INFORMATION SYSTEMS FOR EMERGENCY MANAGEMENT

BARTEL VAN DE WALLE
MURRAY TUROFF
STARR ROXANNE HILTZ
EDITORS

AMIS

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VLADIMIR ZWASS SERIES EDITOR

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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 interconnectedness 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

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.

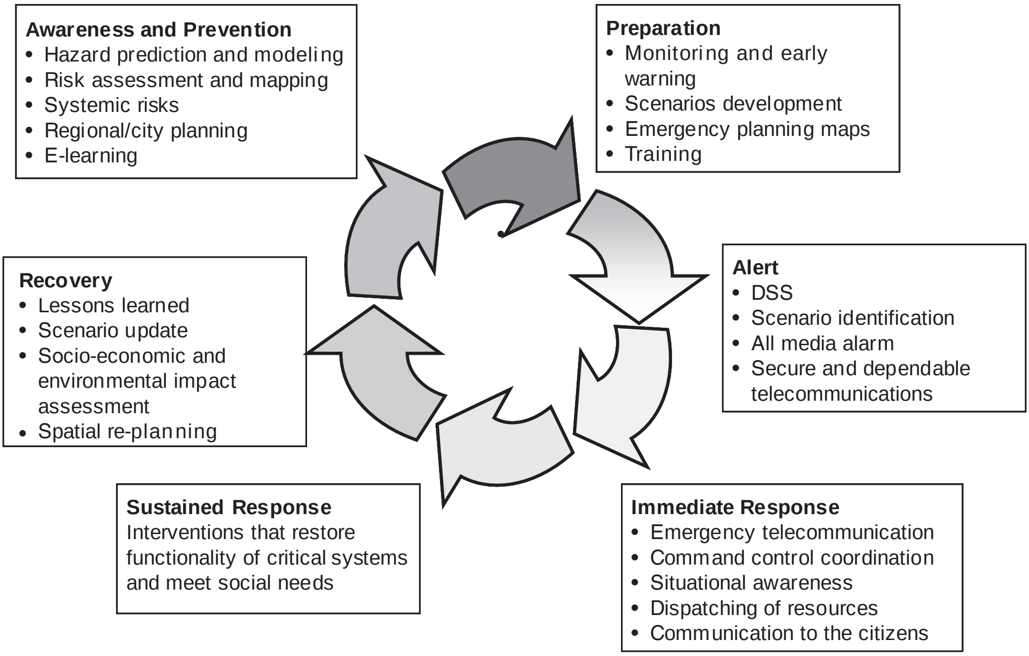
A catastrophe is a disaster with a much more severe and widespread level of devastation. In a catastrophe, much of the housing is unusable, most if not all places of work, recreation, worship, and education such as schools totally shut down. The infrastructures are so badly disrupted that there will 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

CHAPTER 2

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

SUSANNE JUL

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).

Table 2.3

Indicators of Event Kind

		Social agenda	
		Consensus	Conflict
Affect	Community disaster	Natural hazard event	Civil conflict
	Sector disaster	Technology failure	Sabotage
	Trans-system social rupture (TSSR)	Pandemic	Computer virus

While this may be peculiar to certain events, it may also reflect an increase in legal, ethical, and moral conflicts in all aspects of modern society.

The two measures of kind, affect, and social agenda, are independent. Table 2.3 shows examples of different events that represent their intersection.

Implications for Design Problem Features

Identification of sector disasters reveals a third aspect of user knowledge, namely, that responders may have or need knowledge related to a particular task, but unrelated to disaster management or a particular location. Such task-relevant knowledge may range from sophisticated domain knowledge of a specialized professional discipline to knowledge of specific problems and solutions within that discipline.

Identification of sector disasters also raises questions related to task decomposition and division of labor. In ordinary circumstances, assignment of tasks, authority, and responsibility are generally role-based, that is, jobs are defined first and individuals are found (or trained) to fill them. In disasters, particularly in sector disasters, tasks, authority, and responsibility are often assigned according to competence, that is, they are divided and distributed according to the skills and knowledge of the individuals and organizations available. This can mean that tasks that are usually accomplished by a single person are divided across different individuals, potentially from different organizations, and tasks that are normally divided across individuals may be performed by a single person.

Conflict events introduce a separate set of tasks related to law enforcement and control, and raise legal, ethical, and moral concerns. They serve as reminders that, while it is tempting to subordinate design problems surrounding information validation, privacy, and security for reasons of expediency, in the uncertainty afforded by disaster, consideration of such issues may be more important in designing response technology than in designing technologies for routine situations. Similarly TSSRs accentuate the importance of multi- and intercultural questions.

Sector disasters also have indirect implications for context-related design problem features. Events may place responders and/or their tools at increased risk. For instance, in human epidemics, medical personnel may have a high rate of exposure and infection. Increased responder vulnerability may result in the institution of unusual (and possibly unfamiliar) operating procedures. Likewise, in dealing with a computer virus, computational response tools may be subject to infection, and responders may be working with unfamiliar or compromised tools, even if the context is familiar and functioning normally.

Anticipability

The final dimension of disaster considered here, *anticipability*, captures event characteristics that determine what preparedness is possible (Gundel, 2005). It comprises two measures, predictability

Table 2.4

Measures of "Anticipability"

		Influenceability	
		Easy	Hard
Predictability	Easy	1. Conventional (e.g., 1986 Chernobyl)	3. Intractable (e.g., 2005 Hurricane Katrina
	Hard	2. Unexpected (e.g., 1979 Three Mile Island)	4. Fundamental (e.g., 9/11 terrorist attack)

Source: Gundel (2005).

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 as to be believable. So, for instance, the events of the 9/11 terrorist attack were not predictable because, to pre–9/11 social consciousness, using commercial airliners as bombs was both unimaginable and beyond credibility (National Commission on Terrorist Attacks, 2004). 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. Thus, for example, although many measures had been proposed that would have reduced the impact of Hurricane Katrina, the sociopolitical environment of the preceding decades prevented many from being implemented.

These two dimensions result in four classes of events (Table 2.4). Gundel points out that, while responses to conventional events rely on planning and practice, preparation for and response to unexpected events requires improving information exchange and preparing disaster managers to contend with new and unexpected problems. Intractable events rely on organizational and political partnership formation, and, for fundamental events, Gundel advocates formation of expert groups to provide "think-tank expertise" to support preparedness and response.

Implications for User Interface Design Problem Features

The implications of an event's being unpredictable are that responses may present novel problems and tasks, and pose even experienced responders with unfamiliar situations. Responders as well as responding organizations may thus need to develop new procedures and structures, and may be working in unexpected settings. That an event can be intractable implies that novel, event-specific solutions may have to be found to ordinary problems, requiring responders and responding organizations to develop and draw on new resources. Influenceability suggests that events may be difficult to control, and response efforts may need to adjust to sudden changes in location, scale, or priorities. In short, users, tasks, and contexts may not be as predicted at the time of design, and design solutions may need to allow for creativity in use, and flexibility and adaptability in application.

DESIGN PROBLEM SPACE STRUCTURE

The previous examination of three sociological dimensions of disaster exposed twelve design problem features—four related to users, three to tasks, and five to contexts—summarized in Table 2.5. These represent a nominal categorization of individually continuous and conceptu-

Table 2.5

Design Problem Features

	Problem feature	Description	Scale
User	Disaster management knowledge	What is the user's prior knowledge and experience with the concepts, considerations, and procedures of disaster management?	Ordinal
	Task-relevant knowledge	What is the user's prior knowledge and experience with the concepts, considerations, and procedures of the actual task(s) he or she needs to perform?	Ordinal
	Locale-specific knowledge	What is the user's knowledge of local geography, culture, and community resources?	Ordinal
	Locale-independent knowledge	What is the user's knowledge of externally available resources?	Ordinal
Task	Origin	Is the task rooted in a causal agent or in the response itself?	Nominal
	Novelty	Is the task normal and predictable in disaster response?	Ordinal
	Decomposition	What criteria determine how tasks are decomposed and responsibility assigned?	Ordinal
Context	Austerity (infrastructure)	What infrastructure is available and functioning?	Ordinal
	Austerity (tools)	What tools are available and functioning?	Ordinal
	Familiarity	How much does the setting resemble settings with which responders are likely to be familiar?	Ordinal
	Local information access	What information resources are available locally?	Ordinal
	External information access	What information resources are available externally?	Ordinal

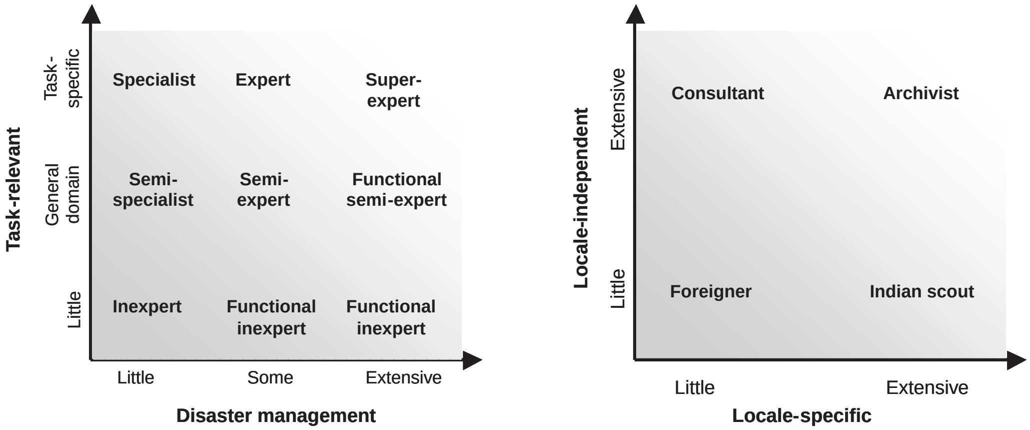
ally independent phenomena and offer dimensions of the design problem space. Several of these dimensions are related but orthogonal, and the resulting structure provides a means of analyzing and characterizing actual design situations. Note that this organization is an interpretive rather than a definitive system of classification and, thus, does not constitute a taxonomy.

The four problem features related to users all pertain to user knowledge and experience, and form two orthogonal pairs (Figure 2.1). The first pair, knowledge of disaster management and knowledge that is relevant to the actual task at hand, are both forms of procedural (skill-based) knowledge (Anderson, 1990) and derive from training and prior experience. Positioning of the target-user population with respect to procedural knowledge determines not only the help and support systems needed but also how much support for learning the design must offer, for example, by exposing task structure and highlighting potentially critical information.

The second pair, locale-specific knowledge and locale-independent knowledge, are both forms of declarative (fact-based) knowledge (Anderson, 1990) and derive from past life experiences, use of information sources, and day-to-day involvement in community or preparedness activities. Positioning of users with respect to declarative knowledge determines how much awareness of potential information sources, support for obtaining help from potential sources, and/or actual information should be embedded in the design.

Although the four dimensions of user knowledge are conceptually independent, some identifiable patterns can be predicted. Someone who has extensive knowledge of disaster management

Figure 2.1 **User Design Problem Features, with Suggested Vocabulary for Different User Types**



PROCEDURAL KNOWLEDGE

DECLARATIVE KNOWLEDGE

can reasonably be expected to have considerable knowledge of locale-independent resources. Similarly, someone with extensive task-specific knowledge can be expected to have locale-independent knowledge within their domain of expertise. And, of course, anyone working in their “home” setting can be expected to have at least a moderate amount of locale-specific knowledge.

The three problem features related to tasks pertain to the generalizability and structure of tasks and subtasks. They form one pair of orthogonal dimensions and one that stands alone (Figure 2.2). One of the latter, task origin, is the only nominal measure in the design space structure and comprises two values: agent- and response-generated. Task origin is associated with task novelty—whether it is a normal and expected part of response. These two dimensions dictate how often and predictably the task occurs in responses, and determine how flexible the design must be and how much creativity it must allow with respect to task structure.

The third task-related feature, task decomposition, refers to the way in which tasks are divided into subtasks, and whether responsibility for tasks and subtasks is assigned based on roles or individual competencies. It reflects how the task is structured and sequenced in actual performance, and dictates how rigidly the task structure and sequencing can be imposed by the design.

The five problem features that relate to context characterize whether resources are available to users. They form one triplet and one pair of orthogonal dimensions (Figure 2.3). Two features, austerity with respect to infrastructure and austerity with respect to tools, concern the physical resources that are available and functioning in the environment. They combine with the third feature, familiarity—similarity of the context to contexts with which the user is likely to be familiar—to describe how readily resources are available to the user, and what conditions the design must accommodate in order to be used.

The two-paired features describe what informational resources are accessible. They distinguish between resources available within the context and those that depend on external communications. These features are independent, but pair to determine what data and support must be embedded in the design, and what can be assumed to be available elsewhere.

Figure 2.2 **Task Design Problem Features, with Suggested Vocabulary for Different Task Types**

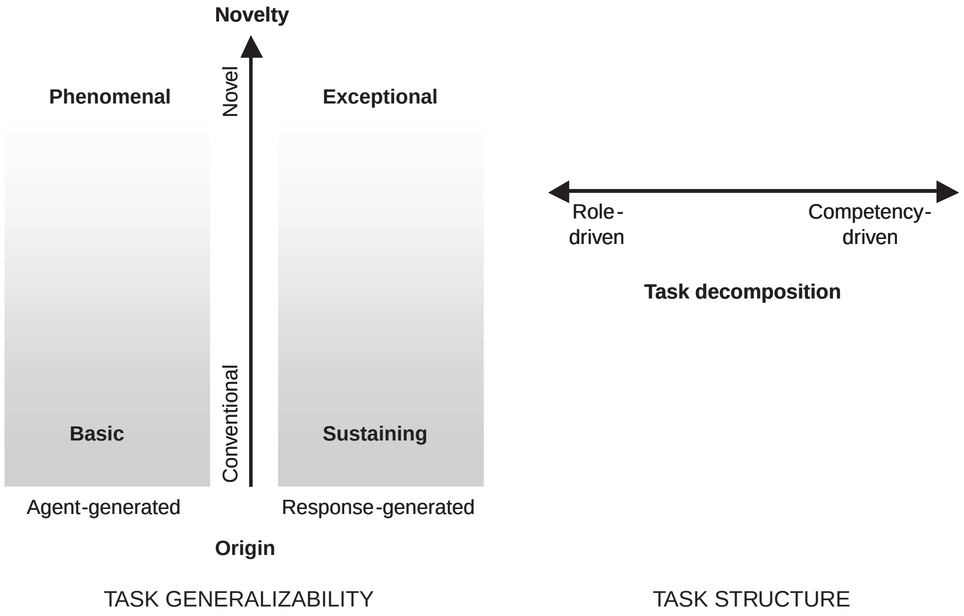
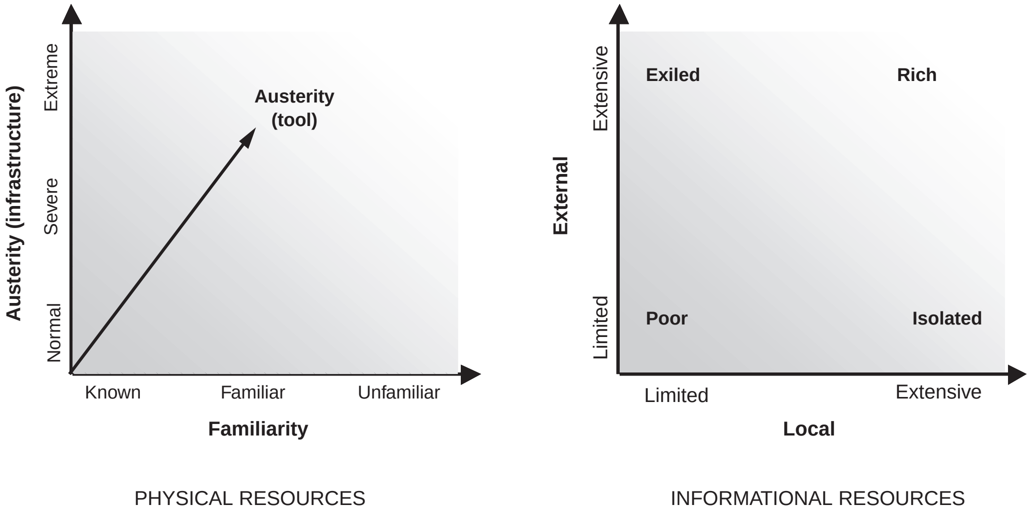


Figure 2.3 **Context Design Problem Features, with Suggested Vocabulary for Different Task Types**



The twelve problem features define a twelve-dimensional framework (Table 2.5, Figures 2.1–2.3) that defines a structuring of the response technology user interface design problem space. This structure can be used to guide analysis of individual design situations in order to determine which regions in the space the design should address and to ensure that critical aspects of the problem are not overlooked.

CASE STUDY: LATHAM COURT FIRE

Understanding the structure of the design problem space of a domain helps designers by identifying characteristic problem features that frequently are critical to design problems in the domain. However, the problem structure does not, in itself, offer understanding of characteristic configurations of design problems—regions in the design problem space around which design situations cluster. This section presents an analysis of a single disaster response, framing the design problem this particular situation poses in terms of users, tasks, and contexts. It is intended to illustrate a real point in the domain problem space, but makes no claim to its representativeness.

The analysis focuses on an apartment-building fire that occurred in Mountain View, California, in 2006. Due to complications of data collection, it focuses on the part of the response carried out by the American Red Cross. While the author was an active participant in the response, understanding of the event and subsequent response relies on Red Cross incident reports and functional logs (American Red Cross, 2006), and Mountain View Fire Department incident and fire investigation reports (Mountain View, CA, Fire Department, 2006).

Data surrounding the backgrounds, experiences, and roles of the individuals who participated in the response were collected via a Web-based survey questionnaire. A total of thirty-nine Red Cross responders participated directly in response activities (including individuals providing dispatch, accounting, and remote mentoring support). Of these, twenty-nine individuals completed the survey. One individual from a community nonprofit was also involved in the response. Similarities in the data pertaining to this individual and to those of many of the Red Cross responders allow them to be included in the analysis. The data thus represent 75 percent of the responders who participated from expanding and extending organizations. These organizations account for 54 percent of an estimated total of seventy-four responders.

Fire on Latham Court

At 4:17 PM on June 13, 2006, Mountain View Communications received the first of several 911 calls reporting smoke coming from a building behind an address on Latham Court. One alarm was called and equipment dispatched. Arriving on scene five to seven minutes later, fire department staff found heavy smoke on the second floor and fire involvement apparent at the east end of a two-story apartment building. As rescue and fire control efforts began, a second alarm was called, and additional equipment arrived seven to eight minutes later.

At 5:24 PM, the local Red Cross chapter received a request to provide assistance to occupants of the twenty-unit apartment building. During the following two hours, thirty-two Red Cross volunteers and staff were contacted, and fourteen were dispatched to the scene.

At 6:09 PM, the last fire truck departed, leaving a battalion chief and three fire investigation officers at the scene. The fire was extinguished. There were no injuries. Four apartments were destroyed or had major damage, but all utilities were shut off and the building declared uninhabitable.

Red Cross responders remained on scene until 10:58 PM, when interviews had been completed with representatives of fourteen households, and financial assistance to cover their food and clothing needs for one to three days had been provided. Accommodations had been arranged for all clients for three nights at the nearby Tropicana Lodge.

While the city emergency services' participation in the response was over, Red Cross operations continued. Most building residents were expected to be able to return to their apartments within

Table 2.6

Scale of Latham Fire Event (Local Disaster)

Impact on community infrastructure	None		
Impact on response	None		
Adequacy of response	Within local planning		
Organizational emergence	Established (city emergency services), expanding (Red Cross), and extending (community services agency) organizations mobilized		
Scope	One 20-unit apartment building		
	No injuries		
	50–60 residents displaced		
Duration of event	2 hours		
Duration of response	Established*	Expanding	Extending
	5 hours	9 days (active response)	4 weeks
		11 weeks (formal response)	
Number of responders	34	39	1

*Estimated from Fire Incident Report.

a few days; however, ensuing building inspection revealed damage to the ventilation system that would not only leave the building uninhabitable for two weeks, but would require all residents to remove all possessions while repairs were being effected. Repairs to the four damaged apartments were expected to take up to four months.

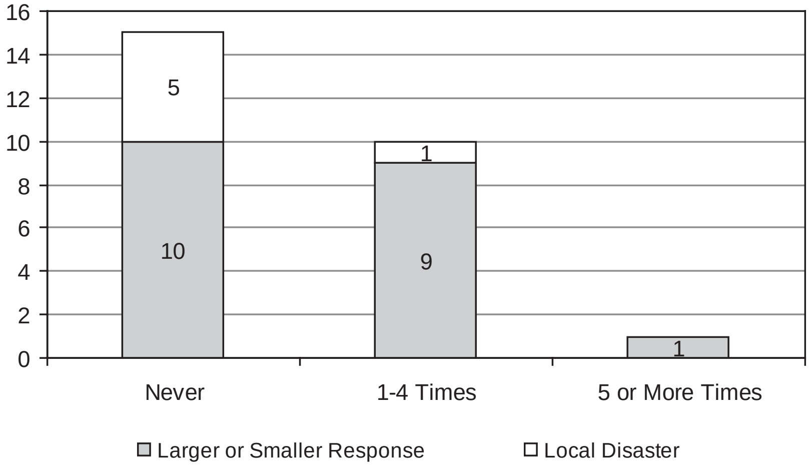
Over the next nine days, an additional twenty-four Red Cross responders became involved, helping forty-nine clients representing sixteen households with immediate needs, including accommodations, food, clothing, medical concerns, emotional support, and translation services. They would also provide information regarding the status of the building and repairs, along with referrals to community resources for housing, legal aid, storage facilities, and social services. A community nonprofit organization devoted to preventing homelessness was involved and rendered additional assistance with food and long-term housing.

On June 21, the Red Cross was able to present each household with a cash grant, formally discharging its functional obligations and releasing most responders from response duties. On August 17, all financial obligations incurred had been met and the Red Cross response concluded officially.

Characterizing the Event

The Latham Court fire was a local disaster: It had no impact on local infrastructure, its effects were limited to a subset of a community, and the response was handled with local resources, but required the involvement of both established and expanding organizations (Table 2.6). It disrupted all functions within the affected area, so was a community disaster. There were no conflicting agendas with respect to either response or recovery, so it was a consensus event. Finally, and unfortunately, it was a conventional disaster that was both easy to predict and to influence.

Figure 2.4 **Responders' Prior Response Experience**



Note: Bars show number of responders with prior experience in responses of this scale (local disaster), and indicate number of responders with experience in larger or smaller responses.

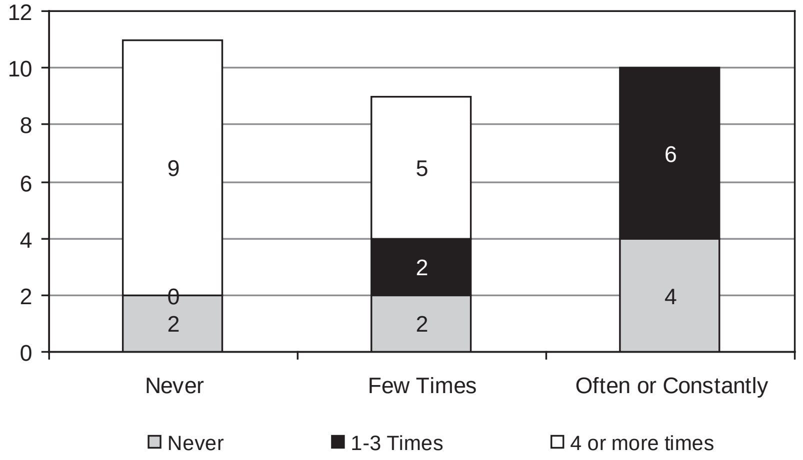
User Design Problem Space

All Red Cross responders had a minimum of ten to fifteen hours of classroom training in Red Cross organizational structure, basic mass care procedures, cardiopulmonary resuscitation, and first aid. Although experienced volunteers are likely to have had additional and possibly more advanced classes, additional training and knowledge are generally obtained in combination with direct response experience. Assessment of responders' knowledge of disaster management is, thus, based on past participation in responses (Figure 2.4): fifteen (50 percent) of the responders had no prior experience with events of this scale (local disaster). Of these, five (16 percent) had no prior response experience whatsoever. One responder had prior experience only with events of this scale, while fourteen responders had some or extensive prior experience with events of this scale as well as with larger or smaller events.

Estimation of responders' task-relevant knowledge is based on their prior experience in the specific role they performed in the response combined with reported frequency of performing unfamiliar tasks/making unfamiliar decisions. As Figure 2.5 shows, responders were fairly equally divided in frequency of encountering unfamiliar tasks. Slightly more than one-third of responders (eleven out of thirty) never encountered unfamiliar tasks, slightly less than one-third did so a few times, and one-third did so frequently. These responses were somewhat correlated with prior experience in the response role, although two responders with no prior experience in their assigned roles reported never performing unfamiliar tasks, and four responders with prior experience reported doing so frequently.

