operational Organizational Structure	Same as pre-disaster	I. Established (e.g., city emergency services)	III. Extending (e.g., church community providing meal service)
	New	II. Expanding (e.g., American Red Cross)	IV. Emergent (e.g., community group formed to collect donations)

Source: Dynes (1998).

engaged in disaster-related activities) (Drabek and McEntire, 2003; Quarantelli, 2005). The so-called DRC (Disaster Research Center) typology characterizes responding organizations in terms of the relationship between the organization's everyday activities and operating structure, and those it assumes during a response.

The typology identifies four types of organizations (Dynes, 1998; Table 2.2): *Established organizations* normally engage in response activities, and their operational structure is unchanged during responses. *Expanding organizations* routinely engage in response activities, however, they must expand their operational structure to do so, typically by recruiting volunteers. *Extending organizations* do not normally perform response activities, but are able to do so using their existing organizational structure. *Emergent organizations* likewise do not normally participate in response, but must create a new organizational structure to do so and are often formed spontaneously.

What and how quickly different organizations are mobilized depends on the scale of an event (Dynes, 1998). Dynes distinguishes between two types of emergency: *local emergencies,* which can be handled entirely by established organizations (e.g., in the United States, most traffic accidents and single-family house fires), and *local disasters,* which require the involvement of an expanding organization (e.g., an apartment-building fire that displaces all residents). In larger events, all four types of organizations are mobilized sequentially: established, expanding, extending, and, lastly, emergent, with the first two activating nearly simultaneously in sudden onset events. As organizations mobilize, responders may be sent to different locations and may transfer between locations as resources and operational needs change.

Although different organizations may be engaged in vastly different tasks, the involvement of diverse individuals and organizations imposes a need for partnership formation, with its attendant themes of cooperation and collaboration (Drabek and McEntire, 2002; Dynes, 1998). Not surprisingly, partnership formation is essential to responses to events of all sizes except local emergencies, and grows increasingly critical as the scale of event increases and more organizations become involved in the response (Quarantelli, 2005).

Table 2.1 summarizes measures of scale, and characteristics of events of different scales. Although differently scaled events are qualitatively distinct, the scale of a particular event may not be apparent until the response is well under way (or even after it is concluded). Additionally, events may transition abruptly from one scale to another as circumstances are compounded or uncovered. Table 2.1 also shows the terms adopted here to denote different scales: local emergency, local disaster, regional disaster, and catastrophic disaster.

Implications for User-Related Problem Features

The differences in organizational emergence associated with scale have direct implications for user knowledge. The four types of organizations vary in regard to individual members' training and experience with disaster response. Members of established organizations are mostly "career" responders (e.g., police officers and paramedics), and may be presumed to have both training and experience with frequently occurring response tasks. Expanding organizations typically have a small core of "habitual" responders (with both training and experience in response). This core is supported by a larger group with training but limited experience, and augmented (when fully mobilized) by a large number of individuals with neither training nor experience.

Members of extending and emergent organizations generally have little or no training or experience with disaster response, with two notable exceptions. First, in disaster-prone areas, such as the Philippines, some extending organizations are mobilized sufficiently often that response tasks become routine and the organization effectively functions as an established organization (Bankoff, 2002). Second, in large responses, established organizations or experienced individuals may partner to form emergent organizations to address specialized demands (Drabek and McEntire, 2003).

Responses to local, regional, and catastrophic disasters thus typically involve semitrained and untrained responders. Logically, the proportion of semitrained and untrained responders increases with the scale of event, and they assume greater responsibility for the response. In catastrophes, they may handle local responses entirely, with experienced responders not arriving until the recovery phase. And even though local emergencies are handled by established organizations, "In 95 percent of all emergencies, the victim or bystander provides the first immediate assistance on the scene" (U.S. Department of Homeland Security, 2006).

Additionally, as the scale of an event increases, more locations are affected, more facilities suffer extensive damage, and more nonlocal responders are brought in. Even in smaller events, nonlocal responders may be brought in through mutual aid agreements to fill gaps in locally available expertise. While nonlocal responders may have knowledge of regionally or nationally available resources, they are unlikely to have the location-specific knowledge that local responders are apt to possess, such as familiarity with geography, culture, and community resources.