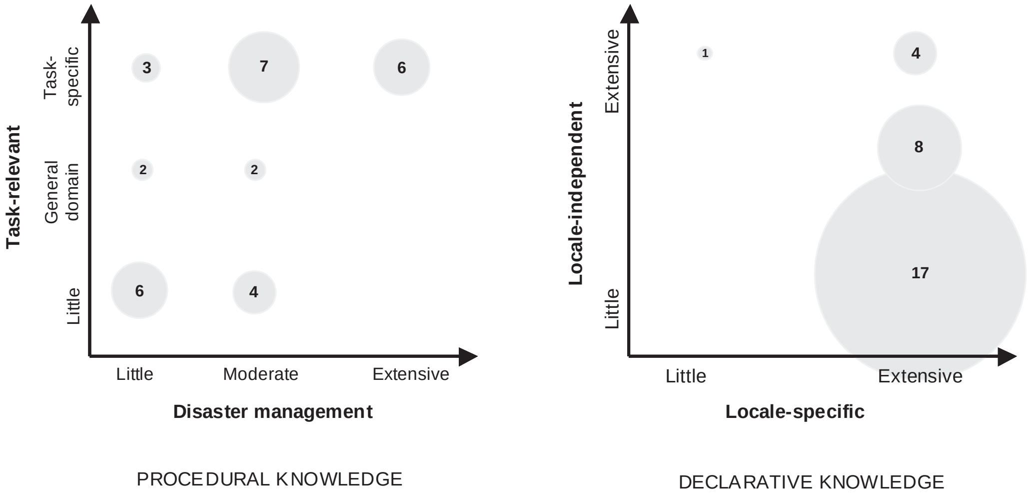
When combined, these measures of responders' procedural knowledge show clustering in two main groups (Figure 2.6): thirteen responders (44 percent) can be classified as experts or super-experts, while ten (33 percent) are inexperts or functional inexperts. The remaining responders tend toward specialists or semispecialists. This distribution of expertise may be indicative of the community of response: Events of this scale are rare (the last local event of this scale, a flood, had been sixteen years earlier), so responders have little occasion to gain expertise locally. However, a significant number of responders have sufficient personal resources to be able to deploy regularly to nonlocal events.

Figure 2.5 **Frequency of Performing Unfamiliar Tasks**



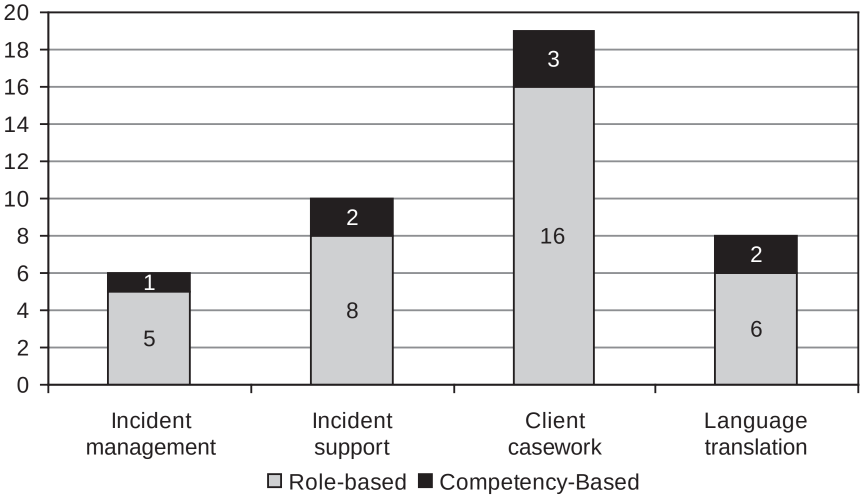
Note: Bars show number of responders reporting performing unfamiliar tasks or making unfamiliar decisions, and indicate responders' prior experience in the specific role they were performing.

Figure 2.6 **Latham Court Response User Design Problem Space**



Locale-specific knowledge was estimated based on length of residence or employment in the area, while assessment of locale-independent knowledge was based on prior experience with larger, nonlocal events. When these measures are combined, a clear pattern emerges of nearly all responders having extensive locale-specific knowledge, and rapidly decreasing numbers having locale-independent knowledge (Figure 2.6). One responder had been brought in from a neighboring jurisdiction under a mutual aid agreement and, unsurprisingly, had little locale-specific but considerable locale-independent knowledge. These patterns are likely typical of a local disaster response in a community with few local events but sufficient affluence to allow participation in nonlocal events.

Figure 2.7 **Number of Responders Performing Given Tasks**



Note: Bars show number of responders reporting having performed given tasks, and indicate whether tasks were part of responsibilities of responder's assigned role or were assumed because of competence or availability.

Task Design Problem Space

The designated role of the American Red Cross in disaster response is to provide nonmedical mass care services. Correspondingly, all tasks undertaken by Red Cross responders to the Latham Court fire were response-generated. No responders reported carrying out any activities that were in any way unusual or novel. All tasks were thus sustaining tasks, as might be expected for a small-scale conventional event.

Tasks could readily be categorized as incident management, incident support, client casework, and language translation. Nineteen responders (nearly two-thirds) performed client casework, ten performed incident support, eight assisted with language translation, and six were involved with incident management (Figure 2.7). The majority of tasks were undertaken as part of the responsibilities of the responder's primary role, however, in all tasks, a small number of responders assumed responsibility for tasks that were outside their reported role, presumably because of competency or availability.

Twelve responders reported performing multiple tasks (Figure 2.8). Seven responders reported a combination that included client casework and language translation. All individuals who performed incident management also assumed other duties—including client casework in all but one case—based on competency. Multitasking and increased competency-based task assignment is common on small-scale responses, but it is not known whether the high rate of competency-based multitasking on the part of incident management staff is typical.

Context Design Problem Space

Response activities were distributed across six different physical locations (Figure 2.9). Initial client interviews and disaster assessment took place at the fire scene where, in the words of one responder, "working conditions were very difficult—noise from fire engines and no lighting or

Figure 2.8 **Task Combinations Reported by Responders**

Incident management	Incident support	Client casework	Language translation	Number of tasks	Number of responders
•				1	0
	•			1	8
		•		1	8
			•	1	1
•	•			2	1
•		•		2	3
		•	•	3	6
•	•	•		3	1
•		•	•	3	1

seating for the clients." In contrast to the physical conditions, however, the fire scene offered direct access to key personnel, including representatives of other agencies, including the fire department and property management.

Subsequent client interviews took place in the lobby or parking lot of the Tropicana Lodge. The lobby was typical of a small American motel, with much of its approximately five feet by eight feet occupied by three armchairs and a small side table. Amenities included air conditioning, use of a local landline telephone, access to telephone directories, and limited use of a fax machine. Mass meetings with clients were held in the gymnasium of a nearby elementary school, which offered a large lighted space, folding chairs, and one folding table. Neither setting offered access to advanced technology or other information sources.

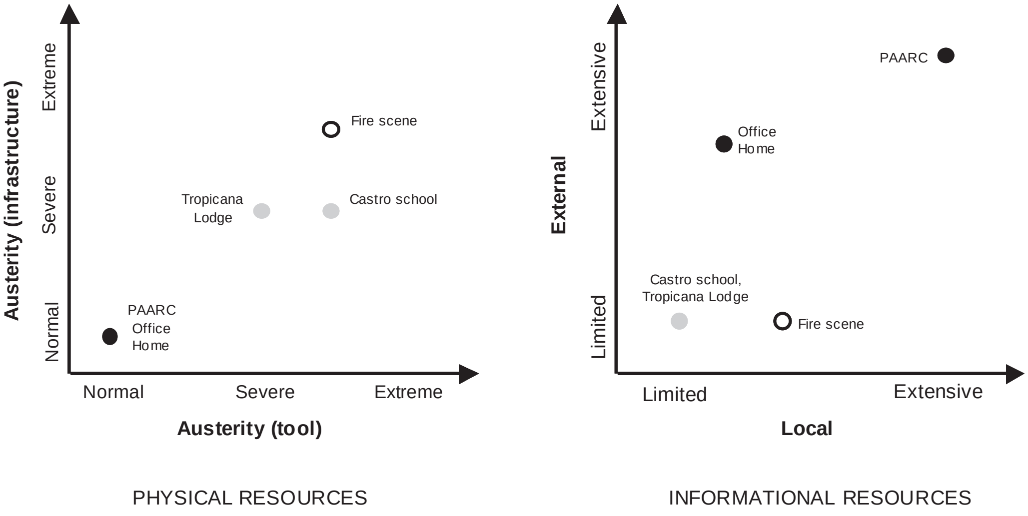
The incident was managed and supported out of the local Red Cross office (PAARC), which boasts all the normal amenities of a modern office. This setting provided immediate access to key individuals (e.g., chapter staff) as well as Red Cross documentation. Some responders also undertook response-related activities at home or in their place of work.

Combining these characteristics shows that the six locations are distributed across the context design problem space (Figure 2.9). Contexts fall into two groups: Traditional work settings (PAARC, home, and office) that offered normal austerity and access to external resources, and with which most responders were familiar, and response-imposed work settings (the fire scene, the school, and the motel) that were severely austere and offered limited access to external resources, and with which significant numbers of responders had limited familiarity. It should be noted that cell phones were functional in all six locations.

As shown in Figure 2.10, two-thirds of responders reported having worked at the PAARC office, nearly two-thirds at the motel, and just over half at the school. Slightly more than one-third worked at the fire scene and one-third each in their home or office. Responders were clearly more familiar with typical work settings, and less familiar with response-imposed locations (where client interactions took place).

This division is particularly interesting as sixteen responders reported working in at least one location from each group (Figure 2.11). Only seven responders worked in only one location (four in a response-imposed setting). Of the thirteen responders who worked in two or three locations, only six worked in locations from a single context group (five only in response-imposed and one in traditional settings). With the exception of the fire scene, all locations were active throughout the nine days of the active response, and many responders switched

Figure 2.9 **Latham Court Response Context Design Problem Space**



Note: The dimension of familiarity is indicated with shading, with denser shading representing greater familiarity.

regularly between the two types of contexts and, consequently, between different tools, information sources, and resources. While the percentage of responders making such switches may be smaller in a larger-scale response, it is likely that a substantial number will be doing so in responses of any scale.

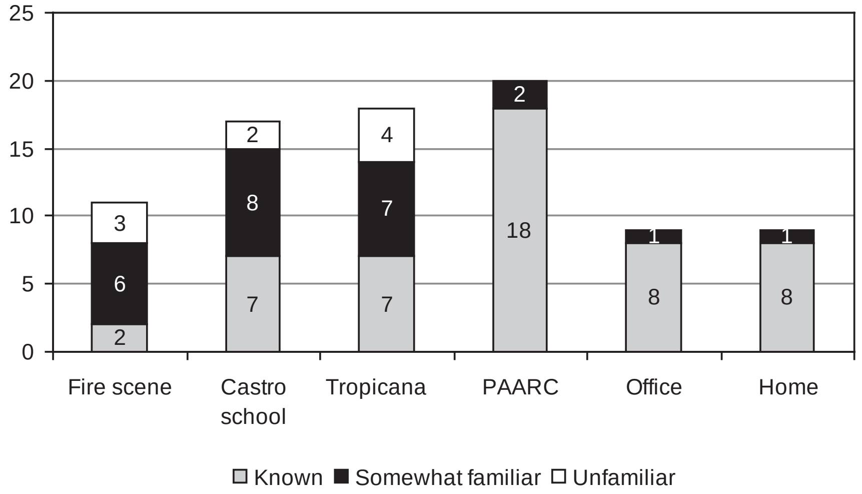
Discussion

The intent of the Latham Court case study was to illustrate application of the theoretical framework to analysis, but a few design implications are worth noting. In addition to yielding basic characterizations of users, tasks, and contexts, the analysis exposed three design problem features that might not otherwise have been apparent. First, a design aimed at this or a similar response should be equally usable by inexpert and expert users. Second, a user is likely to be multitasking, so, regardless of the task the design is intended to support, it must assist with sudden and frequent mental context-switches, for example, through save, pause, and restore capabilities. Third, a user is not only likely to work at a variety of physical locations, but those locations may differ significantly in the resources they offer. The design must thus provide portability, if not of functionality, at least of key data or information.

CONCLUSION

Design is an interesting but challenging and difficult task. It can be made easier and more successful by understanding the structure of the design problem space, that is, what problem features are likely to be critical, ways in which they affect solutions, and relationships among them. This chapter has used sociological theories of crises, emergencies, and disasters to develop a systematic description of the design problem space for user interfaces for response technology. Examination of

Figure 2.10 **Number of Responders Working in Given Contexts**



Note: Bars show number of responders reporting having worked at given locations and indicate their reported familiarity with this type of setting.

Figure 2.11 **Number of Locations in Which Responders Worked**

Note: Bars show number of responders who worked in the given number of locations and indicate whether the mix of locations reported was uniform or diverse.

three sociological dimensions of events, focusing on implications for response, revealed a twelve-dimensional framework for describing users, tasks, and contexts of response technology.

To illustrate analytic use of the framework, it was applied to an actual response to a conventional local disaster (an apartment-building fire). The analysis focused on responders from an extending organization (the American Red Cross), and exposed a wide diversity of users, tasks, and contexts, even in a local disaster response. The complexity of designing user interfaces for response technology is evidenced by the distribution of problem features even in this limited example: they do not occupy a single point or region in the space, but spread across multiple discontiguous regions. The challenge to design is that design requirements may differ significantly between different points and regions, and that the ambiguity and unpredictability of disaster response make it nearly impossible to predict where an actual response will lie.

The framework takes a utilitarian approach to describing critical and characteristic differences among individual design problems, and does not seek to define rigid classifications. It is in the early stages of development and is subject to evolution. At this point, the framework focuses on individual responders. Further work is needed to understand design differences imposed by variations in teams and organizations, by relationships among individuals, teams, and organizations, and by networks of individuals, teams, and organizations. Further validation of the framework and the theoretical approach to understanding design problem spaces is also needed, particularly in their application to a greater variety of responses and to actual design problems.

The theoretical approach to structuring design problem spaces offers designers a means of developing accurate mental problem spaces quickly. It also provides a means for designers and researchers to identify unexplored problems and designs. Ultimately, combination of the present framework with a similar framework focused on the response technology design solution space, exposing possible relationships between the two, will provide a theoretical foundation for a design-oriented discipline of response technology.

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CHAPTER 3

PROTECTING THE PUBLIC, ADDRESSING INDIVIDUAL RIGHTS

Ethical Issues in Emergency Management Information Systems for Public Health Emergencies

IRENE ANNE JILLSON

Abstract: *Ethical principles that are generally considered applicable across religions and national boundaries include beneficence (e.g., "do no harm"), respect for human dignity, and justice. Explanations of these principles are presented and their practical application to emergency public health policies and programs generally and to emergency management information systems specifically is discussed. Among the issues that have received considerable attention are surge capacity—the availability of adequate medical services and supplies for emergency situations and the equitable distribution of services—and risk communication—conveyance of clear and accurate information to the public and to health care providers. The complexities of applying ethical principles to real-life situations are addressed, including for example, public policies to ensure the practical application of distributive justice—with particular concern for vulnerable populations—while balancing the realities of resource availability and institutional infrastructure.*

Keywords: *Ethics, DERMIS, Public Health Emergencies, Health Care, Justice, Public Choice, Individual Rights*

For nearly a decade, emergency management information systems have played an increasingly important role in governments' efforts to ensure that the health and safety of their populations are protected in the event of man-made and natural disasters. Since the incidents of September 11, 2001, and Hurricane Katrina in 2006, for example, the U.S. government has invested significant additional resources in emergency preparedness generally and in emergency management information systems (EMIS) in particular. With the outbreak of severe acute respiratory syndrome (SARS) in 2002–3, the Canadian government increased its investments in preparedness, including EMIS. Globally, the concern about an avian influenza pandemic and bioterrorist attacks as well as natural disasters such as the 2005 tsunami has spurred development of bilateral, regional, and international emergency-preparedness plans. Some of these have included multinational EMIS.

However, in the midst of these plans, which have involved civilian agencies, the military, and combined (civil-military) systems, there has been relatively scant attention paid to ethical issues inherent in public responses to emergencies. Nor have most efforts addressed the ways that EMIS in particular can be designed to incorporate consideration of those issues in order to help ensure that decisions made in the event of emergencies are based on essential ethical principles. This chapter takes as a point of departure responses to public health emergencies in order to provide a basis for consideration of ethical issues and the ways that they can be addressed in responding to emergencies and designing and using emergency management information systems.

The essential ethical principles and their application to public health emergencies presented in this chapter apply broadly to emergency management. Public choices with respect to national planning, including for example, investments in mitigation of possible disasters, preparation against an anticipated disaster, and responses to disasters and recovery, reflect the values of a nation state. They should therefore be predicated explicitly on a commonly agreed set of ethical principles, including, for example, with respect to distributive justice. This would include addressing issues such as access to food and water, transportation, communications, shelter, power, and other essential goods and services. Lack of such access degrades the health and well-being of individuals, communities, and society.

INTRODUCING ETHICAL PRINCIPLES

The ethical principles in distribution of health resources and provision of health care during public health emergencies are essentially the same as those that apply under any circumstances. Societies have considered what we now describe as bioethics or health care ethics since at least Pharonic times. It is useful to recognize that there are essential ethical principles that cross cultural, religious, and national boundaries. This is particularly crucial in light of both global planning for public health emergencies and the increasingly diverse populations within nation states. We can assume that it is possible to consider these principles in emergency-preparedness planning and in the design of EMIS. Examples of the foundations of ethical principles across religions and belief systems include:

- The Code of Hammurabi (from 2500 BC): included provisions concerning the importance of ethical considerations to clinical practice and recognized the physician’s dual responsibility to the patient and to society.
- Pharonic principles: Maat (the principle of ethical balance) and compassionate care for the poor and sick.
- Hindu philosophy: (a) the transcendent character of human life, expressed through the principles of sanctity and quality of life; (b) the duty to preserve and guard individual and communal health; and (c) the duty to rectify imbalances in the processes of nature and to correct and repair states that threaten life and well-being, both of humans and nonhumans (which is important given the need to ensure protection of agricultural, exotic, and other animals during disasters).
- Tikun olam: the Judaic imperative to repair the world, reflecting the divine values of Justice (tzedek), Compassion (hesed), and Peace (shalom).
- Christianity: charity toward individuals and members of society generally, sanctity of human life.
- Islam: Hadith made treatment mandatory or obligatory when a treatment was definitely available and if withholding treatment would be harmful. If one is unsure of any benefit from a treatment and any harm is feared, then it is discouraged.

In 2005, UNESCO promulgated a Universal Draft Declaration on Bioethics and Human Rights that, while not specifically devised to address ethical issues related to public health emergencies, includes principles that apply to these circumstances and that were ostensibly based on consideration of divergent religious, cultural, and national beliefs and values. Four of the principles that apply are:

> *Article 9—Privacy and confidentiality*
> The privacy of the persons concerned and the confidentiality of their personal information should be respected. To the greatest extent possible, such information should not be used or disclosed for purposes other than those for which it was collected or consented to, consistent with international law, in particular international human rights law.
>
> *Article 10—Equality, justice and equity*
> The fundamental equality of all human beings in dignity and rights is to be respected so that they are treated justly and equitably.
>
> *Article 11—Non-discrimination and non-stigmatization*
> No individual or group should be discriminated against or stigmatized on any grounds, in violation of human dignity, human rights and fundamental freedoms.
>
> *Article 14—Social responsibility and health*
> 1. The promotion of health and social development for their people is a central purpose of governments that all sectors of society share.
> 2. Taking into account that the enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being without distinction of race, religion, political belief, economic or social condition, progress in science and technology should advance: (a) access to quality health care and essential medicines . . . ; (b) access to adequate nutrition and water . . .

However, the declaration is not without controversy. Selgelid has suggested that “the principles are stated in absolute terms and conflict with one another . . . and [it] . . . provides no real guidance on how to strike a balance between them in cases where conflict occurs.” He goes on to suggest that “UNESCO’s principles should be revised in order to better address the reality of conflicting values” (Selgelid, 2005). In an effort to articulate a set of “universal” ethical principles for medical and health care ethics, the UNESCO Declaration explicitly and implicitly “ranks respect for human rights, human dignity and fundamental freedoms ahead of respect for cultural diversity and pluralism”—thereby de facto rejecting conventionalist ethical relativism (Kopelman, 2005).

Ethical principles that are generally considered applicable across religions, cultures, and national boundaries, and are therefore applicable to public health emergencies generally, include:

1. Beneficence
    - Do not harm
    - Maximize possible benefits and minimize possible harm in the delivery of care and conduct of research
    - Freedom from exploitation
    - Risk/benefit ratio—balancing individual and societal benefits
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 health care services

The application of these principles, and those specifically considered in the context of emergencies, is addressed in a later section of the chapter.

WHAT IS A PUBLIC HEALTH EMERGENCY?

A public health emergency is defined as:

> an occurrence or imminent threat of an illness or health condition that:
>
> [a] is believed to be caused by any of the following: (i) bioterrorism; (ii) the appearance of a novel or previously controlled or eradicated infectious agent or biological toxin; or (iii) a natural disaster, a chemical attack or accidental release, or a nuclear attack or accident; and
>
> [b] poses a high probability of any of the following harms: (i) a large number of deaths in the affected population; (ii) a large number of serious long-term disabilities in the affected population; or (iii) widespread exposure to an infectious or toxic agent that poses a significant risk of substantial future harm to a large number of people in the affected population. (State of Alaska, 2003)

These emergencies can result from (1) sudden, catastrophic events such as earthquakes, hurricanes, flooding, or industrial incidents; (2) complex, continuing emergencies—including the internal political conflicts and conflicts between and among nation states and the large number of refugees who are displaced by the conflicts; and/or (3) slow onset disasters—such as the increasing prevalence of fatal HIV infection, or economic collapse.

During the course of responding to public health emergencies, laws, regulations, and policies of national as well as state/regional and local jurisdictions govern the way in which both medical services and supplies and "basic resources" are distributed through the public, or linked public/private sector systems. Medical supplies, such as vaccines, medicines, or medical equipment have been the primary focus of emergency resource distribution planning (Centers for Disease Control and Prevention [CDC], 2002; Trust for America's Health, 2003). 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.

THE PROBLEM OF DISTRIBUTING BASIC RESOURCES IN A PUBLIC HEALTH EMERGENCY

Current attention to public health emergency planning in the United States, and to some extent globally, focuses on pandemic influenza (Gostin and Berkman, 2007) and on bioterrorism. Both are quintessential examples of public health emergencies and are useful points of departure for considering basic resource distribution and strategies for minimizing the impact of the emergency in a wider range of emergency situations, such as natural disasters or bioterrorist attacks on food and water supplies. One such strategy is social distancing—used for minimizing opportunities for disease to spread by limiting contact between people. Social distancing measures can include closing public places, canceling public events, and encouraging people to remain in their homes (Gostin and Berkman, 2007).

Historically—at least since the Black Death—social separation and community restrictions have been fundamental pillars for governmental responses to pandemics (Kelly, 2006). Currently, the United States and other governments are developing pandemic influenza response plans based on the notion that decreased social mixing will slow the spread of a respiratory disease. In the past, governments have often closed public places and canceled public events, and, as fear rises, people tend to shun public gatherings (Ferguson et al., 2005). The private sector may take independent action to close down operations, even if not ordered to do so under public health laws.

When people choose to avoid public places such as grocery stores and pharmacies, or those venues are closed, access to basic resources is disrupted. Similarly, stoppage of public transportation may impede access to health care. During periods of social distancing, there is a widespread need for alternative distribution networks for food and potable water, medicine, and other necessities. Given the needs created by this situation, it is imperative that as governments develop emergency response plans that include social distancing, they also set up networks for the distribution of necessary provisions.

Public health emergencies present a range of challenges, most of which have not yet been adequately confronted. A number of government reports have highlighted the States' and other governments' lack of preparedness for an emergency. The Institute of Medicine (IOM) and the Government Accountability Office confirmed that since the events of September 11, 2001, U.S. state and local public health agencies have tried to improve the nation's capacity to respond to major public health threats, but gaps in preparedness remain (Board on HPDP and IOM, 2002; U.S. Government Accountability Office, 2003, 2004). In *The Future of the Public's Health in the 21st Century,* the Institute of Medicine stated that under the glare of a national crisis, domestic preparedness and emergency response capabilities are insufficient because, for example, health information systems are vulnerable and outdated, the public workforce is inadequately trained, and communities remain without access to essential public health services (HPDP and IOM, 2002). Moreover, there is no evidence that there is any substantial effort—or indeed any minimal effort—to ensure that health care providers, emergency responders, and others engaged in response policy and planning or services delivery are trained to consider the ethical implications of the decisions that they make. This is disturbing: if these key personnel are not aware of the ethical considerations, how can they be expected to make ethically sound decisions in the context of emergencies? Moreover, there is minimal cross-training of the various categories of emergency responders (e.g., physicians, firefighters), who may have significantly different educational backgrounds, different worldviews, and different socioeconomic status—all of which can impact decisions made during emergency response situations in which they need to function collaboratively—including with respect to application of ethical principles.

Given our pressing need to improve public health emergency preparedness, it is not surprising that a significant body of literature has been produced. However, the majority of existing academic research focuses on two issues: surge capacity and risk communication. Surge capacity refers to the notion that adequate medical services must be available to deal with the onslaught of sick or injured patients resulting from the emergency event (HPDP and IOM, 2006a, 2006b). Risk communication refers to the idea that information must be conveyed to the public in a clear and transparent manner, in order to relieve anxiety and maintain social order. There is minimal discussion in the academic literature that specifically addresses the ethical issues raised by the emergency management planning generally and EMIS specifically. The lack of attention being paid to these aspects of basic resource distribution plans is particularly notable when one examines existing government emergency-preparedness plans. For example, the Trust for America's Health 2003 report *Ready or Not: Protecting the Public's Health in the Age of Bioterrorism* examined U.S. public health emergency response capacity using ten indicators to rank each state's readiness. These indicators focus exclusively on laboratory capacity, surveillance systems, vaccine distribution plans, hospital and health care worker surge capacity, and medical equipment/supplies. There is no mention in the report of basic resources or of EMIS generally or even of health information systems. Moreover, there is virtually no mention of ethical issues related to emergency readiness or of definitions of essential goods.

Similarly, *Project Public Health Ready* is a collaborative venture between the Centers for Disease Control and Prevention (CDC) and the National Association of County and City Health Officials, last published in 2006. The program evaluates local health department response plans to determine whether the jurisdiction is prepared to carry out all of its responsibilities in the event of an emergency. Response plan strength is evaluated on such issues as workforce competency development, surge capacity, epidemiologic investigations, communications, and practice exercises. EMIS's strength and ethical issues are not considered: this is a gaping hole in the discourse. The *Local Public Health Preparedness and Response Capacity Inventory*, a self-assessment designed by the CDC to help local health agencies evaluate their plans to respond to public health emergencies, mentions legal preparedness, personnel development, surge capacity, risk communication, laboratory capacity, and vaccine distribution. It does not, however, include criteria for assessing whether ethical issues including resource distribution are taken into account during a public health emergency (CDC, 2002).

Planning and assistance for public health emergencies has largely been focused on single jurisdictions (e.g., states, governorates, or local jurisdictions such as counties and districts) and their immediately adjacent neighbors. However, public health emergency events have raised fundamental (and often unresolved) interjurisdictional legal questions, as the SARS outbreak made clear. Extant reports provide minimal analysis of emergency-preparedness laws and policies with respect to resolving which legal authorities and laws across jurisdictions (national and multinational) take precedence in a public health emergency and how these can work together to address urgent needs. This is problematic because in an emergency situation, it is vital to know who is in charge and how facilities and resources can be used and shared; this is particularly critical across national boundaries.

RESPONDING TO PUBLIC HEALTH EMERGENCIES: THE ROLE OF EMIS

In 2006, the World Health Organization (WHO) Southeast Asia Regional Office (SEARO) developed twelve benchmarks (see Table 3.1) by which national emergency-preparedness plans could be assessed. Taking into account significant variations in public and private sector infrastructure generally and availability of data and information specifically, they were devised through a participatory process by eleven member countries of SEARO. These benchmarks are increasingly used by governments and their private sector partners as the basis for initiating emergency-preparedness plans and assessing those that are in place.

Notably, just two of the benchmarks refer specifically to information or surveillance systems, although each of them assumes the immediate availability of accurate, current data and information for assessing, monitoring, and taking appropriate health and other actions.

Moreover, even in the context of countries that have invested significantly in EMIS, there are functional problems. These multiple, discrete systems are often not interoperable at the national, regional, state/governorate, or local levels; have distinct definitions of basic terminology (e.g., definitions of emergency response personnel); and a relatively small number of key stakeholders have been trained in their use. As a consequence, although the systems may be useful in and of themselves, they do not function as a comprehensive EMIS on which policymakers at all levels, emergency response teams, and, most important, the general public can depend. For example, the United States alone has at least seven health-focused EMISs (e.g., Epidemic Information

Table 3.1

The 12 Benchmarks

1. Legal framework and functioning coordination mechanisms and an organizational structure in place for health EPR [emergency preparedness and response] at all levels involving all stakeholders.
2. Regularly updated disaster preparedness and emergency management plan for health sector and Standard Operating Procedures (SOP) (emergency directory, national coordination focal point) in place.
3. Emergency financial (including national budget), physical and regular human resource allocation and accountability procedures established.
4. Rules of engagement (including conduct) for external humanitarian agencies based on needs established.
5. Community plan for mitigation, preparedness and response developed, based on risk identification and participatory vulnerability assessment and backed by a higher level of capacity.
6. Community-based response and preparedness capacity developed, and supported with training and regular simulation/mock drills.
7. Local capacity for emergency provision of essential services and supplies (shelters, safe drinking water, food, communication) developed.
8. Advocacy and awareness developed through education, information management and communication, including media relations (pre-, during and post-event).
9. Capacity to identify risks and assess vulnerability at all levels established.
10. Human resource capabilities continuously updated and maintained.
11. Health facilities built/modified to withstand expected risks.
12. Early warning and surveillance systems for identifying health concerns established.

Source: World Health Organization, Working Group One (2006).

Exchange—EPI-X, Metropolitan Medical Response System—MMRS, National Pharmaceutical Stockpile—NPS, and the National Electronic Disease Surveillance System—NEDSS) (Salinsky, 2002). The latter is critically important for effective, coordinated public health responses. NEDSS is an initiative that promotes the use of data and information system standards to advance the development of efficient, integrated, and interoperable surveillance systems at federal, state, and local levels. It is a major component of the Public Health Information Network (PHIN) in the United States. It is designed to:

1. detect outbreaks rapidly and to monitor the health of the nation;
2. facilitate the electronic transfer of appropriate information from clinical information systems in the health care system to public health departments;
3. reduce provider burden in the provision of information; and
4. enhance both the timeliness and quality of information provided.

In 2004, Turoff and colleagues described a dynamic emergency response management information system (DERMIS) based on a set of “organizing premises and concepts that can be mapped into a set of generic design principles” that served as a framework for “the sensible development of flexible and dynamic EMIS (Turoff et al., 2004). The premises described, and on which DERMIS is based, are:

- Premise 1—System Training and Simulation: An emergency system that is not used on a regular basis before an emergency will never be of use in an actual emergency.

- Premise 2—Information Focus: People responding to an emergency are working 14–18 hour days and have no tolerance or time for things unrelated to dealing with the crisis.
- Premise 3—Crisis Memory: Learning and understanding what actually happened before, during, and after the crisis is extremely important for the improvement of the response process.
- Premise 4—Exceptions as Norms: Almost everything in a crisis is an exception to the norm.
- Premise 5—Scope and Nature of Crisis: The critical problem of the moment is the nature of the crisis, a primary factor requiring people, authority, and resources to be brought together at a specific period of time for a specific purpose.
- Premise 6—Role Transferability: It is impossible to predict who will undertake what specific role in a crisis situation. The actions and privileges of the role need to be well defined in the software of the system, and people must be trained for the possibility of assuming multiple or changing roles.
- Premise 7—Information Validity and Timeliness: Establishing and supporting confidence in a decision by supplying the best possible up-to-date information is critical to those whose actions may risk lives and resources.
- Premise 8—Free Exchange of Information: Crises involve the necessity for many hundreds of individuals from different organizations to be able to freely exchange information, delegate authority, and conduct oversight, without the side effect of information overload.
- Premise 9—Coordination: The crux of the coordination problem for large crisis response groups is that the exact actions and responsibilities of the individuals cannot be predetermined.

Each of these is directly applicable to public health emergencies and, notwithstanding the extensive emergency-preparedness policies and programs that have been enacted in the United States and other countries over the past decade, the issues raised by Turoff and colleagues still pertain. Notably, however, the authors suggest that the primary concern “is with the design of an Emergency Response Management Information System that will directly support the responders in a local crisis situation and the associated coordination structure among all the involved parties and agencies” (Turoff et al., 2004). This relates directly to the twelve WHO benchmarks for emergency preparedness. The proposed approach recognizes the extraordinary change in telecommunication technologies (e.g., widespread use of PDAs, mobile phones, and wireless operations). This is significant: even in resource-poor African countries, low-cost telecommunication technologies such as cell phones are used in logistics management and treatment planning for HIV/AIDS—a “slow onset” disaster (see above).

ETHICAL ISSUES

Ethical Issues Related to Public Health Emergencies Generally

Each of the three broad categories of ethical principles—beneficence, respect for persons/human dignity, and justice—has extensive nuanced interpretations, but fundamentally they reflect societies’ interest in ensuring fairness, protecting individual rights while ensuring the broader social good. These balances are problematic in the context of everyday health care in virtually all countries; they are quite complex in the context of public health emergencies.

Consider, for example, distributive justice. In circumstances of extreme emergency, including public health emergencies, consideration of fair distribution of basic resources is necessary but insufficient: ethical principles demand more than this. The interests of vulnerable populations are undermined well beyond the detriments to their health. A failure to act expeditiously and with equal concern for all citizens, including the poor and less powerful, predictably harms the whole community by eroding public trust and undermining social cohesion. It signals to those affected and to everyone else that the basic human needs of some matter less than those of others, and it thereby fails to show the respect due to all members of the community. Ethical principles, including distributive justice, call for not only a core commitment to a fair distribution of basic resources but also for policies and programs—including health management information systems (HMIS)—that are consistent with the preservation of human dignity and the showing of equal respect for the health and well-being of all members of the community.

For example, if a robust commitment to ethical principles had been an animating principle in the response to Hurricane Katrina, public officials would have understood that vulnerable individuals could not, without special help, protect themselves from harm. They would have understood that as a result of government inaction or delayed action, many people would experience a double loss—first to their health and other tangible interests, and then to their standing as members of a common community in which all possess equal dignity and worth (Gostin and Powers, 2006; Kayman and Ablorh-Odjidja, 2006).

However, this vision has not yet been realized in the area of public health emergency planning generally and resource distribution specifically. Serious and reflective discussions concerning rationing of limited resources during an emergency are generally absent from the public discourse in the United States (Daniels and Sabin, 2002; Powers and Faden, 2006). The public tends to avoid addressing the issue of rationing, viewing the need to do so as an unfortunate consequence of rare situations (Emanuel and Wertheimer, 2006). There seems to be an implicit assumption in the literature that "scarcity is unavoidable and that planning for a full complement of all resource needs during a pandemic would be impossible" (Kotalik, 2005). This also could explain the paucity of clear definitions of what constitutes "essential goods"—these can be perceived differently depending on one's socioeconomic status and worldview—including individual values—and on the real and perceived impact of the emergency on the individuals, family, and his/her community.

There has been some discussion of ethical allocation of scarce resources in the context of vaccines and antiretroviral (ARV) medications. Recently, 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 there is not enough for everyone? Roughly, only 10 percent of the American population will be able to be vaccinated in the first year of an avian flu pandemic (U.S. Department of Health and Human Services [DHHS], 2005b). In low and middle-income countries, an estimated 28 percent of the 7.1 million individuals in immediate need of ARVs at the end of 2006 were receiving these life-extending drugs (World Health Organization, 2007). It is understandable that ethicists and policymakers have begun to develop a framework that can provide guiding principles for a just and effective distribution of the ARVs and avian flu vaccine.

Vaccine distribution in the event of a disaster provides a quintessential example of how distribution of medical services and supplies and other essential goods needs to be considered and the assumptions that underlie distribution plans and the EMIS that support them. In the United States, the Department of Health and Human Services 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, on the basis that this scheme will result in the greatest number of saved lives (DHHS, 2005b). This plan is not, however, universally accepted as ethically sound. At least two alternative views of the application of principles of distributive justice to access to vaccines in the context of a public health emergency have been posited: (1) that a "fair innings" approach should be used, and priority should be given to younger people who have not yet experienced a full life (Emanuel and Wertheimer, 2006); and (2) that a norm of reciprocity should be emphasized—those who accept increased risk should be protected when not all can be (Singer et al., 2003). Marcel Verweij argues that these positions create a false dilemma and that the public's health is best advanced by protecting first those people who are necessary to maintaining critical infrastructure during emergencies (World Health Organization, Working Group One, 2006).

Notably, the term "essential goods" or "basic goods"—in addition to vaccines and medicines—is used frequently in public documents regarding emergency response, but rarely defined. For example, the 2005 White House press release regarding the avian flu pandemic stipulates that "movement of essential personnel, goods and services, and maintenance of critical infrastructure are necessary during an event that spans months in any given community" (Executive Office, President of the United States, Homeland Security Council, 2005), but neither that document, nor the DHHS National Strategy for Pandemic Influenza defines "essential goods" (DHHS, 2005b). Nor do other public documents define essential goods, other than to use general categories of goods and services that include, for example, food, water, and shelter; energy (fuel for cooking, heating) and clothing are also included in some descriptions. Other governments make assumptions about distribution of goods and services, each based on the implicit and explicit values inherent in distribution of public resources and on definitions—expressed in public policy and other instruments—of what constitutes "essential." What constitutes essential food or housing for example? What utilities are essential and how should they be distributed: should there be restrictions on consumption of electricity and fuel to ensure equitable distribution? In addition to potable water, what constitutes "sanitation" goods and services? Transportation to health services can be considered an essential—but is transportation to work, and if so, for which category of workers? There should be transportation available to or provided for health care and emergency responder personnel, public safety workers, and utility workers, certainly, but what other categories of workers should be included? What constitutes essential telecommunications and how should access be ensured and for whom? These considerations and public policies based on them are rarely explicit—perhaps reflecting the difficulty inherent in defining the terms and making the complex, value-laden decisions required for rationing of public goods. International bodies (e.g., the United Nations, World Bank, World Health Organization) and international, regional, and national nongovernmental organizations (NGOs) that are involved in disaster relief (e.g., Oxfam, Médecins Sans Frontières) de facto define essential goods when they plan for and deliver them in time of disaster.

Beyond logistical concerns, the principle of social justice permeates these planning efforts: health emergencies threaten the entire community, but the poor and disabled are at heightened risk. Those with the fewest resources are the least likely to be able to procure additional necessities before social distancing strategies are implemented. They are also the least likely to have private transportation available to seek medical care, and are consequently less likely to be able to receive care and more likely to have to remain in homes with those who are infected. Emergency health plans stress the ability of individuals to comprehend and act quickly on information to take protective action—for example, stay at home, vacate, seek medical care, and stockpile life necessities. It should be anticipated that some of the poor, sick, aged, homeless, or persons with physical (sight, hearing, mobility) or mental (psychosis, depression, learning difficulties) disabilities will not be able to communicate and act as decisively as others would.

The SARS outbreak served as a basis for consideration of how ethical issues could be addressed in a complex public health emergency. Following the outbreak, in 2006, a working group of the University of Toronto Joint Centre for Bioethics considered ethical issues related to the SARS outbreak in Toronto. They derived five categories of ethical issues:

1. *Public health versus civil liberties:* There are times when the interests of protecting public health override some individual rights, such as the freedom of movement. In public health, this takes its most extreme form with involuntary commitment to quarantine.
2. *Privacy of information and the public's need to know:* While the individual has a right to privacy, the state may temporarily suspend this privacy right in case of serious public health risks, when revealing private medical information would help protect public health.
3. *Duty of care:* Health care professionals have a duty to care for the sick while minimizing the possibility of transmitting diseases to the uninfected. Institutions in turn have a reciprocal duty to support and protect health care workers to help them cope with the situation, and to recognize their contributions.
4. *The problem of collateral damage:* Restrictions on entry to SARS-affected hospitals meant that people were denied medical care, sometimes for severe illnesses. There were also restrictions on visits to patients in SARS-affected hospitals. Decision makers faced duties of equity and proportionality in making decisions that weighed the potential harm from these restrictions against benefits from containment of the spread of SARS through rapid and definitive intervention.
5. *Global interdependence:* SARS underlines the increasing risk of emerging diseases and their rapid spread. It points to a duty to strengthen the global health system in the interests of all nations. (Public Health Agency of Canada, 2003)·

Another ethical issue that arose during the SARS outbreak is indirectly related to EMIS: how should findings from research conducted during the outbreak, which is carried out through expedited reviews by institutional review boards (ethical review committees), be incorporated in EMIS and used in the projections, alternative scenarios, and policy options to which they contribute?

Eckenwiler (2004) has suggested additional ethical issues that need to be considered in public health emergencies; these relate specifically to the rights of health care workers during disasters:

- *Proportionality:* policies and practices are ethically justifiable when the risks of harm are minimized and reasonable in relation to anticipated benefits; this seems to call for transforming the health and social structures within which emergency preparedness takes place and, while beyond the scope of those involved in emergency management, should be considered;
- Health provider *participation in emergency management planning* and capacity for making ethically appropriate decisions: when health professionals lack decision-making authority in a health emergency with national security implications, the health of the public suffers; they must also be trained in ethical decision making and have access to accurate, current information on which to base these decisions;
- Principle of *reciprocity:* if health workers take risks, it is society's and their institution's duty to support them. This also assumes access to accurate, adequate information;
- *Disparities* by national economic status and provider type, for example, related to health care providers' (HCPs) duty to care—physicians are mostly trained, but nonprofessional HCPs are not necessarily trained (e.g., volunteers, nonprofessional health care workers).

Ethical Issues Related to Emergency Management Information Systems Supporting Responses to Public Health Emergencies

Notwithstanding the proliferation of EMISs and the potential for these systems to abrogate ethical principles, there has been scant attention to ethical principles, however conceived or categorized, or to ways in which they could be considered in planning and developing EMIS. At a fundamental level, if these issues are not addressed, multinational, national, and regional/state planning is simply not possible. Several broad ethical considerations need to be addressed; these include, for example: To what extent does the EMIS adequately incorporate issues of social justice? In particular, how does the EMIS contribute to assurances that marginalized and particularly vulnerable populations are reached? To what extent are privacy issues addressed and how are they balanced with the *need to know* in order to protect the social good—the potential for widespread outbreak of diseases and/or trauma?

In the case of the SARS outbreak, for example, disease reporting during an outbreak carries the risk of a breach of confidentiality. As the Toronto report noted:

> Boundaries of privacy vary from person to person. Some believe that there is a risk of privacy infringement only if confidentiality is not maintained and a social stigma or loss of employment ensues from the breach. The other view is that a privacy infringement is wrong regardless of whether any harm occurs as a result. In either event, under the ethical value of proportionality, officials must use the least intrusive method to obtain their goal. Legislation such as the (Canadian) Health Protection and Promotion Act prohibits the release of personal information except in very specific circumstances where there is a public good to be served or added protection obtained by releasing an individual’s name. (Public Health Agency of Canada, 2003).

In reviewing existing and planned EMIS from an ethical lens, a number of considerations can be applied. Examples of these ethical considerations are presented in light of the criteria devised by Turoff and colleagues for the design of a dynamic emergency management information system (Turoff et al., 2004).

1. The metaphor or metaphors of a system are the mental models of a system that a user can easily learn in order to create a cognitive map that will make it easier to understand the system. The metaphor allows the user to translate the task objectives into interface actions to carry out those objectives. The type of metaphor that allows a human to create a “road map” or model of an information system is sometimes referred to as a boundary object.

Ethical considerations: issues of privacy and social justice, which are driven by the values of the nation state(s) for which the EMIS is designed.

2. The concept of human roles built into the software of group communication systems and supported by specific privileges and tools for carrying out the actions for those roles.

Ethical considerations: with respect to health care providers, concerns for reciprocity and disparities in education and access to protective equipment and prophylactic medications.

3. The concept of notifications, which are relevant alerts to a user of changes in status, data, and/or information of concern to the given user, brought about by events and/or the actions of other users.

Ethical considerations: balancing individual right to privacy with the need for information on which to base protection of the public health, including defining “confidentiality” in practice—are infectious diseases included or not? Should public health agencies and other emergency response agencies have access to individual electronic medical records? How should informed consent and advanced directive procedures be applied when records may be lost and the situation requires urgent decision making?

4. The concept of context visibility, which is the idea that the components of the meaningful data objects are presented in a context that relates to the understandings of the user. By the user's choice of a particular data element, the system can infer the functions that the user wants to perform at that point in time. When the user is uncertain as to what will be called up or wants to vary the choice he or she needs to be able to obtain all the possible selections as a submenu. This produces a common sense object interface that makes choices self-evident and tailored to the particular user.

Ethical considerations: ensuring that all necessary data elements are incorporated that would allow for distribution of necessary medical goods and services (e.g., access to trauma care, vaccines in the event of a pandemic) as well as distribution of basic goods and services (access to food, water, basic shelter).

5. The original concept of Hypertext which was the possibility of multiple two-way linkages with semantic meanings that allowed a person to utilize any item in the content of the application as a set of menu alternatives to move to other content or functionalities in the interface.

Ethical considerations: the need to ensure access by a full range of health care providers and other emergency responders, so that distributive justice can be addressed and the particular needs of vulnerable populations are served; clarity with regard to specific immediate actions (by type of public health emergency) and roles and responsibilities of key public-sector agencies (e.g., documentation of public health leadership assignments during the response to an incident).

THE WAY FORWARD

By identifying the ways in which ethical principles can be incorporated into emergency-preparedness planning generally and EMIS specifically, the integrity of emergency management planning can be strengthened. Doing so must build on existing EMIS frameworks, including DERMIS, for example (Turoff et al., 2004). These need to take into account not only the necessary components of the EMIS *qua* emergency management—including communication systems, transportation systems, organization of authority and responsibility, workforce continuity, and stockpiling of resources—but also basic ethical principles. This will help jurisdictions to improve their existing emergency management plans and ensure their effectiveness in practical application.

What are some of the practical considerations related to ethical principles? These include legal barriers to protection of privacy and legal and financial barriers to equitable distribution of resources within countries. Financial concerns will be paramount, as already underfunded public health systems are hard-pressed to find the financial resources necessary to stockpile and distribute necessities and to meet urgent and other health needs simultaneously. Similarly, the role of legal authorities is also a key issue, as multiple jurisdictions—including across national boundaries—have to coordinate activities and may be called upon to cooperatively provide urgently needed resources (e.g., potable water, food). National public bodies and international organizations also need to coordinate with the private sector, including for-profit businesses and not-for-profit NGOs.

Unfortunately, few Americans, and indeed few in other countries, can articulate the actions that local, regional, state, and national governments will actually take in a specific emergency. Even when there are promulgated policies, such as state-level disaster plans, they are not clear and not widely disseminated to the public. This comprises policies across the spectrum of emergency preparedness, from initial mitigation (e.g. building standards or transportation requirements) through recovery, including but not limited to the role of the health care system and related infrastructure with its communications and transportation. This also is likely related to the fact that there is no *consistent* international lexicon that defines clearly what constitutes essential goods and services (or that can be used as a basis for application of principles within nation states) and that can be understood by the public. Such a lexicon is a *sine qua non* of any EMIS.

Without transparent policies, and without clear and consistent terminology, those engaged in emergency-preparedness planning, including those who devise and operate EMIS, cannot engage in participatory and rational planning processes and certainly cannot devise effective plans and EMIS. This is critical: emergencies are not necessarily of short-term duration. Indeed, pandemics can last for years or decades, and the consequences of natural disasters such as Katrina can result in de facto emergency situations that last for years.

Moreover, the lack of transparency at all levels of government contributes to and is exacerbated by minimal public engagement in decision making with respect to emergency preparedness. This in turn results in a serious distortion in public policy. For example, from the end of World War II through the 1970s, there was an explicit and implicit public policy that there should be no profiteering from disasters. The obligation on the part of the government was to ensure insofar as possible that individuals and communities received support to reinstate their condition prior to the disaster. The unintended negative consequence was that it was not possible (without circumvention of the policy) to improve the situation of a person or community above that prior to the disaster. For example, it was not, ostensibly, possible to construct a better bridge for a local community to mitigate the possibility of repeated bridge collapse. Nonetheless, the policy helped to reduce, if not eliminate, profiteering and to ensure that individuals and communities had a publicly supported safety net. This helped make certain that essential ethical principles, including but not limited to beneficence, distributive justice, and human dignity, were a foundation of emergency responses. When the public is not aware of public policies, they cannot ensure that they are receiving essential goods and services equitably, as defined by public policy.