Implications for Task-Related Problem Features

Scale-related differences in organizational emergence indirectly reveal a task-related problem feature. As mentioned, partnership formation is critical to events of all sizes. Partnership formation offers an example of a *response-generated task*—a task originating in the response itself. These are contrasted by *agent-generated tasks*—tasks deriving directly from the causal agent. This distinction is often overlooked (Dynes, 1998), but may be important to design problem solving.

Agent-generated tasks are frequently agent-specific and may even be specific to a particular incident type. For instance, fire suppression is not relevant in flooding or water inundation events, and fire ventilation (to prevent buildup of combustible fumes) is not an issue in controlling wildfires. Response-generated tasks, in contrast, are independent of the causal agent. Sheltering and feeding tasks, for example, are largely the same whether homes have been made uninhabitable by an earthquake or whether travelers have been stranded by a snowstorm. Agent-generated tasks may thus not generalize across event types, while response-generated tasks do, and designs should be correspondingly broad in their applications. Note that how a task of either type generalizes as event scale increases may vary across tasks.

Implications for Context-Related Problem Features

The most obvious implication of scale on context-related problem features is the possible loss or destruction of physical resources. Settings that are radically altered or changed may leave responders without familiar points of reference and without familiar tools, including normally available technologies. In catastrophic settings, they may have access only to tools and technologies deployed expressly for the response.

A more insidious implication is the possible loss of access to knowledge resources. Individuals who were expected to play a key role in community organization or response activities may themselves be affected or otherwise unavailable. This may result in loss of critical knowledge of local plans, resources, and decision-making authority. And loss of access to external information sources may leave responders without knowledge of standard operating procedures and externally available resources.

Kind

Sociologists have also found that event *kind* affects response characteristics (Dynes, 1998). One aspect of kind is *affect*, which is an indication of the diversity of the effects of the event. Dynes (1998) separates *community disasters*—events that affect a broad range of physical and human resources (e.g., earthquakes)—from *sector disasters*—events that primarily affect a specialized segment of the community (e.g., computer viruses). Most of the literature examined in the previous section on scale describes responses to community disasters.

Responses to sector disasters may not involve traditional response organizations, but may be handled by sector professionals. For example, in the case of a computer virus, responders may be computer professionals, and, in the case of a human virus, infectious disease epidemiologists. In sector disasters, established response organizations may be providing support services only (for instance, managing crowd control or cross-jurisdictional response coordination) if they are mobilized at all. *Trans-system social ruptures* (TSSRs) are special types of sector disasters that spread rapidly and erratically across geographically dispersed locations, crossing national and international boundaries—for example, the SARS (severe acute respiratory syndrome) outbreak of 2003 (Quarantelli, 2006). TSSRs introduce a social heterogeneity in response that crosses both disciplinary and sociopolitical boundaries, and place a high demand on rapid partnership formation.

Another aspect of kind is *social agenda*, which describes the social context of the response. Quarantelli (1993) distinguishes between *consensus-type* events, in which there is general agreement on the goals and the agenda of the response (generally, to provide needed aid and restore normalcy), from *conflict-type* events, in which different factions have different agendas (e.g., restoring normalcy versus redefining normality). While social agenda is generally related directly to the causal agent (e.g., whether natural or man-made), it may also reflect a greater social context unrelated to the specific event (e.g., a response undertaken in the midst of a civil war).

The previous discussion of measures of scale was largely based on literature reflecting consensus events. There is evidence that responses to conflict events exhibit significant differences, particularly surrounding individual and organizational behaviors (Quarantelli, 1993). It appears, for instance, that organizational emergence is less commonplace, and established organizations assume much greater responsibility for response efforts. Also, looting and other antisocial behaviors are more typically observed in conflict events, and law-enforcement agencies generally play a much greater role in response. More recent events, such as the 9/11 terrorist attack and the 2005 Hurricane Katrina, have exhibited characteristics of both types of events (Peek and Sutton, 2003).