There will always be natural and man-made emergencies, always situations that require, over the short and long term, that societies respond to urgent human needs. The earthquake and floods in China and the floods in the Midwest of the United States in 2008, the political turmoil that has impacted essential services in several countries, and the growing concern about a global food shortage all remind us that we must take responsibility to ensure that our common values are considered in the development of national and international policies and public instruments and programs to address them. EMIS—the mechanism for collecting and disseminating data and information to inform public policy and to assure that it is implemented effectively and efficiently—should in turn be designed and maintained to ensure that ethical issues are considered.

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PART II

INDIVIDUAL AND ORGANIZATIONAL CONTEXT

CHAPTER 4

MITIGATING MALADAPTIVE THREAT RIGIDITY RESPONSES TO CRISIS

LINDA PLOTNICK AND MURRAY TUROFF

Abstract: *In this chapter we review the original theory of "threat rigidity" as proposed in 1981 by Staw and co-workers and discuss additional insights made in the accumulated literature to the present day. Research has shown that in response to a threat, organizations, groups, and individuals often respond in rigid, habitual ways. While there are times that such learned responses can be effective, in the face of a large, unforeseen, new threat, rigidity of response is often maladaptive. Based upon this review of the literature about the threat rigidity thesis, we will review literature that leads us to propose a model of an individual's cognitive responses to threat and present a set of recommendations how best to avoid the adverse effects of the threat rigidity syndrome in the emergency management and business continuity environments.*

Keywords: *Threat Rigidity, Cognitive Absorption, Focused Immersion, Mindfulness, High Reliability Organizations, Crew Resource Management*

THE THREAT RIGIDITY CHALLENGE

Research has shown that when faced with a threat, organizations, groups, and individuals often react with well-learned behaviors or habitual responses (D'Aunno and Sutton, 1992; Staw et al., 1981). This habitual response may, in some situations, be effective. For example, pilots are well trained to handle a stall. If a plane stalls, the pilot is able to react with automaticity (Lim et al., 1996) and perform the necessary actions quickly, without effort or planning. Thus, for familiar threats, responding in a rigid, habitual way may well be adaptive and effective at reducing the threat. However, if the threat is new, habitual responses may be maladaptive and may exacerbate the situation. This rigidity of response has been observed under many different kinds of threats, from financial threats to emergencies that threaten to cause loss of life. Understanding this response and when and why it can be maladaptive has implications for organizational and system design. If the maladaptive responses can be mitigated, then responses to threats can be adaptive and effective.

The threat rigidity thesis, proposed by Staw, Sandelands, and Dutton (1981), is an attempt to explain and model this response to threat, to understand the mechanisms that underlie it, and to explore the consequences of this proclivity toward rigid, maladaptive responses in the face of adversity.

In the model, environmental change is seen to lead to a threat; the threat then results in a restriction of information and constriction of control in an attempt to focus limited resources on dealing with the threat and to make certain there is centralized decision making. This in turn leads to rigidity in response (Staw et al., 1981). Rather than reducing the stress that precipitates the perception of threat, it can increase it to a point that is counterproductive. Some stress is needed to focus attention and to achieve cognitive absorption. When an individual is under stress, blood goes to the brain and heart to guarantee enough blood for the most important sensing and attention processes. However, there is a point at which too much stress will degrade performance. The rigid response, when maladaptive, is ineffective and intensifies the threat. When the rigid response is not maladaptive, such as in the case that the environmental change is not radical or the threat is a familiar one, the responses are effective and the threat is reduced. An example is the difference between civilians and military and police personnel in times of war. Civilians caught in a war or in the process of being robbed often freeze, unable to react. Those are unfamiliar threat/stress situations for civilians and they react in maladaptive ways. On the other hand, military and police personnel are heavily trained so that those events are not unfamiliar and they are able to react appropriately in such situations. Threats need not be so dramatically life threatening. For example, the threat of a lack of control over resources can result in stress that leads to a rigid, maladaptive response.

Staw defines a threat as “an environmental event that has impending negative or harmful consequences for the entity” (Staw et al., 1981, p. 502). Incremental, small environmental changes will produce threats for which learned behavior responses can be effective. But, radical changes will create threats that require new, flexible responses. It is this flexible responsiveness that the threat rigidity thesis proposes is lacking (Staw et al., 1981).

For individuals, the threat causes psychological stress that results in their perception of an unfamiliar stimulus as something they had experienced in the past instead of something new (ibid.). Cognitive simplification occurs to manage the overload that the new, complex threat creates. The individual processes the signals input as if they were of a simpler nature, unaware that he or she is ignoring cues that would provide for a more realistic understanding of the situation. Being under threat causes anxiety and psychological arousal. Research has shown that anxiety results in a reduced sensitivity to stimulation, decreased sensitivity to peripheral cues, and increased difficulty discriminating details (ibid.). An individual who is anxious, therefore, is less likely to actually perceive and understand that a threat is new and different. Staw and colleagues (1981) also note that disaster research has demonstrated that the stress and anxiety of being under a threat can cause individuals to withdraw and reduce information processing. As a result, individuals become less flexible in solving problems. Of course, not everyone responds in the same way, nor does every threat elicit the same response. More familiar or frequently occurring threats may be handled more effectively as the dominant, habitual responses are likely to be appropriate. It is when the threat is different than that with which the individual has experience, and the threat causes sufficient anxiety to reduce the individual’s ability to respond adaptively to it, that maladaptive responses are likely. The implication is that for training to be effective, it must either incorporate all possible threats (not likely to be possible) or train the individual to be flexible in responding. System and organization support for flexibility is important as well. For example, a system that reduces information overload will help to mitigate the anxiety that an individual under threat might feel.

THREAT RIGIDITY AND GROUPTHINK

Group effects of being under threat, according to the threat rigidity thesis, include altering group cohesion, leadership effects, and effects on group consensus and uniformity (Staw et al., 1981). The important determinants of effects on group cohesion are whether the threat is external or internal to the group, and whether or not the group has an expectation of success (ibid.). With a history of success and/or an expectation of success, group cohesion is likely to increase. Cohesion may disintegrate if there is an expectation of failure. If the threat is seen to be external to the group, then the group will rally together in an attempt to face it; if it is internal to the group, then cohesion will be reduced, divisiveness will increase, and consensus will be difficult to reach. However, under external threat, Staw and colleagues (1981) propose, there will be pressure for uniformity of thought, alternate opinions will be dismissed, and "groupthink" may result. This pressure for conformity with the dominant opinion then results in constriction of control.

Groupthink may be the result of any of a number of causes. For example, peer pressure can have a powerful effect on individuals. Even without overt peer pressure, an individual who experiences feelings of uncertainty, especially in complex, ambiguous situations, may defer to the consensus of the majority in what has been called the "majority effect" or "Asch effect." In the 1950s, Asch (1956) conducted studies in which a single subject was asked for judgment when the rest of the group had expressed an incorrect judgment. This subject, called the "critical subject," was unaware that the others in the group were confederates intentionally making an incorrect decision. Despite the fact that the confederates exerted no overt pressure on the critical subject and merely, in turn, individually made an incorrect choice, at least a third of the time the critical subject also expressed the majority (incorrect) view *even though he or she suspected or knew with certainty that the majority opinion was incorrect.* That is, in most cases when a critical subject yielded, s/he actually knew the correct answer but was so filled with self-doubt and/or other factors such as being afraid of being judged defective by the majority, or being embarrassed, that s/he succumbed to the majority. Asch noted of the critical subjects who resisted the majority and still expressed a correct, minority opinion that "our observations suggest that independence requires the capacity to accept the fact of opposition without a lowered sense of personal worth" (Asch, 1956, p. 51). In a crisis, the Asch effect must be avoided. Minority opinions may hold the key to effective response. The lesson from the Asch experiments is that if dissent is encouraged and valued, individuals will be less likely to feel lowered self-worth when engaging in it. Encouraging the raising of contradictions and dissent without penalty for error may enable members of a group or organization to resist the majority. This public encouragement and rewarding of expressions of minority views is a hallmark attribute of highly reliable organizations (HROs), which will be discussed further later in this chapter.

This propensity for groupthink may be exacerbated if, as the threat rigidity thesis predicts, information flow is restricted and new information is not sought. Then, there will be a reduced ability to scan the environment for new information to reduce the uncertainty and ambiguity. This reduction in ability to seek new information is not just externally driven through reduced channels, but, under threat, internally driven by cognitive narrowing and simplification, which serves to reduce uncertainty for the individual. If there is trust for the majority and majority viewpoint, then it is reasonable to propose that the individual uncertain of what is right, who has reduced ability, through a threat rigidity response, to reduce that uncertainty, will succumb to the power of the majority consensus, resulting in groupthink. If the authority figure does not trust his or her subordinates, then under a threat the constriction of control becomes exacerbated as the leader will not consider the information that comes from subordinates. Thus, trust must be developed before the crisis if the maladaptive responses predicted by the threat rigidity thesis are to be avoided.

ORGANIZATIONAL RESPONSE TO THREAT

Organizational culture can set the stage for how information is gathered, how much or little is sought, and how it is interpreted (Feldman and March, 1981). Misinterpretation can be promoted as a result of the politics of persuasion. The cost structure for gathering information can inhibit information gathering or, in the case that the cost is borne by those not using the data, promote the gathering of irrelevant information. When the specter of a threat arises, guided by its organizational culture, the organization may then respond in ways that do not promote appropriate gathering and interpretation of information.

At the organizational level, Staw and colleagues (1981) propose, the response to threat affects information searching and control processes. The overall effect is a restriction in information processing. However, when the threat is first detected, information search may increase in an attempt to confirm the presence of the threat. Then, as information overload and habitual responses occur, there is likely to be a radical reduction in search efforts. After a decision is made, there may be an increase in search activity as evidence to support the decision is sought (Staw et al., 1981). At that time, new information will be ignored as the focus will be on confirmatory information. Control becomes centralized and procedures become more formalized as the organization attempts to coordinate responses. Interestingly, research has shown that the exception is responses to natural disasters; in those cases, decisions are pushed down the organization, rather than up and centralized (ibid.). Staw and colleagues (1981, p. 514) posited that "a threat may force a control response that results in the strengthening of tightly coupled links within organizations and the dissolution of weak links." This is not contrary to the idea that control is centralized in response to threat. Rather, the control then becomes centralized within the organizational units in this case.

Constriction of control can be a maladaptive response because in a crisis, the expertise needed to manage the crisis may not reside in those who have formal authority. Additionally, if earlier leadership decisions were the cause of the crisis or exacerbated it, reverting back to centralized decision making can only reinforce the underlying cause of the crisis, making it worse, instead of better. Instead of tightening control, the people making the final decision need to, reach out and seek information from those with relevant expertise. This requires a measure of trust on the part of the authority figure for those who have expertise. However, pushing decision making down the organization to those with expertise will not be effective unless centralized oversight remains. Consider three groups involved in managing a crisis. If expertise is deferred to within those groups without oversight, each group may request resources that, in sum, exhaust the resources available for the response. The oversight needs to include forecasting of resource needs as well as balancing the entire effort's demand on resources lest the resources be misused or exhausted and not available when needed as the crisis unfolds. Oversight becomes especially important if there is competition between groups within the response team. Competition for resources can impair response, as can failure to share information between groups. So, a dual effort needs to be in place to counteract the maladaptive constriction of control. There needs to be deference to expertise and delegation of authority, all the while concomitantly maintaining oversight.

Deferring to expertise can be a challenge—especially when electronic communication is the primary means of communication. Persons in authority need to know who the experts are and where and how to find them. Design of electronic communication media for use in emergencies must take this need into consideration. This need is noted by Turoff and colleagues (2004) in their description of a dynamic emergency response management information system (DERMIS). Through automatic notifications and free exchange of information, those with expertise can be recognized and reached when needed.

RESEARCH ON THE THREAT RIGIDITY THESIS

Research has been inconsistent in attempts to confirm or refute this thesis. The threat rigidity thesis has been tested, examined, modified, and expanded by a number of researchers. An analysis of eleven such studies was done. The studies take place in different organizational domains, and the threats vary. Even where the threat rigidity thesis was supported, analysis showed there were weaknesses in the studies that made the results suspect. A weakness of some of the studies examined was that they ignored the threat rigidity model's intervening variables of restriction of information processing and constriction of control (Audia and Greve, 2002; Griffin et al., 1995; Ketchen and Palmer, 1999). Thus, it is not clear in those cases whether the rigidity outcomes were attributable to the threat as proposed by the thesis. Poor operationalization of the independent variable was another problem found in the analyses (Griffin et al., 1995). The length of time that an organization is under stress was not controlled for (Griffith, 2004) in some of the studies. This is a serious limitation: if an organization is under stress and the level of stress is stable, it might not constitute the level of threat (impending radical change) for which the thesis would predict rigid response. There was often significant time elapsed from the onset of the threat and the study of organizational processes (Anderson et al., 2003), which raises the question, not yet addressed in the literature, as to whether the rigidity effects are short-lived or permanent and, if not permanent, whether the duration can be predicted. A study of chemical plants (Meszaros, 1999) did not directly test the thesis, but analysis of the decision-making process each company took, the author noted, has relevance to it. In the case of high-consequence, low-probability threats, the companies carefully analyzed the situation, eliciting the opinions of many (i.e., flexible response) but became rigid with centralization of authority when the actual decision was made. The implication is that threats may affect flexibility at different stages of the threat (e.g., imminent or not imminent) and those differences may, at least partially, account for some of the contradictions in study results as reported in the literature.

Additional studies compared and tested the threat rigidity thesis against other, conflicting theories (e.g., prospect theory, behavioral theory of the firm). Again, the results were mixed. A summary of the eleven studies analyzed is found in Appendix 4.1 at the end of this chapter.

What is of interest for this chapter is the research that has found additional variables that are hypothesized to affect the rigidity of response in the face of a threat, particularly those variables that are relevant to emergency response situations. Threats in many of the studies were financial; in others, it was external stress or the probability of an accident that caused disaster. D'Aunno and Sutton (1992) studied the responses of drug abuse treatment organizations responding to changes in funding amounts and sources. Thus, the threat was a financial one. The study extends the threat rigidity thesis to include increased competition among members of the organization as a measure of rigidity of response. Their results supported the threat rigidity thesis. Rigidity in response was seen by the increased reliance on rigid use of existing procedures, less participation, and workforce reductions (D'Aunno and Sutton, 1992). But, what was interesting was that in the face of the threat, competition was also seen to increase. Competition among members can decrease team cohesiveness and cause conflict. This is thus another motivation to try to mitigate the maladaptive responses to threats.

Competition between organizations or units of an organization in a crisis can create enormous problems. This was seen in the 2001 anthrax contamination scare in the United States. Anthrax was detected, among other places, in post offices in Washington, D.C., and New Jersey. The FBI had a vested interest in keeping the investigation secret to avoid providing information that might help those carrying out the threats. On the other hand, the Centers for Disease Control has a policy of public disclosure to head off the potential spread of the outbreak and maximize treatment effectiveness. The conflict was resolved, albeit not through careful deliberation, when the newspapers broke the story and revealed facts of the investigation. Another example of the ineffective results that can occur when organizations refuse to agree on actions or policies was the rigidity experienced in response to the 2005 Hurricane Katrina disaster, which pitted local responders against state and federal agencies. That is, when there are such conflicting goals and a lack of clear centralized responsibility for all aspects of a wide-scale disaster as well as an associated lack of oversight to ensure fair distribution of available resources, conflict can result that impedes the management of the crisis.

Gladstein and Reilly (1985) found some support for the threat rigidity thesis applied to groups in a study that used a business simulation game, the Tycoon Game, to test the effects of an external threat on the model's intervening variables of restriction of information processing and constriction of control. In this study, the final outcome of rigidity of response was not examined. Business students played the Tycoon simulation game using scenarios in which the threat was financial loss, about which they had to make a decision. Time pressure was manipulated by decreasing the time to complete a scenario exercise midway through the game. Time pressure is not part of the threat rigidity model, but was assumed by the researchers to impact the level of stress (Gladstein and Reilly, 1985). The researchers propose that in order for there to be awareness of a threat, increased stress must be present. That is, if an organism does not experience stress, it will not perceive the existence of a threat. Stress is thus seen as a precursor to the perception of threat. Our interpretation of this and associated studies is that rigidity is the result of stress that is coupled with anxiety as a major product. As we shall see, stress is also a condition that can trigger a person's attention and concentration, in turn potentially producing a mental state of "cognitive absorption."

The results of this study partially supported the threat rigidity thesis (Gladstein and Reilly, 1985). Increases in threat, as operationalized by loss and time pressure, resulted in restriction of information processing. Higher levels of threat were not shown to cause more constriction of control, however. The authors offer as a possible explanation the observation that the subjects were students accustomed to working in groups. Furthermore, the scenarios the subjects used seemed to require a division of labor to reach a decision so that no one person could take control. Therefore, they responded by dividing the work and continued to work in the egalitarian group mode with which they were familiar. The findings also showed that increased time pressure reduced the amount of discussion that took place, although it did not affect the amount of information used.

The Gladstein and Reilly (1985) study is important as it is one of the few in the literature that considers the effect of threat on information processing and degree of centralization of control. It also adds to the understanding of the threat rigidity thesis by proposing that stress is a necessary condition for the perception of threat. It is, after all, the perception of threat, not an absolute value of threat, that creates the conditions for rigidity in response.

Many authors assume that threat rigidity is also a phenomenon for groups and teams. Certainly, if the factors affecting individuals are present for a majority or more of a team or group, this could explain consequences such as "groupthink." However, we have to remember that there are other causes having the same results, for example, a group may have a strong leader who has no real expertise in solving a problem but has authority or domination over the group.

An important element in the rigid response in the threat rigidity thesis is that rigidity is expressed by reliance on well-learned responses at the expense of finding new, adaptive ways of responding. In newly formed groups there is no history of collective habitual response, although, of course, at the individual level the responses would be predicted to be habitual. A study by Harrington, Lemak, and Kendall (2002) was designed to examine just that issue. The authors report on the design of a study that tests whether or not the threat rigidity thesis applies to newly formed teams. Because there are no well-learned group responses in a newly formed team, the authors predict that in the case of an external threat, newly formed teams will respond with increased flexibility. This is contrary to the outcome predicted by the threat rigidity thesis.

Newly formed teams do not have a history of trust or experience with the members' capabilities. Therefore, the researchers predict, if a threat is internal, members of the team may respond by assuming that the difficulties are a result of incompetence on the part of other team members and will, accordingly, respond with increased rigidity. Thus, the authors propose that the situation of internal threats is more threatening than external ones to newly formed teams (Harrington et al., 2002).

The researchers, in an extension of the ideas about cohesiveness expressed by Staw and colleagues (1981), propose that the likelihood of success or failure will interact with the threat (Harrington et al., 2002). If a threat is external and there is an anticipation of failure to handle the threat, the researchers hypothesize that the threat will be seen as far greater and rigidity in response will increase. Thus, an anticipation of failure will reverse the predicted outcome in the case of an external threat to a newly formed team. If the threat is internal and there is a high likelihood of success, rigidity will still increase, the researchers propose, because the perception of internal threat will be so disruptive as to make even this situation result in rigid responses. The researchers do not report details of the findings but indicate that newly formed teams place greater importance on internal than on external threats. What is significant here is the observation and conjecture that newly formed teams may respond differently than teams that have a history. Threat rigidity can be triggered in preexisting or newly formed teams but more easily in new teams because they have lower levels of experience together. For newly formed teams, trust and team cohesion, which help to promote behaviors that can mitigate threat rigidity, are more likely to be absent or not well developed. Emergency response teams are often ad hoc teams without history formed to handle a specific emergency and thus this conjecture is relevant. Also important is the proposition that internal threats may result in responses different from external ones. When interorganizational teams are formed to manage emergencies, competition and other conflicts may occur, creating internal threats. Thus, the impact of both internal and external threats is salient to emergency response teams.

Other studies have compared and tested the threat rigidity thesis against other, conflicting theories (e.g., prospect theory, behavioral theory of the firm) and have mixed results (e.g., Anderson et al., 2003; Ketchen and Palmer, 1999). Kennedy (1998) proposes a new theory that both reconciles and explains the different outcomes predicted by the threat rigidity thesis and other theories (e.g., prospect theory) at the level of the individual. The new theory proposes that the behavioral outcomes of being under a threat will depend on the impact a decision has on the individual's preferred identity. That is, individuals have, for themselves, an identity they wish to maintain. Their reactions to threat will be mediated by an attempt to maintain that identity. Kennedy suggests that the interaction factors of desired identity and domain familiarity must be considered when predicting behaviors that will result from threat. Individuals under threat may act out of denial of reality in order to preserve preconceived notions of the image they wish to portray. Additionally, familiarity with the domain is proposed to be an interaction factor such that the less familiar the domain, the less risky behavior will be under threat (Kennedy, 1998). This is consistent with the threat rigidity thesis because the less familiar the domain, the greater the threat and, therefore, the more rigid the response. However, it adds the proposition that individuals often act to preserve an image that they wish to portray. This can lead to unexpected responses if not considered when analyzing responses under a threat.

Clearly then, more research is needed to study the threat rigidity thesis under various conditions in different domains. Reconciling the results of the different studies requires a deep understanding of the phenomenon and the conditions under which it occurs. It might, for example, be fruitful to analyze actual communication before, during, and after a crisis when communication is captured by electronic communication media. Danowski and Edison-Swift (1985) analyzed communication in a study of an organization undergoing an organizational and financial crisis. They found that communication increased, the number of communicators increased, messages became shorter, and the communication networks underwent a shift such that individual networks became less interlocking, meaning that individuals communicated with others who did not communicate among themselves. While this study involved only one organization undergoing a particular crisis and the contents of the messages were not analyzed, it suggests one of the contributors to rigid response. That is, at the onset of a crisis if an organization does not have a process for dealing with it, the obvious outcome is more communication as people struggle to ascertain what is going on and how to deal with it. This increase in the amount and breadth of communication can be manifold and therefore can increase the potential for information overload. Information overload will exacerbate the potential for a rigid response. This is particularly important when one considers that large-scale disasters cross all sorts of political, geographic, and organizational boundaries. The results of the Danowski and Edison-Swift (1985) study raise a red flag for the importance of planning and support for the communication process and structure to handle a major crisis to avoid very high levels of information overload and greatly increased stress, which creates the foundation for an increased rigidity in response. However, as will be discussed, the impact of information overload and resulting threat rigidity can be ameliorated by organizational and system design. Further research in this and other areas that describe the environment of crisis and the reactions to it could provide great insight into the threat rigidity response and help reconcile differences in study results about it.

Nowhere is a threat more likely to involve a radical change in environment than the threat of an emergency. Emergencies are, by nature, unpredictable, complex, and often unanticipated. The threat of an emergency often needs to be handled quickly and effectively to avoid dire consequences. Maladaptive, rigid responses can be deadly in some cases. Contradictory results (see Appendix 4.1) are reported in the literature of studies that test the threat rigidity thesis. Nonetheless, there is enough support for the probability of maladaptive, rigid response to threat to warrant consideration of organizational and system design to support mitigation of the rigidity in response. Rigid response need not be a foregone conclusion in the face of a major response. In an emergency, creativity and flexibility of decision making must be supported as improvisation is often needed to respond to an emergency (Mendonça et al., 2001; Vogus and Sutcliffe, 2002). Examples of creativity in emergency management were the use of ferries as ambulances to bring those injured in the terrorist attacks on September 11, 2001, to the National Guard field hospital in New Jersey, and the use of containers in New Zealand as temporary dike gates to allow flood waters out of an area at low tide and to keep them out for high tides. If creativity can be supported in emergency response, then the rigid responses predicted by the threat rigidity thesis can be minimized even in the face of a new, unanticipated large emergency, thus making the responses more effective.

DECISION MAKING BY MUDDLING THROUGH

Emergencies are “wicked problems” as defined by Rittel and Webber (1973). One cannot fully define them by describing all possible solutions ahead of time; as each decision is made, the situation changes and the requirements for resolution change as well. Emergencies have the characteristics of wicked problems. For example, the consequences of a decision cannot be fully assessed at the time the decision is made; every decision is important, as a decision changes the nature of the emergency and its consequences; and each emergency is unique, so that no one set of solutions will effectively resolve all emergencies of a "type." Responding to a wicked problem such as an emergency requires what Lindblom called "muddling through" or disjointed incrementalism (Lindblom, 1959, 1979).

In an ideal world with ideal perfectly rational humans, there would be no need to worry about threat rigidity in response to stress, crisis, or emergencies. People would make decisions rationally, in an orderly fashion described as the "rational comprehensive method" by Lindblom (1959) in his classic article, "The Science of 'Muddling Through.'" This purely rational approach to decision making would have the decision maker first list, in rank order, all the goals s/he wished to accomplish. Then s/he would research thoroughly all of the possible alternatives and then compare all of the alternatives, using all of the relevant theories, ranking them by the value they would provide. This would presumably lead naturally to the best decision (Balzer, 1979; Lindblom, 1959). But human beings have cognitive limitations that limit their ability to adapt perfectly to complex environments or to act perfectly rationally; that is, we experience "bounded rationality" (Simon, 1991). Therefore, that ideal is neither cognitively possible nor would it be possible to achieve such a process in a timely manner—especially given the exigent and time-critical nature of crisis. What decision makers do, instead, is what Lindblom terms the "successive limited comparison method" or "muddling through" (Lindblom, 1959). Muddling through is a process by which decision makers tend to limit the scope of their thought process to one or a few goals, limit the alternatives that are considered to those that spring to mind or are readily available, and limit analysis, which could cause important outcomes to be missed or overlooked. Thus, the response of threat rigidity can exacerbate an already compromised, but cognitively necessary, process. However, this process will not necessarily lead to compromised decisions. For example, Balzer (1979) notes that by seeking advice and input from others who have different experiences, and therefore different perspectives, one can "muddle through" better. But with a rigid response, less input is sought as control and information are restricted. However, strategies do exist to maximize the potential for good decision making within the constraints of human cognitive ability. Technological support can also be provided to increase the scope of analysis and flexibility of response, thus improving outcomes. For example, scanning the environment is a process that is part of muddling through. Encouragement of scanning the environment and supporting it through technology can improve the results. Muddling through relies on the experience and instinct of the decision maker to a great degree. This allows for creativity and flexibility—as long as the organizational culture and technology support and encourage it. So, muddling through can be thought of as an adaptation to human limitations that under the right conditions can be a process that mitigates rigidity in response. The remainder of this chapter will explore these strategies and technological designs.

COGNITIVE ABSORPTION

Lessons can be learned from the literature that point to ways in which organizations and individuals can promote flexible, adaptive responses to emergencies. In particular, the concepts of cognitive absorption, mindfulness, and crew resource management offer insight into how attention to detail, use of experience, and intuition can help individuals and groups avoid or lessen maladaptive responses to threats.

Individuals react differently to the same external stimuli because their innate traits and current psychological states may differ from each other. Cognitive absorption is a psychological state in which an individual is deeply involved in an activity (Agarwal and Karahanna, 2000). It has five dimensions: temporal dissociation, focused immersion, heightened enjoyment, control, and curiosity or challenge (ibid.). Originally conceptualized by Agarwal and Karahanna (2000) to express a state of absorption in software use (and especially in games), we propose it as a state that can occur with involvement in any activity, including responding to a threat, and involves factors such as creativity that may lessen threat rigidity.

Temporal dissociation is a condition in which the individual is not aware of the passage of time while engaged in an activity, and focused immersion is a state whereby the individual is completely engaged in an activity so that he or she is oblivious to other demands (ibid.). While there may be no pleasure gained in responding to a threat, there is a "sense of accomplishment" or satisfaction in contributing to the successful response to a difficult situation. The other dimensions of cognitive absorption are clearly a part of emergency management and response. Agarwal and Karahanna (2000) posit that when an individual is in a state of cognitive absorption, s/he feels less cognitive burden. Therefore, we propose that the person so absorbed will have less susceptibility to cognitive overload, thus reducing the restriction of information and reducing the rigidity of response. Temporal dissociation and focused immersion enable the cognitively absorbed individual to resist distractions and focus on the task at hand. Curiosity is defined by Agarwal and Kashanna (2000, p. 673) as "tapping into the extent the experience arouses an individual's sensory and cognitive curiosity." Antecedents to cognitive absorption are proposed to be playfulness and personal innovativeness (Agarwal and Kashanna, 2000). Both traits will increase an individual's ability to improvise as needed and to perceive more options under stress. However, one can also interpret the combination of the prior factors as creating a challenge that results in the same innovative performance. Thus, a person who is cognitively absorbed, we propose, will have less cognitive overload, be better able to perceive options and resist restriction of information, be more innovative, and feel a sense of control despite efforts from superiors to constrict control, and therefore will be better able to respond flexibly to a threat. Temporal dissociation and focused immersion enable the cognitively absorbed individual to resist distractions and focus on his or her tasks.

There is concern about the impact of interruptions because of the time it takes to rethink and respond when people are interrupted while they are performing complex tasks such as programming (Hallowell, 2006). In emergencies, interruptions are common. For example, when a superior wants briefings from those who are trying to make decisions about actions to respond to situations she or he will interrupt the decision maker. System design must recognize this and have interruptions queued up with a passive signal on the screen that the user can note without losing concentration and respond to after finishing her or his current thoughts. That is, the system has to support "shadowing." Shadowing is a human cognitive ability that can be seen, for example, in a cocktail party when one ignores all the conversations in the background yet is able to hear and note the mention of his or her name if it is spoken in the background. The person mentioned is able to pick his or her name out of the background chatter and note that it was spoken and who said it all the while continuing to engage in the current conversation.

In sum, we propose that a person who is cognitively absorbed will have less cognitive overload, be better able to perceive options and resist restriction of information, be more innovative, and feel a sense of control, and therefore be better able to respond flexibly to threat. Thus it is incumbent upon organizations to have a philosophy and provide systems that promote cognitive absorption.

SUMMARY OF FACTORS

In the lists below, the individual and organizational factors that can contribute to maladaptive responses in emergency are summarized. For most of these factors, the extent of their impact is not known, as there have been scant empirical studies of them. However, any single factor or combination of factors can enhance the effects of threat rigidity. Most have been discussed above. Those that were not addressed in the preceding discussion are annotated within the lists.

Individual factors are:

- Habituated responses
- Cognitive overload
- Cognitive narrowing
- Cognitive simplification
- Cognitive burden
- Stress producing anxiety
- Stress producing attention/concentration
- Peer pressure
- Lack of trust downward
- Trust in group together with uncertainty as to self-ability
- Anxiety
- Expectations of success or anticipation of low consequence
- Expectation of positive/negative impact on self-image
- Perception of external stressors
- Lack of curiosity/creativity
- Lack of sense of control
- Distraction—lack of focused immersion
- Temporal dissociation or lack thereof
- Perception of reality
- Expectation of better information if actions/decisions are delayed
- Feeling that better information exists but is not being delivered
- Lack of trust/confidence in other taking over a person's role
- Interruptions in task (e.g., superiors requesting a briefing so they can talk to the press, thus taking you away from your tasks) can prevent cognitive absorption

Organizational factors are:

- Groupthink
- Competition
- Lack of group cohesion
- Constriction of control
- Restriction of information flow
- Lack of oversight
- Competition for resources/limited resources
- Not deferring to expertise
- Resource limitation
- Perception of limited temporary nature of threat
- Ignoring contradiction
- Ignoring weak signals
- Not updating expectations
- Familiarity of the threat
- Time pressure

- History of success or failure
- Level and homogeneity of threats
- Normalized number of injured and dead
- Process losses due to mismatch of task assignment, heterogeneity of group, and so on
- Production blocking
- Hidden disagreements underlying a fake consensus can create conflict and resistance
- Lack of authority or freedom of information can inhibit the use of experts' knowledge
- Inhibited information exchange among team members—a form of restriction of information
- Inhibited information exchange external to team—a form of restriction of information
- Pressure to generate premature consensus—can lead to groupthink
- Conflict of goals of team members reflecting different organizations

MINDFULNESS: LESSONS LEARNED FROM HIGH RELIABILITY ORGANIZATIONS

Mindfulness, described first in the writings of Weick, is another factor that can impact threat rigidity. Mindfulness combines the properties of attention to detail with experience in similar situations to describe a state of mind that can reduce the threat rigidity phenomenon.

Knowing what to focus on is as important, perhaps, as being able to focus and to be cognitively absorbed. High reliability organizations (HROs) are those organizations that have far fewer mishaps than expected given the characteristics of their domain. HROs are not necessarily accident free; rather, they are able to anticipate and avoid most accidents and, when they do occur, minimize the effects and learn from them. Weick and Sutcliffe (2001, p. 10) propose five characteristics, which they term “mindfulness,” that enable HROs to do this: preoccupation with failure, reluctance to simplify interpretations, sensitivity to operations, commitment to resilience, and deference to expertise.

A preoccupation with failure allows an entity, whether an organization or individual, to focus on things that go wrong. In this way, small failures can be managed before they become big failures. Mindfulness requires that an assumption be made of complexity. That is, instead of engaging in cognitive simplification to make management easier, mindful people and organizations seek out the complexities of a situation in order to have a more accurate “big picture.” This involves looking for the small nuances that might otherwise be ignored and result in a problem growing out of control. Weick and Sutcliffe characterize sensitivity to operations as, “ongoing concern with the unexpected” (2001, p. 13). That is, even when the situation seems normal, mindfulness requires the organization and its people to be alert to minor anomalies that may signal potential problems. This requires that there be an active effort to avoid restriction of information. It also requires that individuals feel enough comfort to voice their concerns publicly and to be encouraged to do so. This is a radical shift from the environments in many traditional organizations. Encouraging the voicing of concerns can avoid the problem of groupthink. A commitment to resilience requires one to expect that there will be errors and to develop techniques to recover quickly from them while they are still small and manageable. Weick and Sutcliffe (2001) point out that in order to do this, experts must be on board and valued so that the small errors can be detected and handled. This requires deference to expertise, the final characteristic of mindfulness. HROs defer to expertise in times of emergency. That is, authority migrates down the chain of command to those best suited to make decisions in such adverse conditions. This can counteract the propensity, characteristic of threat rigidity, toward constriction of control.

Not being mindful can increase process loss that results in maladaptive responses to threat. Potential productivity is the productivity that can be achieved if the right person does the right thing at the right time, given the available resources, task, group composition, and group size (Steiner, 1972). Steiner calls the process that maximizes the effective use of the available resources, the "prescribed process." Note that the "prescribed process" is one that depends upon the situation. That is, it is not a habitual response if the habitual response is maladaptive. Actual productivity is the potential productivity less losses due to faulty processes (ibid.). If expertise is not deferred to, process loss is likely to result, as the "right" person will not be assigned to critical tasks (i.e., there will be a mismatch in task assignments). Process loss is a critical problem for emergency response teams, as any process loss can inhibit the ability to respond appropriately. Emergency response teams are often "large" in size, which can increase potential productivity (ibid.), but that increase can be offset by increased coordination difficulties and an increased propensity for mismatched task assignments (ibid.). Additionally, emergency response teams comprising members of multiple organizations are likely to be heterogeneous in composition. This increases the difficulty of achieving the "prescribed process" because it makes it more difficult to match the right person to the right task (ibid.). This is another impetus for such teams to collaborate before a crisis because interacting when there is no threat will help the team identify experts and their areas of expertise during a crisis. Thus being mindful can reduce process loss, and reducing process loss increases production and performance.

Mindfulness requires that people continually update their expectations (Weick and Sutcliffe, 2001). Mindful people and organizations never assume that all is well or that what they expected to occur has, in fact, occurred. They are always alert and monitoring for evidence to the contrary. Plans are not strictly adhered to; rather, responses are updated based upon the new information that the continual scanning for nuances and contradictions reveals. This constant monitoring and philosophy of "expecting the unexpected" (ibid.) can prevent maladaptive habitual responses to an extreme or new emergency.

What is noticeable is that HROs act in a way that is consistent with effective muddling through (Turoff et al., 2008). For example, muddling through requires "a greater analytical preoccupation with ills to be remedied than positive goals to be sought" (Lindblom, 1979, p. 517). This is consistent with the preoccupation with error that HROs exhibit. While HRO theory was developed around organizations dealing with complex physical systems (e.g., nuclear power plants, aircraft carriers), the same concepts appearing in the theory of muddling through do not require a physical system to justify the concept. All one needs is a complex organization that deals with wicked problems. For example, Rittel and Webber (1973) consider all of planning as wicked.

We propose that cognitive absorption and mindfulness can mitigate the rigidity effects of being under threat. There is a synergy, an interaction, between the two such that being mindful promotes cognitive absorption and vice versa. This can increase resistance to threat rigidity behavior. For example, if one is mindful, adapts expectations, and responds to weak signals, then there is a flexibility in thought needed to be creative (cognitive absorption). By being cognitively absorbed and mindful, an individual will increase his or her resistance to threat rigidity responses and can effectively "muddle through." System design must support these adaptive processes. But design that is based upon an engineering or economist view of reality is based upon the rational comprehensive approach and thus will not support muddling through. System design must have features that allow users to effectively muddle through and make sense of the reality they face.

LESSONS FROM CREW RESOURCE MANAGEMENT (CRM)

Another particular application where many of the same considerations as found in HROs are in place is the philosophy and guidelines of Crew Resource Management (CRM). Insights from

CRM can help mitigate the threat rigidity effect. CRM comprises a set of principles and methods for mitigating error in aviation (McKinney, 2008). The guiding principle is to "accept that errors will occur but to mitigate the errors that do occur by training in decision making, communication, situational awareness, stress, leadership, and workload sharing" (ibid.). Situational awareness is paramount to effective decision making and is an ongoing process providing a feedback loop such that as feedback provides new information, it creates input for further decision making. It is an important philosophy that even though one individual may have primary responsibility for decision making, the process is considered a team effort. This is consistent with the HRO philosophy of deferring to expertise. Situational awareness involves detecting cues, interpreting them, and integrating them into the understanding of the situation. This is precisely what is needed for an HRO and for cognitive awareness.

Rigid response need not be a foregone conclusion in the face of a major threat. In an emergency, creativity and flexibility of decision making must be supported, as improvisation is often needed to respond to an emergency (Mendonça et al., 2001; Vogus and Sutcliffe, 2002). Mendonça and colleagues (2001) note that in designing a system to support flexible response, the limitations of human cognition must be considered in the design. If that can be accomplished, then the rigid responses that the threat rigidity thesis predicts can be minimized, thus making the responses more effective. That is, individual challenges to accomplishing the goals of CRM must be overcome (McKinney, 2008). These challenges include the individual characteristics that we described above as contributing to threat rigidity. McKinney (2008) reports that in order to assist individuals in overcoming these challenges, an information technology (IT) system used in a crisis needs to encompass the following functionality:

- Simplify data and minimize filtering—this gives crisis managers data in as close to original form as possible, allowing them to make their own inferences based on their expertise and allowing them to detect nuances that a filtering of data might conceal.
- Support feature matching and adaptive story telling—this will allow the teams to match the situation to familiar situations or stories that describe the situation in ways that suggest actions that will manage the crisis.
- Reduce cognitive overload—cognitive overload is a factor that can lead to cognitive simplification and thus to maladaptive responses. Reduction of cognitive overload can be accomplished by, for example, chunking and categorization of data.
- Direct attention efficiently—to promote effective environmental scanning for cues, systems should alert users to important cues.
- Reduce confirmation bias—HROs constantly reevaluate assumptions and seek contrary information. A system can help by flagging contrary information.
- Adaptively aid diagnosis and action selection cycles—system adaptation can be done by, for example, alerting users to others interested in certain data and to data that could be used in selecting actions.

A DYNAMIC MODEL OF INDIVIDUAL COGNITIVE PROCESSES

The processes involved in responding to a threat and attempting to mitigate threat rigidity are dynamic. As the event unfolds and actions are taken, the direction of the event and future responses are influenced. If one treats this subject as a static model, as is often done in the management literature, the analysis of the situation will ignore the real dynamics of what is taking place. As has been described in this chapter, one can analyze threat rigidity at the individual or group level. In this section we discuss an individual's response to threat and present a dynamic feedback model describing the most important cognitive factors that determine the level of rigidity of response for the individual. Threat rigidity at the group level is also dynamic. However, a model describing a group that is dealing with threat rigidity would be far more complex and contain many more factors (e.g., process gains and losses), some of which have not yet been studied in depth except for specific situations. Therefore, we focus on developing a model for the individual and defer the group analysis for future research.

At the individual level, the degree of rigidity in response results from cognitive processes that are influenced by both the environment and individual characteristics (e.g., experience). Figure 4.1 is a diagram of the most important factors in a dynamic feedback model of how an individual's experience and other characteristics interact with the environment to influence the level of threat rigidity in response.

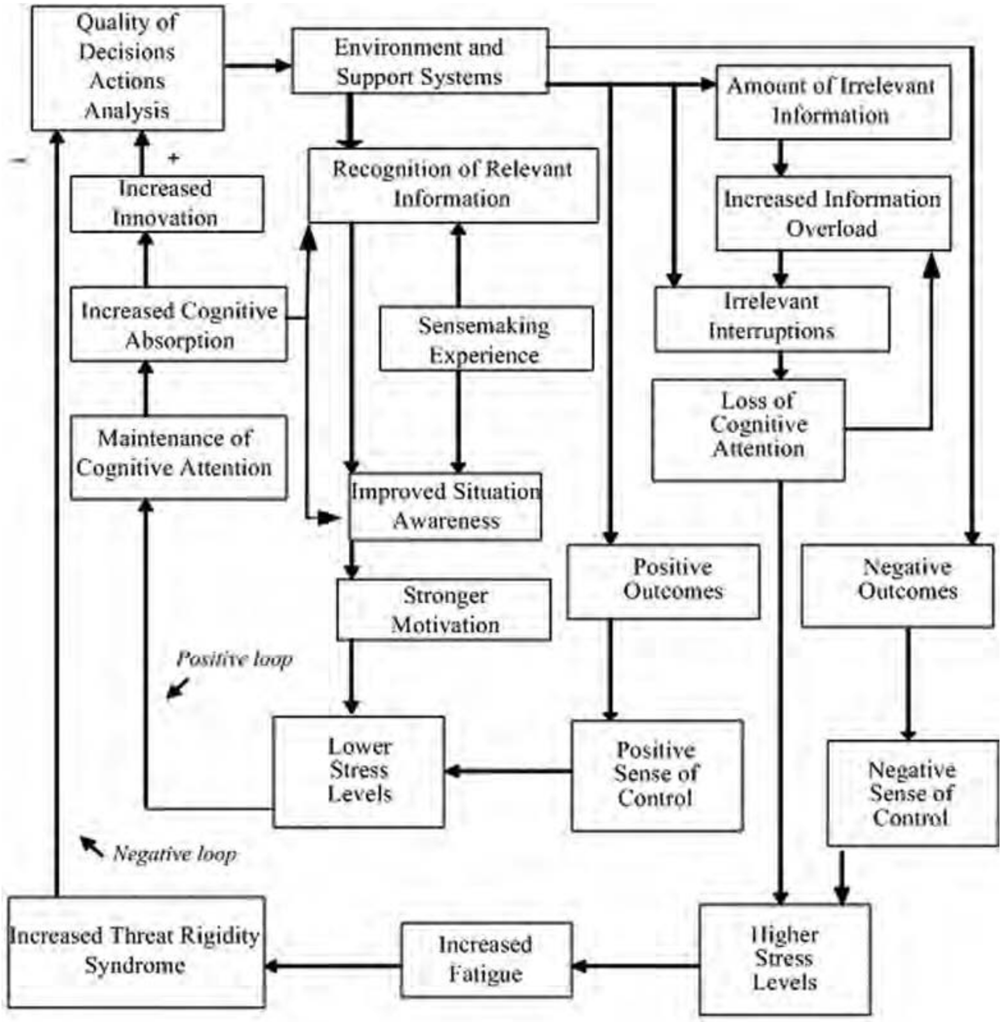
Most real-world studies in information systems are case studies that are done after the fact. This results in various analysis models that are correlative in nature and therefore static. Even though the real-world system is dynamic, the models resulting from most statistical after-the-fact models are static. What is important in our model (Figure 4.1) is that we have taken the various factors derived in prior, after-the-fact, studies of threat rigidity and gaming and expressed a dynamic feedback model with a positive and negative feedback loop that impacts the quality of the decision process. The input into the Decisions Action Analysis box in the upper left corner (from the Threat Rigidity Syndrome box) is an outer negative loop that will tend to produce lower quality decisions, and the second input loop to the right of that (from the Innovation box) will influence higher quality decisions to be made.

The primary external factors are the environment and the relevant experience of the individual. Experience influences individuals' ability to appropriately judge information as relevant and their ability to reach a realistic understanding of the given situation. The amount of stress felt is a critical factor determining the transition at any time between a state of threat rigidity and a state of cognitively absorbed decision making, carrying out actions, and/or doing analysis. The amount of fatigue one feels will moderate the amount of stress felt. A certain amount of stress is beneficial and necessary for a person to enter a state of attention and ultimately to achieve cognitive absorption for intense levels of performance. However, stress at a high level, especially when coupled with lack of sleep and a sense of lack of control, can lead to potentially poor performance of relying on memorized rules to carry out decision making and analysis.

It has been proposed that the relationship between stress and performance is an inverted U-shaped curve, although results of empirical studies to test that have been inconsistent (Kavanagh, 2005). McGrath (1976) posits that the reason for this inconsistency is that the impact of stress on performance is mediated by both task difficulty and the level of arousal (reaction to stress). He found that if arousal and task difficulty are increasing together as stress increases, then the graph of stress against performance is curvilinear in an inverted U-shaped curve (ibid.). Arousal, McGrath found, has a positive monotonic relationship with performance while task difficulty is negatively associated with performance. At low levels of stress, arousal is low and thus performance is low. At high levels of stress, arousal is high but the performance is low nonetheless if the task difficulty is high because of the opposite effects of arousal and task difficulty on performance. That is, it is the task difficulty effects that diminish the performance (ibid.). In an emergency, which is a complex problem, arousal and task difficulty are both likely to be high. Therefore, in such situations, performance under stress will be an inverted U-shaped curve.

Low levels of stress will not affect performance; moderate amounts of stress will drive blood to the brain and increase adrenaline thus improving performance, while high levels of stress will

Figure 4.1 **Dynamic Process Diagram for the Individual Threat Rigidity Syndrome as a Cognitive Process**



have deleterious effects on performance as described in this chapter. The optimal level of stress varies as an individual factor, as it depends on such individual characteristics as experience and knowledge. A critical factor in determining whether the stress level is optimal for an individual is whether or not the person feels able to cope with the situation and have a real impact on preventing negative outcomes. When an individual feels competent and has feelings of control, the U-shaped curve “shifts right” and his or her optimal level of stress is higher than in the case where a person feels unable to manage and as if his or her actions will not be effective. Therefore, it is important to promote feelings that help a person to respond well to stress. While there will always be individual differences in how much stress a person can manage effectively, an organization can create an environment (e.g., HRO) that maximizes an individual’s ability to respond effectively under stress. For example, by having a philosophy of listening to the voices of the experts, a leader/organization will encourage feelings in an individual that his or her actions are important no matter what role they have in the process because they will expect that they will be called upon when their expertise is needed.

In emergency situations, interruptions are also an important factor because they are so common and they can divert one's attention and dilute focused immersion. Often, superiors do not hesitate to interrupt those engaged in the command and control process when they feel a need for information. This creates a need for designing the supporting information system in a way that helps people handle interruptions. Unfortunately, for most existing systems, the proper interface and data organization for the policy and leadership level are not carefully considered in the design. The observation is that discontinuity is the rule, continuity the exception, while unfortunately for most existing systems, the proper interface and data organization for the policy and leadership level are not carefully considered in the design. However, as will be seen in the following sections, some systems have considered these issues, and from them lessons can be learned that can improve design of systems to help manage this issue. Managing interruptions and easing communication can also benefit from having trained observers who act as intermediaries to "translate" what is going on, easing and clarifying communication of what is needed to interact with the public and what is needed in communication to leadership from other involved organizations.

At the individual level, the process of managing a threat under stress can cause a catastrophic degradation of performance and force the individual to respond rigidly, relying on following rules rather than concentrating on problem solving and seeking innovative solutions. This may work for a person with lower levels of experience when the situation is very similar to what was involved in his or her training. However, when the situation has new and different characteristics and problems to be solved, this can create disastrous effects. Mitigating threat rigidity requires a multipronged approach. As has been discussed, organizational culture that promotes flexibility in response is important (e.g., HROs). It is also important to have in place the technology to support the philosophy of response best suited for flexibility and creativity. In the next sections we discuss these system needs and how looking to the past at innovative systems is instructive for building the systems of the future.

LESSONS FROM THE PAST: EMISARI AND EIES

It is important that when a computer-mediated communication (CMC) system is designed, it take advantage of the capabilities of the technology rather than just automating collaboration as it takes place face to face (Hiltz and Turoff, 1985). Visionaries of the past have created systems with functionality and design paradigms that are instructive for reducing the maladaptive effects of threat rigidity in emergency planning and response. One such system was EMISARI. EMISARI was developed in 1971 for the Office of Emergency Preparedness to support decision making during national emergencies (Turoff, 1991). Its first use was to support decision making during the wage-price freeze of the 1970s, and it continued to be used for about twenty additional national emergencies during its active life. The functionality of the system was prescient for the needs of today, and some of the features have still not been implemented commonly in today's systems. However, its messaging, conferencing, and data reporting, unheard of at the time, are now commonly available in collaborative systems. As a decision support tool it supported collaborative efforts in time-critical emergencies in which experts needed to collaborate to respond to and resolve national emergencies. An important attribute of the system was the designation of "roles." Roles were not just for permissions but also used to make sure that the appropriate people had access to the information that they needed. Roles and responsibilities could be dynamically modified as the situation changed and demanded. In a crisis, team membership may not be static. As a situation progressed, roles could be assigned that reflected the dynamically changing composition of the team. Lessons can be learned from EMISARI. Some of the functionality it had that can mitigate maladaptive threat rigidity responses are:

- "People could address messages to the "data," so anyone trying to interpret the data, explain why it was particular, or act on it could associate a discussion (set of footnotes) with the data" (Turoff, 1991, p. 87).

This functionality can reduce simplification because a variety of messages that fully expose the complexity of the information can be attached to data. It can also reduce information overload because it organizes the data in "chunks" of information that are relevant to the situation. Information overload is avoided by using hypertext to link the messages to the data. Messages can be shorter as well by using hypertext. That is, the user can "dig down" into the data to retrieve related messages and, for a given message, use a hypertext link to gain more information.

- "One type of data table was a time series that calculated a regression extrapolation each time a new entry was made, and flagged values outside of expected predictions" (ibid.).

This functionality increases vigilance for contradiction as it brings such contradiction to the attention of the users.

- "Group notebooks (bulletin boards) had separate roles for those maintaining entries and those able to only read. Tracking of key words searched in the entities determined what people were looking for but could not find. This was used as an indirect communication channel to the group that made decisions about new types of information that should be added to the system" (ibid.).

By alerting decision makers to the information sought by the users, deference to expertise is supported. That is, the information needs of the expert users can be more easily attended to. In addition, this helps mitigate the propensity for restriction of information by flagging information needs. A commitment to full information and responding to the needs of the expert users needs to be made by the decision makers, however, in order to fully maximize the benefits of this functionality.

Another system from the past that incorporated design principles relevant to overcoming threat rigidity was EIES (pronounced "eyes") and its various specialized versions and subsystems. It was designed in 1975 at the New Jersey Institute of Technology for collaborative work and to advance the state-of-the art of computer conferencing systems. An important function provided by EIES was voting. Voting on issues was a feature of the subsystem called TOURS. Voting can be used as a mechanism of ensuring that expert opinion is heard, that is, a means of deferring to expertise. A more recent proposal is for a dynamic voting schema (White et al., 2007, 2008) that would allow for dynamic voting to reach consensus in a modified Dephi procedure. Delphi is a voting procedure that enables a group of experts to reach consensus. In a traditional Delphi, there are rounds of voting and ranking of items in which all of the participant experts are engaged. The interesting idea of a dynamic Delphi is that experts can vote on any issue at any time, change their vote as the situation changes, and need not participate in voting on issues in which they do not feel comfortable (i.e., do not have expertise). This concept extends the idea of voting and Delphi to allow for maximizing deference to expertise in a critical situation.

Other features of EIES that were found to promote full access to relevant information without information overload were “notification” and user-defined delivery schemas (Hiltz and Turoff, 1985). EIES users could set options that controlled how and when messages were received: automatically, on request, items for certain conferences, or items based on keywords. Having the user control the delivery of information allowed for customization according to a particular user’s cognitive style and therefore would reduce cognitive overload. Additionally, when a message was modified, all receivers who had read the initial message were notified of the change and could therefore be kept up to date on changing status and information.

Additionally, a CMC used in crisis management should allow for users to organize information and set priorities (Hiltz and Turoff, 1985). If the users do not have that control, needed information can be filtered. Think of the spam filtering provided on many e-mail systems. No matter how effective it may be, there are times that needed e-mails are placed into the spam folder. In a crisis situation the analogous misplacement of needed information can be costly in terms of the effectiveness of the user. Equally important is the recognition that individual users have different preferences for information organization and handling. What works well for one person may not work for another. Information overload can be reduced and effectiveness increased by providing user-defined tailoring of both the interface and the information organization functionalities. Opposite to information overload but potentially equally disastrous is what Hiltz and Turoff (1985) call “information entropy.” That is where important information is not recognized by the user because of information overload or poor organization of the data. Vigilance for contradiction and free flow of information is hindered by information entropy. As noted above, flagging “outliers” is one technique to avoid information entropy. Additionally, allowing users to organize information in a way best suited to themselves and to gain experience with a system by using it before a crisis occurs are both ways to combat information entropy.

SUPPORTING FLEXIBLE RESPONSE: A PROPOSED EMERGENCY RESPONSE MANAGEMENT SYSTEM

Modern management information systems can support efforts to ameliorate maladaptive threat rigidity effects. Insight into how a system can help avoid rigidity in response can be found in Turoff and associates’ (2004) description of a dynamic emergency response management information system (DERMIS). The proposed DERMIS would be dynamic, robust, and flexible. The guiding principles and requirements for the design of DERMIS, as proposed by the authors, can be examined in light of the threat rigidity thesis. General principles that drive the design of DERMIS, as discussed below with some examples, can mitigate the rigid effects of being under threat in an emergency. They are also good principles for any system that will be used to support decision making in a time of threat; the challenge is to incorporate them into system and organizational process design. The following principles are described in the Turoff and associates’ paper and summarized with examples here:

- *For an emergency response system to be useful in an emergency, it needs to be used on a regular basis* (Turoff et al. 2004, p. 10).
    1. By using any system on a regular basis, when a crisis occurs, using the system will be a familiar activity.
    2. Surprise training exercises as a part of regular use allows for learning how to respond flexibly. Users will be able to make “improvements to the system as part of the exercises, they are going to be more likely to avoid the rigidity of response resulting for the threat and its contributing stress factors” (Turoff et al., 2004).

3. The usual response under threat may be to follow procedure, but the training exercises will allow for learning to respond flexibly and creatively.

- *Emergency responders work long hours and don't have time to deal with irrelevant things during a real crisis* (Turoff et al., 2004, p. 11).
  1. Attention is narrowed according to the threat rigidity thesis, and communication overload occurs. A well-designed system must allow filtering based upon the particular needs of each user to help mitigate these effects.
  2. However, at the same time, the system must permit the user to have access to all the relevant information so as to make good decisions.

- *Free Exchange of Information . . . to be able to freely exchange information, delegate authority, and conduct oversight, without the side effect of information overload* (Turoff et al., 2004, p. 13).
  1. Support for communication is vital. Incorporating support for communication can help avoid the restriction of information that the threat rigidity thesis predicts will result from information overload, which then results in rigid responses as control centralizes.
  2. Turoff and colleagues note that during the events of 9/11 there was a loss of communication and many responders acted strictly in accordance with protocol, resulting in loss of life that might have been avoided (Turoff et al., 2004). While not following protocol is no guarantee that errors can be mitigated, during and after 9/11 there were really only two choices—continue or retreat. The major issue was the lack of communications. Without communications it might be best for the individuals or small teams to know they are free to make a decision in an emergency situation. It is important that before the emergency the responders understand they have this freedom in a situation like that of 9/11. This is similar to the way military platoons operate. However, it should be noted that events such as the loss of support systems, for example, communications, are not often part of the training process. There were also times of too much communication that was unregulated. Repeated messages resulted in unnecessary duplication of efforts. Thus, communication, like the porridge Goldilocks ate, needs to be "just right." A system such as the proposed DERMIS can help realize this goal.

- *The crux of the coordination problem for large crisis response groups is that the exact actions and responsibilities of the individuals cannot be pre-determined* (Turoff et al., 2004, p. 15).
  1. The system should allow for dynamic assignment of existing roles and the self-choice of involvement by other individuals who recognize that they can contribute, as problems occur.

Generalizing the above principles to systems to support decision making under other threats and for other types of users will result in systems that reduce the stressors and other factors that result in maladaptive rigid responses.

The DERMIS design itself is cognizant of the human limitations that create a propensity to rigid response. For example:

- The DERMIS design uses a familiar metaphor for information organization, dissemination, and recording. It uses event logs, a format familiar to the responders, which will thus mitigate the psychological stress effects that limit the ability to "identify and discriminate among visual stimuli" (Staw et al., 1981, pp. 503–504).

- The checklist, another familiar metaphor, is also incorporated into the design of DERMIS.
- Automatic notifications to users concerning relevant information or situations they are tracking help to avoid information overload, as does the capability for users to organize the notifications as they wish.
- The lesson for all system design is to use familiar metaphors and incorporate the ability for users to personalize the presentation in a manner best suited to their cognitive style.
- Use of links is critical to the design of DERMIS. For example "a single item of data must have associated with it all the links that express its relationship with other data" (Turoff et al., 2004, p. 32).
    1. This means that updating or creating data will result in the automatic updating of all related links.
    2. This avoids the restriction of information that can be brought about by the simplification that the threat rigidity thesis predicts.

- The system would support a "flat" communication process (ibid.).
    1. This helps avoid the restriction of information and centralization of control that prevents all opinions and ideas from being heard, and results in response rigidity.
    2. Dynamic forming of teams.
        a. DERMIS would support dynamic forming of teams based upon the roles needed for the situation.
        b. Threats that cause radical changes in the environment cannot be fully planned for. Supporting open communication will be more effective when the communication is from those best suited for the particular situation at hand. This may well vary depending upon the characteristics of the threat.

Thus, DERMIS as proposed by Turoff and colleagues (2004) is an example of how a system can be designed in a way that is cognizant of the factors that lead to rigidity in response under threat and is designed to mitigate those effects. One can see how it also supports the guiding principles of CRM and HROs. We conclude this discussion of DERMIS with a musing by a reader of an early version of this chapter (Rice, 2007) who, with levity, wondered, " . . . would an external crisis management system be an EPI-DERMIS?"

CONCLUSION

Thus, we have outlined some theoretical foundations that can guide efforts to mitigate the effects of threat rigidity (e.g., cognitive absorption, mindfulness) and proposed a model of the cognitive processes by which individuals respond to threat rigidly or flexibly. We have reviewed the theory and empirical results from a number of different areas and shown how they fit together to explain some of the observed properties of the threat rigidity thesis. We have proposed a model from that synthesis of the cognitive processes of an individual experiencing threat and discussed system-design elements that take into consideration the impediments to flexible, adaptive response. If anything is certain, it is that we are, and will continue to be, facing both increased frequency and intensity of natural disasters and that there is a finite probability that some will be extreme, such as Katrina or a pandemic. Terrorist attacks that defeat the safeguards being set in place are also likely to be more widespread and crippling than has been the case in the past. Command and control of all phases before, during, and after such events can no longer be adequately served by localized centers in isolation. If we are to respond adequately, we need large-scale networks of collaborative nodes that cut across different organizations of all types and dynamically cooperate. Organizations involved will include government, utilities, and even volunteers. Such networks can have thousands of people involved in all of the many aspects, with fundamental decision making delegated to those closest to the action. At the same time, those concerned with resources available throughout the disaster or emergency area must have adequate information to do oversight so that "good" allocations can be made of needed and available resources.

Attempting to face the challenges of modern emergencies and disasters with the assumption that the emergency team will not be created until such disasters occur is foolish and doomed to failure. Even though no one can ever perfectly predict a disaster or who will be involved on the team spanning on-site responders and the supporting command and control operation, it is still possible to identify who should be a major part of the operation. The thousands to be involved must be a part of the group that plans and trains together in at least the virtual environment in which they collaborate when an actual disaster occurs. They must act as a virtual organization that cuts across many real organizations, and they must be in constant contact. Professional groups today that come together across many different organizations to improve their professional collaboration and create new insights on the Web are usually called "communities of practice." These are the people who often cut across classical disciplines dealing with the scientific, engineering, and management professions because the problems they need to solve require very heterogeneous, large groups of experts. The point is, a single group will not have all the experience and expertise needed to handle a major new and unforeseen crisis. So there is a strong need to share experiences and case studies of what worked and what did not in prior situations. Plans must include a process for building and utilizing a true knowledge base that can be applied to future events.

The first and foremost observation is that the technology exists to allow groups to develop plans and conduct training online in an asynchronous manner using modern discussion systems and tailored systems for specific tasks. These tasks may include developing and improving threat scenarios, response scenarios, and plans, and even evaluating games for the conflict between offensive threats and defense responses (Turoff et al., 2006; White et al., 2007; Yao and Turoff, 2007). This means that a large-scale team of many hundreds working both on the large team and in subgroups can devote two to four hours a week to becoming part of the total team and getting to know and trust one another as a team. Building trust ahead of time can promote communication during a crisis insofar as during an emergency, people, including responders, will reach out to contact those in their "primary social group" (Katz and Rice, 2002). Most disaster teams are only created when the disaster occurs, and this is a major contributor to problems and the possibility of reduced effectiveness and a lack of innovativeness. Teams that build trust, have experience innovating together, and have experience working with the technology they will use in a crisis will be better able to respond when a crisis arises.

This larger group should be the one that works continuously, in a part-time manner, on developing and improving plans. In terms of getting around the organizational barriers to do this across organizations, it might have to be something created to operate as a pubic system, open to pubic participation in a 911.gov-type local community and government system (Shneiderman and Preece, 2007). Members of the public are often the ones on the scene to respond in the event of an emergency. During the events of 9/11, despite the loss of many communication channels, the public found ways to communicate with others about their current situation (Katz and Rice, 2002). They were creative in developing ad hoc solutions to get around the failure of traditional communication channels (ibid.). Including the public in emergency preparedness and response can ameliorate some of the obstacles to effective and flexible response. One approach suggested in the literature is to develop a universal emergency scale that will be understood by all, whether or not the emergency is familiar (Plotnick et al., 2007). Another option is the use of a dynamic wiki that can be used on a regular basis and also during a crisis to facilitate creating a community of practice that spans organizational boundaries (White et al., 2008). This wiki is proposed to have dynamic voting capabilities to allow for distributed experts to reach consensus when decisions are of a time critical nature.

Other objectives that are made possible once teams are created and allowed to collaborate on a continuous basis are:

- Adopt HRO-type attitudes for the members of emergency collaborative groups as described above:
    - Preoccupation with failure
    - Reluctance to simplify interpretations
    - Sensitivity to operations
    - Commitment to resilience
    - Deference to expertise
- Design support systems that encourage open exchange of information and ability of members to find and get involved in any problem to which they can contribute (Turoff et al., 2004).
- Train people to be creative or innovate through the use of group problem-solving exercises designed for that purpose.
- Train people to be onsite observers in disaster areas as their primary activity to free others from doing this part-time and provide better situation awareness to those in the command and control and resource allocation processes (ibid.).
- Work by leaders to develop open communication and trust. Communication is pivotal to the development of trust, and in particular to the development of swift trust (e.g., Iacono and Weisband, 1997). Swift trust is a form of initial trust often needed in virtual teams where history and face-to-face cues are not available for the development of the trust often seen in traditional teams. Swift trust is based not on experience with the trustee (i.e., not based upon actual evidence) but with the trustee’s role or categories (e.g., stereotypes), or on the presumption that someone who is respected has already vetted the trustee and found him or her to be trustworthy (Meyerson et al., 1996). In a crisis response team, this trust can be built upon the presumption of expertise of the trustee. However, in order for it to develop and grow into long-term trust, effective communication must be ongoing and the abilities of the distributed members must be visible.
- Work by leaders in oversight positions to develop a team identity for all team members. Experts have often developed strong affiliations with their organizations (subgroups), and when organizations attempt to work together as a team, if a team identity is not developed, in-group/out-group bias (Huang and Ocker, 2006) can exacerbate competition and prevent trust from developing amongst all the team members. Team-building exercises before the advent of a crisis can help.
- Ability to meet the challenge of detecting when individuals are being driven to lower quality performance in decision analysis (Figure 4.1), which is important for deciding when to relieve people of their roles if and when replacements are available.

The only thing certain about the future is that the future is uncertain. Lessons learned from the past and from organizations that have philosophies that can mitigate maladaptive responses to unforeseen crisis must be heeded, and they must be heeded before the crisis occurs.

APPENDIX 4.1

SUMMARY OF STUDIES OF THREAT RIGIDITY

Article reporting study	Situation studied	Explicit variables and/or hypotheses	Results	Weaknesses and/or implications
Griffin, Tesluk, and Jacobs (1995) “Bargaining Cycles and Work-Related Attitudes: Evidence for the Threat-Rigidity Effects”	Teacher attitudes during the year of a contract negotiation were examined. The threat was the negotiation; rigidity of response was operationalized as homogeneity of attitude.	*Independent variable:* Year during the contract negotiation cycle *Dependent variables:* Teacher attitudes toward pay, benefits, and school administration; general satisfaction with teaching	• Attitudes were more homogeneous during the negotiation year than before or after (conclusion of support for threat rigidity thesis). • Satisfaction not significantly different during the different years of the bargaining cycle.	• Intervening variables of the threat rigidity model were not examined or measured. • Effectiveness of unions not differentiated. • Operationalization of threat as negotiation year specious—not all contracts negotiated have critical issues.
D’Aunno and Sutton (1992) “The Responses of Drug Abuse Treatment Organizations to Financial Adversity: A Partial Test of the Threat Rigidity Thesis”	A test of the entire threat rigidity model in the situation of drug abuse treatment organizations responding to changes in funding amounts and sources.	*Independent variables:* Changes in funding amounts; changes in number of funding sources *Dependent variables:* Participative decision making; workforce reductions; competition	• When funding was decreased, rigid use of existing procedures, workforce reductions, and more competition were observed. • No relationship between funding decreases and participation in decisions. • Funding source reductions resulted in less participation, more workforce reductions and more competition. • Threat rigidity thesis was “modestly” supported.	• Although the intervening variables of the threat rigidity thesis were considered, they were not directly measured. • All the organizations were small and from one domain.

Griffith (2004) “Ineffective Schools as Organizational Reactions to Stress”	A study of schools under stress as defined by size of student population, type of population (e.g., race and ethnicity), economic level of students; uses open systems theory as foundation for defining stress as a threat; surveys of teachers, parents, principals, and students.	*Independent variable:* Stress on schools *Dependent variables:* H_1: School boundary permeability H_2: Emphasis on control and regulation of internal processes H_3: Internal dissention	H_1: When schools were under stress, parents were less involved (support of threat rigidity). Other measures were not shown to be related to school stress. H_2: Not supported. Schools experiencing stress did not emphasize control and regulation of processes more; for example, principals were still involved in community. H_3: Consistent with threat rigidity thesis, both less consensus and more probability of changes in principal were shown.	• Length of time the schools were under stress was not controlled. • Study assumes equivalence of open systems theory and threat rigidity thesis—needs to be validated.
Meszaros (1999) “Preventative Choices: Organizations’ Heuristics, Decision Processes and Catastrophic Risk”	A case study of six chemical plants under the threat (not imminent) of possible failure that could result in death and/or injury.	*Independent variable:* Possible threat of plant failure *Dependent variables:* Steps in the decision making process	• The thesis was not directly tested, but the analysis of the decision-making process taken has relevance to it. The companies did a thorough and careful analysis of the problem, including many opinions, but exhibited rigidity in actual decision making by deferring to a higher authority, even when the decision was contrary to the results of the analysis.	• The results indicate a gap in research—threat may vary in degree for different steps in decision making (thus rigidity of response may vary). These differences may account for some of the contradictions in reported study results.
Gladstein and Reilly (1985) “Group Decision Making Under Stress: The Tycoon Game”	A business simulation game was used to test the effects of an external threat on the intervening variables of the threat rigidity thesis.	*Independent variables:* Degree of threat perceived (measured by potential financial impact); time pressure *Dependent variables:* Amount of group discussion; channel usage variability; amount of information used; decision influence; decision centrality; stress level	• Partial support for the threat rigidity thesis. • Increases in threat were observed to increase restriction of information processing. • Not supported was the hypothesis that higher threat would cause more constriction of control.	• Subjects were students used to working in groups and the task required division of labor. • Implication is that the thesis may not hold under all situations.

Harrington, Lemak, and Kendall (2002) “The Threat-Rigidity Thesis in Newly Formed Teams: An Empirical Test and Theoretical Extension”	The design of a study to test the thesis as it applies to newly formed teams is reported.	Not fully reported: *Independent variables:* Internal/external threat; likelihood of success *Dependent variable:* Rigidity of response	• Results not fully reported. However, the authors indicate that newly formed teams place greater importance on internal threats.	• Newly formed teams do not have a history of habituated response. Further investigation into the effects of threat on them is warranted.
Anderson, Allred, and Sloan (2003) “Effect of Hospital Conversion on Organizational Decision Making and Service Coordination”	Process changes in hospitals that had converted to for-profit status (FP) from having been not-for-profit (NP) were analyzed to ascertain whether the observed changes would be predicted by the threat rigidity thesis, complexity theory, or neither.	*Independent variable:* Conversion from NP to FP *Dependent variables:* Participation in decision making (PDM) by MDs and RNs; service coordination; influence of MDs and RNs over the final decision	• Overall, complexity theory was supported and the threat rigidity thesis was not.	• No data from the converted hospitals from before conversions. • Conversions took place three to six years before the study was undertaken—the more serious limitation—it was unknown if there were rigid responses at the time of conversion. • Implication—need to investigate whether threat rigidity responses are temporary, and if they are, whether or not (and how) the duration of rigidity can be predicted.
Ketchen and Palmer (1999) “Strategic Responses to Poor Organizational Performance: A Test of Competing Perspectives”	Ninety hospitals in one region were examined to assess whether they were poor performers. Performance was measured by hospital bed occupancy. Threat rigidity thesis would predict poor performers would have habituated responses; behavioral theory of the firm would predict poor performers would undergo more change.	*Independent variable:* Organizational performance *Dependent variables:* Addition or deletion of high technologies; changes in domain by adding or deleting services	• Overall, the behavioral theory of the firm was supported and there was no support for the threat rigidity thesis.	• Hospitals were not evaluated before their performance degraded and became poor. The study did not consider the information processing or locus of control, which are the antecedents to the rigidity of response in the threat rigidity thesis. The hospitals were not examined immediately during or after being under the threat.

Kennedy (1998) “The Role of Identity and Familiarity in Risky Decisions”	A new theory is proposed that would both reconcile and explain the different outcomes predicted by the threat rigidity thesis, prospect theory, and self-protection theory at the level of the individual; a study design in which students will engage in a gambling exercise is presented that would test the new theory.	The new theory proposes that the behavioral outcomes of being under threat will depend on the impact a decision will have on the individual’s preferred identity. *Independent variables:* Identity; familiarity of task *Dependent variable:* Riskiness of behavior	• A study is proposed but, at the time of the article, not yet completed.	• I do not believe the author has accurately stated what the theories under consideration would predict in all cases. • Important theoretical considerations are ignored in the formulation of the new theory and hypotheses (e.g., how similar an “unfamiliar” situation is to a familiar one may impact the reactions).
Audia and Greve (2002) “Performance, Firm Size, and Factory Expansion in the Shipbuilding Industry”	A new theory is proposed that would take into account, reconcile, and incorporate the threat rigidity thesis and prospect theory to predict outcomes of being under threat. An interaction variable of size of the firm is introduced, which is predicted to influence the response to the threat of poor performance. The new theory also extends prospect theory to include March and Shapira’s shifting-focus model of risk taking.[a] Eight Japanese shipbuilders were analyzed.	*Independent variables:* Financial performance as compared to aspiration level measured by ROE, ROA, ROS, and sales *Interaction variable:* Size of the firm *Dependent variables:* Factory expansion (operationalization of risk)	• Without considering firm size, the threat rigidity thesis was supported. • For each measurement of performance (ROE, RO, ROS, sales), when performance was below aspiration levels, small firms exhibited rigidity (reduction in expansion) but large firms were unaffected. • Therefore, overall the threat rigidity thesis was supported and the new theory was only partially supported.	• The addition of consideration of firm size may be important to explain seeming contradictions in theories that predict decision makers’ responses under financial threat. • The study did not examine the threat rigidity model’s intervening variables.

Barnett and Pratt (2000) "From Threat-Rigidity to Flexibility. Toward a Learning Model of Autogenic Crisis in Organizations"	The threat rigidity thesis is examined under a different sort of threat—one that is intentionally created by management in an effort to respond with innovation to a possible, albeit not imminent, threat and a new model, "the threat flexibility model," is proposed. The researchers predicted that under latent threat, authority will decentralize and communication will increase, resulting in a more flexible organization.	The new model: *Independent variable:* Threat *Intervening variables:* Generation of knowledge; expansion of control *Dependent variable:* Response flexibility	• The model was not tested. No results.	• The definition of threat as used in the threat rigidity thesis is not adhered to. • At times the authors refer to their model as complementary to threat rigidity thesis, at other times as contradictory or an update. It may be none of the above. There was no existing threat (the companies were at the height of success), and the responses were controlled organizational changes.

[a] March, J.G., Shapira, K. 1992. "Variable Risk Preferences and the Focus of Attention." *Psychological Review*, 9, 172–183 as cited in Audia and Greve, 2002.

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CHAPTER 5

DO EXPERT TEAMS IN RAPID CRISIS RESPONSE USE THEIR TOOLS EFFICIENTLY?

JIRI TRNKA, THOMAS KEMPER, AND STEFAN SCHNEIDERBAUER

Abstract: *The operational use of earth observation technologies by expert teams in the crisis response domain is a critical sociotechnical process. The unique context and characteristics of every crisis have an impact on the extent to which these technologies, such as computer-based tools for object identification, feature recognition, and change detection, will be used, and how the actual work and the interactions of expert teams deploying the technologies will emerge. Beyond the mere technical characteristics of functioning and operating the earth observation technologies, crucial prerequisites for their successful application in a crisis situation are predominantly set by "soft" factors such as management, process control, and clear and accurate communication. The knowledge of these factors is essential in order to build and train expert teams capable of using these technologies and performing effectively under a wide variety of situations and conditions. This chapter reviews experience and lessons learned from a simulation of operational deployment of earth observation technologies by expert teams in rapid crisis response. The exploitation of these technologies by expert teams while responding to a nuclear emergency scenario is studied. On the basis of the scenario-based exercise methodology, a real-time simulation was prepared and executed. In this simulation, three teams composed of experts were given the task of providing rapid mapping products within thirty-three hours. During this period the teams had access to satellite imagery as well as off-the-shelf and custom computer-based tools. This chapter identifies opportunities and constraints regarding the practical application of earth observation technologies by expert teams in rapid crisis response. The chapter also suggests areas for further research.*

Keywords: *Crisis Response, Expert Team, Simulation, Earth Observation Technologies*

Information and communication technologies (ICT) are and will continue to be among the essential elements of crisis management, facilitating more effective, flexible, and sophisticated response (Comfort, 1993; Comfort et al., 2001; Medonça et al., 2001; Wybo and Lonka, 2002). Advanced geospatial technologies, such as space-based sensors, unmanned aerial vehicles, high volume data processing tools, and integrated geospatial databases are examples of ICT providing possibilities of obtaining a fast and reliable situation assessment when crises occur. This chapter focuses attention on a specific group of advanced geospatial technologies, so-called earth observation technologies (EOT), which are specifically designed for collection, management, fusion, and visualization of satellite imagery.

Thanks to their strategic and multipurpose nature, EOT can support a comprehensive approach to global issues, providing data on places on the globe that are too dangerous or too remote to monitor by any other means (Voigt et al., 2007). The advantages of satellite imagery and its analysis have been emphasized by many authors. This includes, for example, damage assessment (Eguchi et al., 2005; Pesaresi et al., 2007), humanitarian aid planning (Giada et al., 2003), and crisis response coordination (Voigt et al., 2005). EOT has been used, for example, in rapid mapping of floods in Romania in 2006 and in Mozambique in 2007, earthquakes in Iran in 2003 and in Pakistan in 2005, forest fires in Indonesia in 2006 and in Spain and Greece in 2007, as well as base and crisis mapping in Sudan in 2004 and 2007. However, even if the potential of EOT is well recognized, today's operational deployments of EOT are still carried out on a rather ad hoc basis from operation to operation, where the majority of the data analyses are performed manually by skilled operators (Voigt et al., 2009). Consequently, there are only a few scientific publications containing documented knowledge and experience of the operational deployment of these technologies.

A question is thus, how and to what extent current EOT can be put into operational use in crisis response in order to benefit from the possibilities they provide, and at the same time, to meet the known demands of crisis management with respect to contingency, adaptive capacity, and uncertainty. Authors working in various fields, such as computer-supported cooperative work (Schmidt and Bannon, 1992), distributed cognition (Hutchins, 1995), and cognitive systems engineering (Hollnagel and Woods, 2005), all emphasize the importance of scrutinizing the usefulness of new systems when applied in practice, rather than drawing conclusions from a theoretical understanding of the potential benefits of new technologies. This is particularly important in the case of crisis response applications.

EOT such as computer-based tools for object identification, feature recognition, change detection, and data fusion require advanced skills and a knowledge of methods and techniques related to these tools. In other words, experts in disciplines such as computer science, geography, and statistics are required to operate the technology and carry out data management and analysis. Beyond the mere technical characteristics of functioning and operating these technologies, crucial prerequisites for their successful application in crisis situations are predominantly set by "soft" factors such as management, process control, and clear and accurate communication. The knowledge of these factors is essential in order to build and train expert teams capable of using EOT and able to perform effectively under a wide variety of situations and conditions.

The research focus of this chapter is thus on gaining knowledge of operational deployment of EOT by expert teams in rapid crisis response. Attention is given to expert teams providing 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 EOT in a simulated crisis response scenario.

THEORETICAL FRAMEWORK

The idea of supporting decision makers with explicit expertise, including analysis of satellite imagery over distance, is not new. For example, in the area of the military, this remote expert support has been implemented as a part of the "reachback" concept (Neal, 2000; Mackenzie et al., 2007), where such expert teams are sometimes recognized as "digitally enabled units" or "digital squads" (Custer, 2003). However, it is a dangerous fallacy to believe that advantageous effects of new technologies in one context (e.g., warfare) are directly transferable to another context (e.g., crisis response) (Coletta, 2003). The characteristics of crisis response, such as complexity, uncertainty, spatial and temporal characteristics, and number of stakeholders, do not allow generalization of research and experience gained from ICT applications in other fields and “normal life” situations (Wybo and Lonka, 2002).

It is thus essential that expert teams using EOT are studied in an appropriate context. In this sense, context represents crisis–response–related circumstances, facts and conditions, which influence the actions and behavior of teams responding to crisis situations (Hollnagel and Woods, 2005). The complexity and dynamics of crises create specific challenges and demands for the coordination of the task-related activities. The complexity and dynamics also have an impact on how the team members carrying out these activities are coordinated (Brehmer and Svenmarck, 1995; Johansson and Hollnagel, 2007; Johansson et al., 2005; Rogalski, 1999). Moreover, the way a team accomplishes its tasks and how tools are used during this process is, among others, determined by the tasks and characteristics of the tools (Hollnagel and Woods, 2005). This means that—in our case—an expert team using EOT is required to have the capacity to coordinate its task-related activities as well as the activities related to the functioning of the team, while taking into account the present circumstances, its current tasks, and the characteristics of the available tools. Each of these—circumstances, tasks, tools, and team capacity—places different constraints on the team, shaping what and how activities are executed. These constraints not only limit the team’s range of possible actions but also provide opportunities for certain actions to take place (Woltjer, 2005). The team’s ability to manage these constraints and their interdependent nature, as well as to organize and coordinate its work within these constraints, determines whether the team is able to complete its tasks, and also the way they do it and with what outcome (Persson, 1997; Woltjer, 2005).

In the following text we identify and discuss some of these constraints, which could have a vital/important impact on whether and how expert teams deploy EOT in crisis response situations.

Teams and Teamwork in Crisis Response

Teamwork is a set of goal-oriented activities in which a number of people are engaged in a collaborative manner (Orasanu and Salas, 1993). If a number of people (team members) are to function as a team that strives toward its goals, these goals need to be shared within the team in order for them to act in a unified way toward the goals, as the team members’ actions are interrelated and interdependent (Artman, 2000; Orasanu and Salas, 1993). How the team’s actions are organized and coordinated underlies the functioning and performance of the team (Jones and Roelofsma, 2000).

Different configurations of teams have an impact on communication and can lead to different outcomes of team work (Artman, 2000). The nature of communication in collocated and distributed teams may differ in a number of ways (Driskell et al., 2003). In distributed teams, some of the team members perform without spatial and temporal proximity to the rest of the team (Artman, 1999). This means that face-to-face interaction with some of the team members has to be replaced by communication mediated through a technical system. Team configuration, as documented by experimental and field study research, has an impact on the type of communication used, and quantity and quality of the exchanged data (Artman, 2000). In other words, team configuration is tightly related to communication and has an essential impact on team interaction, how work is performed, and whether a collaborative task is accomplished successfully or not (Johansson et al., 2007; Johansson and Hollnagel, 2007; Orasanu and Salas, 1993; Stout et al., 1999; Wertsch, 1997).

Specific to crisis response, teams responding to crisis situations are affected by the emergence of crises that force the teams to shift from routine management to more situation-driven and problem-solving–focused operations, as documented in disaster research (Comfort, 1993; Drabek and McEntire, 2003; Quarantelli, 1997; Stallings, 2002). The emergence of crises, characterized by a low degree of predictability, and of time and resource constraints (Perrow, 1984), leads to continuously shifting demands to which the teams must be able to adjust. The teams may need to share resources with others, their freedom of choice may be constrained in terms of what actions they take, and they may no longer be able to communicate in a systematic way (Auf der Heide, 1989; Granot, 1997; Quarantelli, 1997). In order to complete their tasks, they need to prove flexibility and must be able to adapt and improvise (Mendonça et al., 2001, 2003; Mendonça and Wallace, 2004). An absence of improvisation and adaptation signifies in practice the inability of a team to cope with dynamic situations and to adjust to current conditions (Hollnagel, 2006). The ability to demonstrate adaptive behavior and effective coordination, and the degree to which this behavior and coordination works successfully, is thus a fundamental condition for effective teamwork in crisis response (Johansson, 2005; Johansson and Hollnagel, 2007; Persson, 1997).

The dynamics, complexity, and high risk of these situations, together with the related need for adaptability influence the ways that onsite response teams engage in their activities. Experience from research on teams in control of dynamic and high-risk situations, for example, military operations, suggests that similar impacts are observed on teams at a distance from the operational area, collaborating remotely with the onsite teams in this area as with those who are onsite (Custer, 2003). In other words, constraints affecting the onsite response teams may have a similar effect on the remote expert teams. This means that the remote expert teams may need to demonstrate adaptive behavior similar to that of the onsite teams in order to cope with the ongoing situation and the shifting demands of their tasks.

Issues Related to Tools and Tasks

The nature of tasks that an expert team using EOT would face requires various processes of rather complex working steps. A sequence of such a process chain is, for example, (1) selection and tasking of suitable satellites, (2) download and assessment of the collected data, (3) preprocessing of these data (e.g., radiometric and geometric enhancement), (4) thematic analysis (e.g., feature identification, change detection, and classification), (5) fusion (e.g., integration of the analytical results with other data sources), and (6) visualization (e.g., map production and generation of three-dimensional visualizations). This is of course an ideal situation. In reality, some of the steps may be executed in an iterative way as a result of various circumstances, such as bad weather conditions, technical failures, or misunderstandings of task specifications. The processes are thus characterized by high component and coordinative complexity (Zigurs and Buckland, 1998) as they contain a large number of distinct steps, with nonlinear relations and interactions between these steps. Therefore, expert teams using EOT have to operate under some very specific conditions due to the nature of their tasks and the characteristics of the tools they use.

The first condition is the numerous different tools required in these processes. The tools are represented by various sensors and data repositories, as well as computer-based applications for image rectification, feature extraction, and data integration. The physical location of some of these tools is often at a distance from the location of the expert teams. This is the case, for example, for geostationary satellites, their ground stations, data repositories, and so on. This distance creates specific requirements and constraints with respect to the teams' communication. The expert teams must be able to access and share large volumes of data from the physical sites where the data are collected and stored. At the same time they must also distribute and exchange large volumes of data among the team members. This means that the part of the communication concerning data exchange will always be mediated through a technical system.

The second condition is that, in most cases, the process chains are to some extent predefined for technical and/or organizational reasons in order to reduce the complexity of the processes. A technical reason is, for example, the lack of interoperability that hinders the integration of one working result into the next process step. An example of an organizational reason is the specialization of an expert team in a certain type of solution path. In this sense, the choice of one tool may affect (a) the selection of other tools in the process, (b) the way these tools are used, and (c) the degree to which the tools are applicable within the process. The choice of the different tools for the chain of working steps leads to difficulties in reversing the process in a case of mistake or failure. Altering a process chain by swapping from one solution path to another is also difficult and challenging. This risk increases with progress along the process chain.

The shifting demands of a crisis response with respect to the circumstances and the tasks may require that the expert teams provide remote support to be adaptive in a way similar to the onsite teams. To be adaptive requires, among other things, that tasks can be accomplished in more than one way. That is, there are multiple solution paths to the desired outcomes (Hollnagel, 1986; Zigurs and Buckland, 1998). The expert teams are, however, limited in this sense by the constraints represented by their different tools as well as by the constraints in terms of interdependency among these tools (Woltjer, 2005). This situation restrains the teams' possible range of actions when choosing alternative solution paths, and thus reduces their adaptive capacity and flexibility.

Simulations

A traditional approach to dealing with the issue of technology in crisis response is to study historical events and human experience. However, it is extremely difficult for someone to gain insight into the processes involved in an emerging crisis situation, or even retrospectively to find out what happened and what was done (Trnka, 2007). Crisis response operations are thus rarely reviewed, and it is difficult to document and grasp organizational learning (Turoff, 2002). The approach is unlikely to be sufficient concerning design and implementation of new ICT for future crises, because of (1) the missing operational structures with respect to the technology concerned, and (2) the greater complexity of the crises and increasingly sophisticated responses (Rubin, 1998). This raises the question of how to design and evaluate ICT in such a challenging field as crisis response. In many situations, simulations—as a methodological means of studying human systems or their parts (Crookall and Saunders, 1998)—are often the only way for the research and development community and the prospective users to confront and analyze these situations and systems (Brynielsson, 2006).

The field of simulations is broad. The simulations relevant in our context are those that involve humans and are interactive multiperson settings reproducing reality or its parts (Crookall and Saunders, 1998). They replicate situations and processes in which 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 this case they are known as war games and have been used both for training and research purposes (Crichton et al., 2000; Klein and Cooper, 1982; Lewis and Barlow, 2005). For further discussion and a historical review of the different types of simulations and applications in this domain see Boin and colleagues (2004), Kleiboer (1997), and Rubel (2001).

Our interest lies in exploring how expert teams deploy EOT in a crisis response scenario. Simulations suitable for this type of study are called scenario-based real-time situation and procedure simulations. In these simulations, participants—real and prospective decision makers or operators (in our case experts)—act based upon hypothetical conditions (defined via scenario), while using real and simulated resources. The simulations are executed in real time, that is, "moving around the clock" (Rubel, 2001), where participants face tasks conducted in real time, and where the development of the tasks can be described as dynamic (Brehmer, 1987). The simulation participants are performing active role playing as their actions and behavior are both influenced by and dependent on the other simulation participants (Crano and Brewer, 2002). Active role playing by the participants thus represents internal parameters governing the simulations (Gestrelius, 1998), and the simulations may therefore contain both planned and unplanned variations (Crano and Brewer, 2002).

An essential feature of these simulations is the level of control in the simulation. The level of control has significant influence on various simulation features and settings, such as task and content fidelity, simulation complexity, and so on. In the context of this research we therefore distinguish two levels of control—high and low—in simulations.

High-level control simulations often have research questions in the form of hypotheses and are frequently carried out in the form of comparative studies. The data collection focuses mainly on quantitative data (statistics) in order to analyze in depth what interactions took place. These simulations are in many cases faster than normal time, use predefined scenarios, and evaluate simulated/assumed technological capabilities or simpler ICT tools.

Microworld studies are one example of high-level control simulations. Microworlds are small-scale, low-fidelity computer simulations, providing a computer-generated task environment that has complex, dynamic and opaque characteristics (Granlund, 1997, 2002; Svenmarck and Brehmer, 1991). Important characteristics of the real world can be selected and used to create a small and well-controlled simulation that retains these characteristics (Granlund, 2002). Many of the characteristics of microworlds are thus similar to the characteristics of tasks that people normally encounter in "real life" situations, allowing controlled studies of collaborative decision making (Brehmer and Dörner, 1993; Gonzalez et al., 2005; Granlund et al., 2001; Rolo and Diaz-Cabrera, 2001). The simulations are usually rather short, between twenty and thirty minutes per session; at the same time, larger sets of sessions are commonly run. As the simulation is fully computer-based, advanced monitoring tools can be used, and data on a wide range of parameters can be gathered (Granlund et al., 2001). Microworlds have been used, for example, to investigate the effects of computer-mediated communications, geographic information systems (GIS), and other ICT on situational awareness, performance, and communication in command and control teams (Artman and Granlund, 1998; Granlund, 2004; Johansson et al., 2007; Trnka et al., 2005).

Operational games are another example of high-level control simulations. They are intended for complex situations where we need to know "what is going on" (Shubik, 1972) and are designed to be as close to reality as feasible (Thomas, 1984). Operational games are therefore of a more explorative nature and have a much longer duration than microworld simulations. They have been used to assess information support and seeking, as well as to design and evaluate decision support systems (often prototypes) in various crisis situations (Beroggi et al., 2001; Gu and Mendonça, 2005; Kraus et al., 1992; Mendonça et al., 2003).

Compared to high-level control simulations, low-control simulations have the form of case studies. The focus of data collection and analysis is also different. The attention is given primarily to qualitative data and qualitative analysis on how different interactions and processes took place. The low-level control simulations are characterized by a high level of task, content, and environmental fidelity, and the use of progressively unfolding scenarios. The pace of the simulation is the same as normal time. The artifacts studied in these simulations are often real ICT tools or their high-fidelity prototypes.

Simulations based upon military and crisis management exercise methodology are examples of low-level control simulations. These simulations are commonly used as training events but can also be used as methodological tools of evaluation research. Functional exercises, as one example, focus on one or more specific operational activities or functional posts (Peterson and Perry, 1999). They are executed at the same tempo as normal time, involve operational personnel, and can be executed both indoors and in the field. A special type of functional exercises is so-called communications-simulated exercise, focusing on callout, command and control, and communication (Payne, 1999). Communications-simulated exercises are conducted indoors, use progressively unfolding scenarios, involve several functional posts and organizations (combined exercises), and can be designed in both simple and complex ways (ibid.). Full-scale exercises, as another example, engage most or all of the functions that would be involved in a real event (Peterson and Perry, 1999). For this reason, full-scale exercises are always located at least partly outdoors in order to achieve high realism (Perry, 2004). Both the functional and full-scale exercises can have a duration of hours to days.

A number of research simulations have been carried out using exercise methodology. Mackenzie (Mackenzie et al., 2007) used a full-scale exercise to study computer-supported collaborative work between remote experts and onsite crisis response teams, where experts provided the response teams with a remote real-time assessment of a crisis situation via audio/video. Woltjer (Woltjer et al., 2006a, b) describes a functional exercise, where use of communication technologies and coordination in critical infrastructure failure recovery was studied. Trnka (Trnka and Jenvald, 2006; Trnka et al., 2006) combined functional exercise methodology with operational games to study information seeking, data exchange, and communication. Artman and Persson (2000; Persson and Worm, 2002) studied the impact of technologies on collaboration, communication, and teamwork with the help of functional exercises.

METHODOLOGY

The aim of this research was to gain knowledge of operational deployment of EOT by expert teams in rapid crisis response. The methodological approach was an explorative qualitative study using a low-control simulation.

Low-level control simulation is a suitable technique used to study human–machine systems, such as real crisis response teams, which are difficult to observe during dynamic and nonroutine situations (Woods and Hollnagel, 2006). When people face ill-specified goals and large problem spaces, they often invent creative ways of circumventing dilemmas and making use of accessible technologies. Low-level control simulations are therefore an appropriate approach for documenting how such behavior emerges and how different interactions and processes take place.

The simulation this chapter refers to is a scenario-based real-time simulation, which stemmed from a functional exercise methodology. The simulation was planned and executed under the name GNEX-06. The simulation was implemented within the scope of the activities of the European Commission's funded Network of Excellence on Global Monitoring for Security and Stability (NoE GMOSS). This network includes more than 120 experts and about 30 organizations in the area of earth observations, remote sensing, security, and crisis response. The GNEX-06 simulation involved various researchers from the organizations participating in the NoE GMOSS. The participating researchers from this network were organized into three independent expert teams with an average twenty-one members on 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.

Teams

The type of teams and technologies the simulation focused on were not initially in place or operational. This affected the way the teams were selected and prepared. Researchers participating in the NoE GMOSS represented a base from which simulation participants were selected. The number of teams was limited to three (Alpha, Bravo, and Charlie). This was influenced by four major factors. First, the number of possible teams was limited by the number of researchers associated with the NoE GMOSS. Second, each team needed capabilities in the following three areas: (a) earth observation data analysis (including feature recognition, change detection, and infrastructure monitoring), (b) data integration and visualization, and (c) security concepts. The number of available experts in each area was also a limiting factor. Third, the simulation duration was a priori fixed at thirty-three hours, which created additional demands on staffing of the teams. And fourth, monitoring and control of a large number of teams in the simulation was also a challenging task with respect to the management of the simulation.

As a result, the three teams participating in the simulation were temporary teams, that is, the teams did not preexist, although some of the team members met initially or worked together prior to the simulation. The organizations were allocated to the teams in such a way that each team had sufficient capabilities in the area of earth observation data analysis, data integration and visualization, and security concepts.

The organizations participating in the NoE GMOSS were informed three months ahead of the simulation about which team they belonged to and about the general nature of the simulation tasks. Each team had one predefined coordinating organization operating at a coordination point. The three coordination points were in different geographical locations (each in a different country). From this point on, each team negotiated and agreed on the team's size and configuration, means of coordination, and methods of communication. Each team also negotiated which tools they planned to use and could operate.

Scenario and Tasks

The simulation was built on a single, self-contained event. This event was an incident in a nuclear power plant followed by a release of radioactive noble gases.

An essential factor in designing the scenario was the high level of fidelity (realism) of the scenario and tasks. The goal was to define a realistically challenging scenario and tasks that would force the simulation participants into novel ways of using EOT. The scenario and the tasks were developed by the simulation management team (to which the authors belonged) together with the nuclear safety experts of the German Nuclear Reactor Remote Monitoring System of the Ministry of Environment of Baden-Württemberg (Kernreaktor-Fern-Überwachung, Ministerium für Umwelt und Verkehr Baden-Württemberg). The situations that were envisaged in the scenario were based on previous nuclear emergency exercises.

According to the scenario a serious accident at a nuclear power plant led to immediate shutdown of the reactor. Radioactive material was released into the atmosphere for a short period of time. Heavy precipitation and thunderstorms occurred over the concerned area after the accident, resulting in locally heterogeneous low to intermediate ground contamination. All necessary immediate and early countermeasures were taken in the affected areas. Crisis response organizations requested provision of data and analyses to support their negotiations on further possible countermeasures.

The tasks were to provide detailed information on: (1) the current land use in the contaminated areas, and (2) changes in the industrial sites and urban areas (including nature and type of infrastructure changes). Analysis and support was requested in the form of tabulated statistics, maps, and a report, including reliability/quality statements. Furthermore, a summary of the production and processing work, including a short description of methods, tools, data, and difficulties and problems encountered during the work, was also requested. The teams were asked to complete their tasks within thirty-three hours.

The tasks required that a process chain from data access to visualization be executed. In other words, the initial step—selection and tasking of suitable satellites—was excluded. This decision was made due to the time demands involved in this step. Instead, the teams were given access to a data repository where the following data were available: ENVISAT ASAR, SPOT5, and Quickbird images, SRTM data, modeled contamination, and topographic maps.

Simulation Execution

The simulation was executed in autumn 2006. It was launched on October 10, 2006, at 08:45 CET, with the release of the scenario and task specification. Due to the simulation complexity and dynamics, the distribution of the teams' coordination points at different geographical locations, and the simulation length, the simulation was controlled continuously by five simulation managers during its entire duration. Based on the simulation development the simulation managers were allowed to launch additional incidents in the scenario if necessary to control the development of the simulation. The simulation was self-perpetuating, as the scenario and team interaction provided sufficient complexity. No additional incidents were therefore necessary. The simulation was concluded by the simulation managers on October 11, 2006, at 18:15 CET, thirty-three hours after the launch.

Data Collection

Observations

The main data collection technique was observations by human observers. Each team was assigned two observers, who followed the teams during the entire simulation. The observers were located at the teams' coordination points. The observations were carried out in a semistructured way, and the observers were instructed to focus their observations on the use of EOT. Further, the observers also focused on team configuration, communication within the teams, coordination, task allocation, and adaptive behavior. The observations of adaptive behavior were centered on the following three categories described by Westrum (2006, 59–64):

- Foresight—Foresight involves creatively imagining and anticipating failure and preparing for actions upon detection of these failures, for example, through the generation of alternative plans;
- Coping—Coping with a new situation means adapting to its changing requirements on action. Coping behavior may include reallocation of resources, changes in strategies and tactics, reprioritization, improvisation in the face of unanticipated events, and so on;
- Recovery—Recovery includes getting the situation under control and steering it so that normal functioning can be resumed.

These categories have been used previously in assessment of teams during crisis response simulations. See, for example, Woltjer and colleagues (2006b).

The observers received specific instructions for their observations prior to the simulation in the form of an observation guide. This observation guide contained 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.

After-Action Review

Following the termination of the simulation, an after-action review was scheduled in order to provide the simulation participants with immediate feedback. An after-action review is a professional discussion of an event, such as a real response operation or training session that aims to provide personnel (in our case simulation participants) with feedback and reflection on their mission and tasks performance (Rankin et al., 1995; Scott, 1983). Taking into account the form of work (computer-supported work on digital data) and the high abstraction of the process, the after-action review was designed as a one- to two-hour event, using self-evaluation as the main technique. The after-action review was undertaken individually by each team together with their observers, based on a guide specifically prepared for this simulation. The self-evaluation focused in particular on the participants' own perception of the key situations, and on a discussion about the type of processes carried out successfully, partially successfully (could be solved short term), and unsuccessfully (could only have been solved medium and long term). During the after-action review, the participants were also stimulated to discuss questions and topics related to their collaborative work, such as communication, information exchange, and team behavior. Besides the recommended topics and questions in the guide, the participants had the chance to discuss additional topics.

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. The evaluation of EOT deployed was based on the observer reports and teams' summary of the production and processing work. The analysis was centered on the tools used and the use of commercial off-the-shelf (COTS) tools versus specialized in-house–developed tools, which are freely accessible within the NoE GMOSS. The evaluation of products took into account all types of results including maps, statistics, reports, and additional products, and focused primarily on the quality and reliability of the delivered products.

The crisis decision-making–related evaluation was done by the simulation management team together with the nuclear safety experts, who participated in the scenario preparation. Attention was given to usefulness of the provided information and the added value of this information for decision makers. In the evaluation, the nuclear safety experts represented prospective decision makers in the context of the simulation scenario. The evaluation was based on their day-to-day work and exercise experience, and focused on the possibility to integrate the products into the decision making and working reality.

Workshops

The data collection process was completed by two workshops, in which a sample of simulation participants and observers took part. The workshops were accomplished in the form of two half-day-long workshops. During these workshops outcomes of the simulation were presented, followed by an informal discussion. These two workshops were held within six months of the simulation.

DISCUSSION OF RESULTS AND FINDINGS

In the following section, the main findings of the GNEX-06 simulation are presented. The discussion is based on (a) expert evaluation of the products and EOT used, (b) observer reports,

Table 5.1

Land-Use Classes for Each Team for the Three Major Land-Use Groups

Land-use group	Team Alpha	Team Bravo	Team Charlie
Urban	Urban area Industrial developments Building and construction sites Major roads	Built-up area	Urban/industrial
Forest	Woodland	Forest	Forest
Agriculture	Low vegetation (e.g., grassland) Discontinuous vegetation Rural mineral surfaces	Standing crop Bare soil	Grassland Agriculture

Table 5.2

Area Statistics (in square kilometers) **for Each Team Summarized for Major Land-Use Classes**

Area statistics	Team Alpha	Team Bravo	Team Charlie	CORINE*
Urban	3.527	5.13	6.157	4.96
Forest	8.295	8.04	7.161	7.13
Agriculture	9.92	8.63	8.47	8.49
Other	0.508	0.45	0.462	1.67

*CORINE is a European-wide land-cover and land-use classification system.

(c) participants' reflection on their performance in the after-action review, (d) comments and discussion at the workshops, and (e) observations by the simulation managers.

Product Assessment

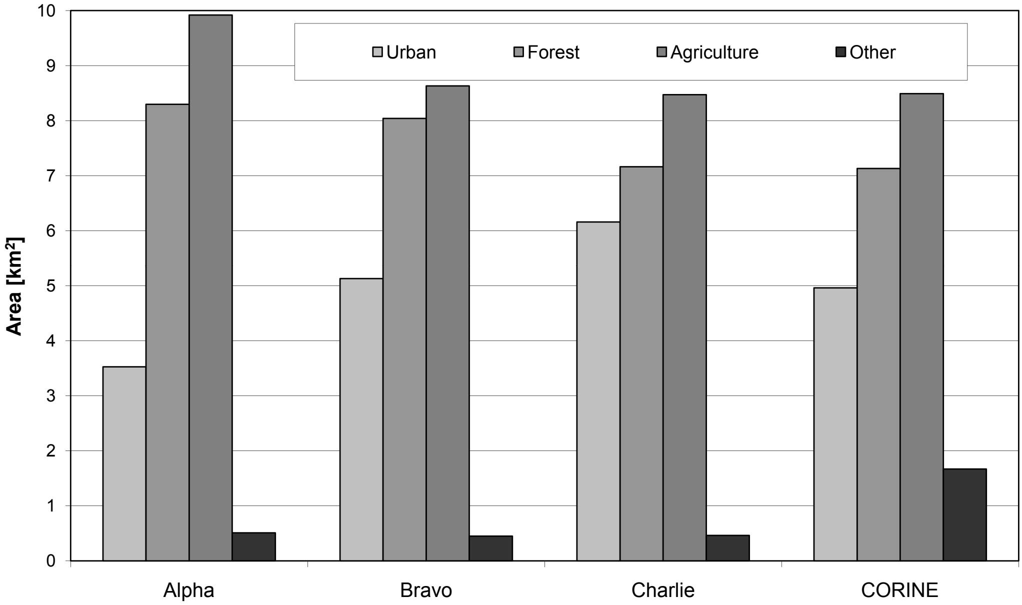
The delivered products were different in terms of the content between the teams. This was already discovered in the early stage of their assessment. The difference was both in the way the outcomes presented in the products that were classified and how these were visualized (see examples in Figure 5.1 and Table 5.1).

In terms of classification of the outcomes, none of the three teams used the CORINE land cover classification scheme. CORINE refers to the pan-European land-use classification, which provides a unique and comparable data set of land cover for Europe (Büttner et al., 2002). This scheme is used as the "de facto standard" for classification of data over Europe. The teams used classification schemes of unknown origin in the analysis (see Figure 5.2). Team Alpha used eight different classification classes; team Bravo four; and team Charlie four. This inconsistency in classification made it difficult to directly compare the results from the different teams.

We resolved the situation by grouping the classes into three major land-use classes (urban, agriculture, forest, see Table 5.2) and comparing the teams' own classification schemes against the CORINE scheme with the help of area statistics (Table 5.2 and Figure 5.2). When doing this it is important to keep in mind that the CORINE data set was derived from Landsat data with a

Figure 5.1 **Example of Map Products**

Figure 5.2 **A Comparison of Area Statistics for Each Team**



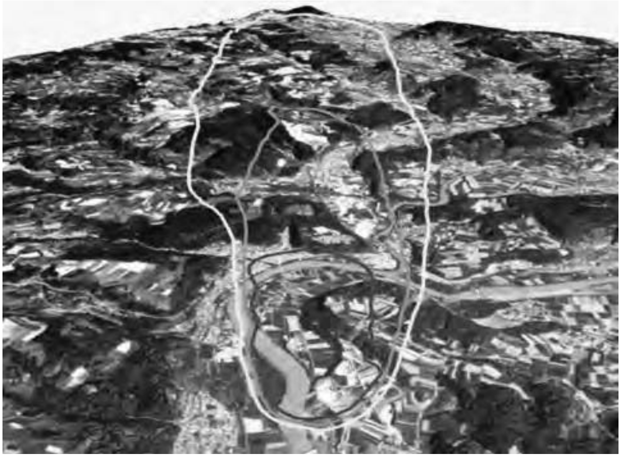
resampled pixel size of 25 m and a minimum size per land-use unit of 25 ha. The classifications in the scenario were based on SPOT data with a pixel size of 5 m. Nevertheless, not all differences can be attributed to the different pixel spacing. Major differences were observed for urban land use, where team Alpha underestimated by 29 percent and team Charlie overestimated by 24 percent compared to CORINE.

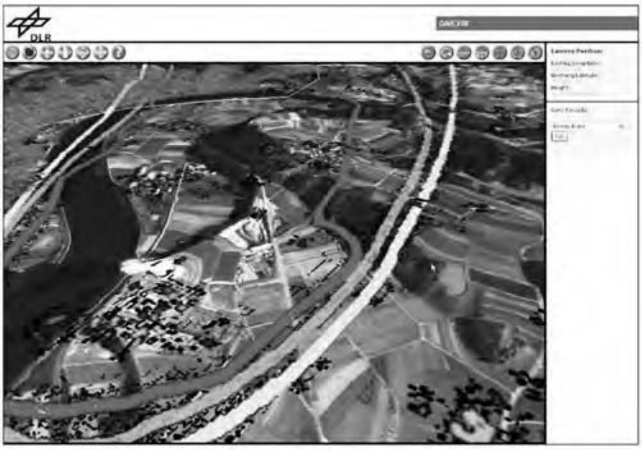
Taking into account these findings, the importance of quality statements for the decision makers becomes crucial if nonstandard classifications or new thematic analyses are made. Quality statements allow the decision makers to estimate products' reliability and to balance various products against each other in the decision-making processes. In the scope of the simulation the teams were asked to provide such quality and reliability statements. It turned out that the issue of data quality did not receive sufficient attention in the products provided by all three teams. Instead, only very vague statements were included, since the teams faced difficulties in monitoring and assessing the process and product quality during the simulation. Such a situation made any comparison between the products from the different teams very difficult and highlights the need for standardized quality assessments and validation procedures.

A similar situation occurred when the map products generated by the teams were evaluated. All the products were of high graphic quality; however, none of the teams followed the commonly used cartographic standards and recommendations in terms of color schemes, map layouts, and the like. Not following certain visualization rules and standards then requires the extra attention of those using such nonstandard maps. It may also lead to difficulties, or even confusion, when such maps need to be combined visually with other products, such as traditional topographical maps. This was also felt during the expert evaluation.

Besides this fact, the nuclear safety experts, who judged the products as prospective decision makers, valued particularly the map products as a form of support that would facilitate their work in a real event. They also appreciated the level of detail of the products. Beyond the

Figure 5.3 **Example of Additional Products: Team Alpha (top), Team Bravo (middle), and Team Charlie (bottom)**





tasks the teams were requested to accomplish in the scenario, all three teams provided additional products mainly aiming at an enhanced visualization of the results (see Figure 5.3). The nuclear safety experts valued these products as nice add-ons, but did not see them as relevant for their decision making.

The after-action review and the workshops revealed that the lack of applied standards in land-use classification and cartographic visualization in the teams' product was primarily caused by (1) missing cartographical or ecological expertise on the teams, and (2) intense time constraints in the last stages of the simulation. Furthermore, the simulation revealed the complexity and challenge of quality management in this type of analytical process when carried out under time constraints. The failed quality management was identified, both by the teams themselves and the expert evaluators, as an important lesson learned. The discussions during the after-action review and workshops also suggested the establishment of a dedicated function in such teams in order to manage the data quality issues.

Use of Tools

A wide range of tools was used by the teams in order to accomplish the tasks. Team Alpha used seven tools of which three were COTS; team Bravo used ten tools of which eight were COTS; and team Charlie also used ten tools of which seven were COTS. In total the teams used nineteen different tools to accomplish the same tasks. Three tools—all COTS—were used by all three teams (see Table 5.3).

The analysis of the collected data also showed that the number and variety of tools used were different throughout the simulation. Both the number and variety were greatest in the early phases of the simulation, during the preprocessing of the data (e.g., radiometric and geometric enhancement). In order to preprocess the data, the teams used ten different tools, of which seven were advanced, in-house–developed tools (Table 5.4). The final stage of the process—visualization—was characterized by a reduced number and variety of the tools used, compared with the initial steps of the process chain. Only five tools were used in this stage, all COTS. It seems that the time constraints and the increasing workload had an impact on the choice of tools. With increasing time

Table 5.3

Overview of Tools Used by the Teams During the Simulation

Team Alpha	Team Bravo	Team Charlie
ENVI®	ENVI®	ENVI®
ERDAS Imagine®	ERDAS Imagine®	ERDAS Imagine®
ArcGIS®	ArcGIS®	ArcGIS®
ORFEO toolbox*	PCI Geomatics®	PCI Geomatica®
Pan-sharpening*	eCognition Professional®	eCoginition Professional®
Automated line detection*	GoogleEarth®	Leica Virtual Explorer®
Speckle reduction*	Morphological Tools	Adobe Photoshop®
	VNS (Visual Nature Studio)	ATCOR—SPOT correction and analysis tool*
	IMPACT—Image Processing and Classification Tool Kit*	Xdibias—SPOT rectification software*
	RSG—Remote Sensing Software Package*	EGEO—ASAR processing tool*

*In-house–developed tool.

Table 5.4

Overview of Tools Used by the Teams During the Simulation

Tools vs. team and process step	Team Alpha	Team Bravo	Team Charlie
Preprocessing	ENVI® ERDAS Imagine® ORFEO toolbox* Pan-sharpening* Speckle reduction*	ENVI® ERDAS Imagine® PCI Geomatics® IMPACT—Image Processing and Classification Tool Kit* RSG—Remote Sensing Software Package*	ENVI® ERDAS Imagine® PCI Geomatica® ATCOR—SPOT correction and analysis tool* Xdibias—SPOT rectification software*
Thematic analysis	ENVI® ERDAS Imagine® ORFEO toolbox* Automated line detection* Morphological Tools IMPACT—Image Processing and Classification Tool Kit* RSG—Remote Sensing Software Package*	ENVI® ERDAS Imagine® PCI Geomatics® eCognition Professional®	ENVI® ERDAS Imagine® PCI Geomatics® eCognition Professional®
Fusion	ArcGIS®	ArcGIS®	ArcGIS®
Dissemination	ArcGIS® GoogleEarth® VNS (Visual Nature Studio)	ArcGIS® Leica Virtual Explorer® Photoshop	ArcGIS®

*In-house–developed tool.

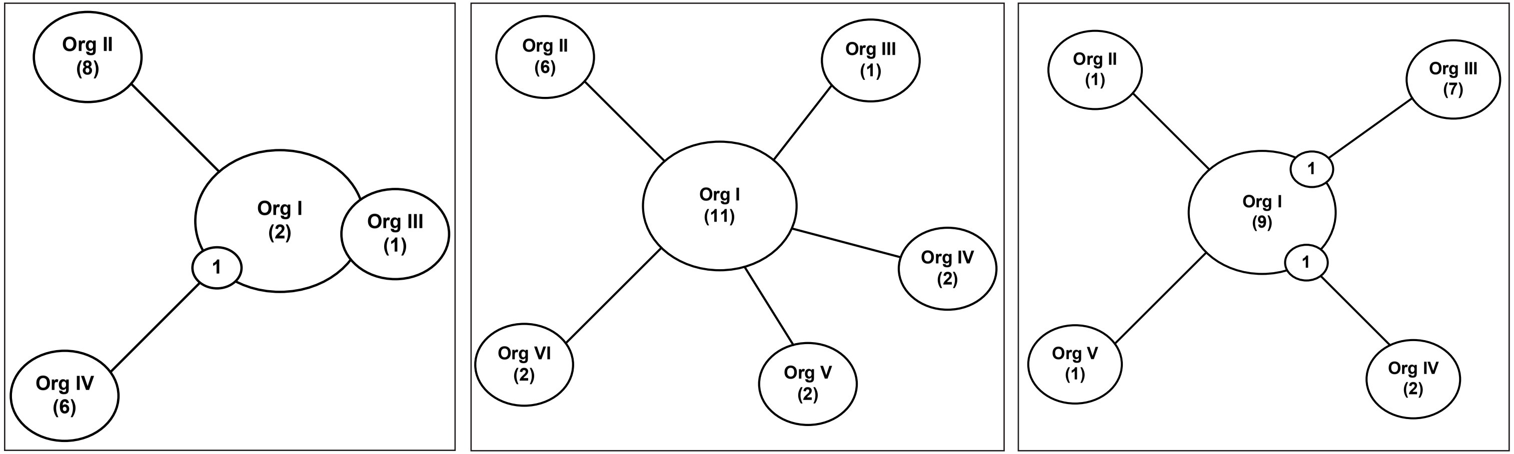
pressure the teams tended to switch from advanced in-house–developed tools to COTS, which are well-known and commonly used in the remote-sensing domain.

Organization and Coordination of the Teams

Team configuration, communication used, means of coordination, organization of working steps, and data sharing during the GNEX-06 simulation remained the full responsibility of the individual teams. As a result, the working procedures pursued during the simulation differed significantly from one team to the other. In accordance with this, the problems experienced by the teams varied to a similar degree.

Members of the team Alpha made preparations for the simulation by identifying one point of contact in each organization belonging to the team. Additionally, team Alpha agreed beforehand on modalities for communication and data exchange. From team Alpha, two out of four participating organizations sent a representative to the coordination point. However, the majority of the participating researchers were distributed at remote geographical sites (fourteen of eighteen team members; see Figure 5.4). The team coordinator communicated directly with the remote sites, even if the site (organization) was present personally at the coordination point. All the team members at the coordination point were working in the same room or area, and exchanged information or discussed upcoming issues continuously on a face-to-face basis. The team had a good situational

Figure 5.4 **Team Configurations with Respect to the Coordination Point and Geographical Locations of the Participating Organizations: Team Alpha (left), Team Bravo (middle), and Team Charlie (right)**



Note: The number in brackets is the number of experts involved in the simulation at the respective location.

overview and was able to swiftly redistribute tasks thanks to early reports provided by the remote sites. A good balance of technical experience gained by the organizations in the scope of former work led to an even distribution of tasks among the team members and participating organizations. Information exchange between the coordination point and the remote sites was carried out in the form of one-to-one communication.

Team Bravo made extensive preparations ahead of the simulation, including the designation of a point of contact, an agreement on modes of communication, and a test of these communication modes. The team decided to carry out their work in an extremely dispersed manner, that is, five out of six organizations of the team were not personally represented at the coordination point. At the beginning of the simulation, a set of tasks was assigned to each organization. Team Bravo collected reports and communicated regularly by means of moderated teleconference meetings, always concluding with an open discussion. Additional communication events with the remote sites were done on one-to-many as well as one-to-one bases. The team did not experience any problems based on communication. All team members at the coordination point (eleven out of twenty-four team members, see Figure 5.4) were located in one area. The communication among these team members was carried out personally in the form of face-to-face communication and group discussion. Two organizations, one of which was the coordinating organization, divided most of the tasks between themselves and carried out most of the work. These two organizations came from the same country and had experience in cooperation and data exchange in the past. At the same time, the allocation of the tasks corresponded well to the distribution of capabilities within the team.

Of all teams, the Charlie team made the least preparations in terms of communication, that is, they only exchanged phone numbers and e-mail addresses. Two out of the four remotely contributing organizations sent a representative to the coordination point (see Figure 5.4). The team coordinator communicated with the remote organizations through these representatives. For organizations without an appointee, the team coordinator made direct contact with those sites. During the simulation, team Charlie experienced the most communication problems of all teams. For example, the coordination point was not able to communicate at all with the two exclusively remotely working organizations for a period of several hours. It is notable that the communication with those organizations represented personally at the coordination point did not suffer from a similar communication breakdown. Half of the team members (eleven out of twenty-two team members, see Figure 5.4) at the coordination point were distributed over several buildings, floors, and rooms. The mode of communication and information sharing often held the form of one-to-one discussion (via phone, e-mail, and face-to-face communication). In regularly planned and carried out meetings, the team members working at the coordination point exchanged briefing reports and discussed a limited number of issues. The main discussions took place at an informal level between the team members of only one organization. Communication with remote organizations took the form of one-to-one communication and was mainly carried out by the team coordinator. Most of the tasks were allocated among the team members from the coordinating organization.

The findings of the GNEX-06 simulation show that good communication preparation reduces the negative effects caused by distributed settings and missing face-to-face interaction. Nevertheless, all three teams experienced “friction of distance” in collaboration with the remote organizations. This was reflected in the way tasks in the processes were allocated. Team members who had shared experience or had already been working together beforehand had the tendency (a) to share tasks among themselves and (b) to exclude team members (organizations) with whom they had not worked before. This could be observed in two of the three teams.

Nevertheless, all three teams experienced confusion at some point regarding the assignment of tasks, progress of work, and degree of task completion, as reported by the observers. In this context, no previously shared working experience and limited coordination practice could be seen as contributing factors to the communication disturbances and problematic task sharing. These problems led to the redundancy and juxtaposition of products, rather than a coherent product delivery. This may point to an ineffective use of resources, indicating that only low attention was paid to the task specifications. Some of the organizations even used the simulation to demonstrate their own capabilities in the form of additional products, without discussing or negotiating this with other team members, as noticed by some of the observers. At the same time, it helped as a backup solution when the participating organizations were not able to carry out the required work in time. On the other hand, the supply of additional products can even be seen as an example of how some team members were following their own judgments about what may be relevant and necessary.

Process Control and Adaptive Behavior

The simulation, in particular the after-action review, revealed that feedback loops, with respect to completeness and quality of the particular steps in the process, are complex and time consuming (up to several hours). In other words, there is often no direct and immediate feedback following each step. This affects how the teams can respond to situations when a particular step has to be redone. For example, the team members with the correct knowledge may already have been engaged in other activities. The combination of the high abstraction of the processes and long feedback loops, together with disturbed communication, had negative effects on the team members' understanding of "how the team was doing," as experienced, for example, by team Charlie. Another issue brought to light by the simulation was the importance of time management and related stress factors. In this simulation, the scenario put the teams under severe time constraints and required rapid actions, obliging the teams to undertake short planning with quick decisions. This is something the team members had not previously experienced to such a degree. This was perceived by some of the participants as a stressful and disturbing element to the performance and teamwork.

One of the points of interest was the adaptive work, that is, foresight, coping, and recovery behavior. Only a limited amount of anticipative or foresight behavior, such as the preparation of alternative plans, was observed in all three teams. Examples of this kind of behavior were the launching of an own FTP server by team Bravo and the deliberate doubling of task allocation to two different organizations by team Charlie in a situation where communication with remote sites had broken down. On the other hand, the teams performed very strongly and showed good coping capacities in the form of swiftly reassigning tasks when looking at challenges in reprioritization and improvisation. This is particularly valid for the coordination points. Some coordinating work could be interpreted as "good coping practices" though it originated rather from communication problems and fuzzy task allocations that led to a redundancy of products. Thanks to good coping practices—regardless of their reasons or origins—no situation requiring recovery actions occurred.

There were only a few occasions when backup plans were prepared as discussed above. This lack of alternative plan provision and contingency planning was pointed out as a problem, especially by the observers with operational experience, who identified this behavior as risky. For example, the observers reported that no expert had questioned the data provided describing the current crisis situation (e.g., the accuracy of the data determining the extent of the contaminated area). During the after-action review, all teams identified time constraints as a major contributing factor to how the teams' progress was managed, as well as to explain why alternative and backup plans were not generated.

The experience from this simulation suggests how essential it is that such expert teams also receive crisis-management–related training in a number of dimensions/areas such as contingency planning, management, and communication.

Methodological Issues

The GNEX-06 simulation was successfully executed. The scenario and the simulation as whole obtained a high level of acceptance by the simulation participants. In the following discussion we go through the main methodological lessons learned from the GNEX-06 simulation.

To document and analyze the performance and behavior of large distributed teams in a real-life context was a demanding task, with respect to the simulation control as well as the requirements on extent of data collection. The extent of the GNEX-06 simulation, executed at fourteen different locations in nine countries over a period of thirty-three hours, was one such challenge. Simulations are often managed using human observers as the main technique to obtain data for the purposes of simulation control. For practical reasons, it was difficult to have human observers at every location. Instead, observers were located in only three locations, which were the teams' coordination points. This resulted in a limited situational picture obtained by the simulation managers, with respect to what was going on at the other eleven locations. Taking into account the experience of this simulation, a more intensive and complex scenario would represent a major test for the simulation managers to gain an understanding of the simulation in progress and consequently achieve the simulation objectives. This would also represent a challenge for more intensive involvement of the different decision makers in this type of simulation.

During the simulation, it was discovered that human observers have limited capabilities in observing people executing and managing abstract processes with the aid of computers. In this context, some of the observers described the difficulties of examining such work without intensively interacting with the team members. The experience gained from the GNEX-06 simulation suggests that self-evaluation made by the participants could sometimes be the only way to gain a view of what was going on in this type of complex process. Our experience suggests complementing "traditional" human observations with other data collection techniques and tools. It is a challenge to map communication and data exchange in a simulation of this size (sixty-four simulation participants), where a wide range of communication modes is used (telephone, e-mail, face-to-face, one-to-one, one-to-many). It is apparent that various computer-supported monitoring and data collection tools are necessary in order to gain in-depth insights into the teams' work procedures, use of tools, and communication. An example of such a tool is the monitoring of participants' e-mail exchange and telephone communication, or detailed monitoring of data flows.

Taking into account the previous findings, the nature of the method of large-scale low-control simulations represents a methodological approach that is suitable for situations where we need to find out whether different processes and interactions take place. But the methodology cannot identify in detail why the processes and interactions took place, what their cause was, and so on. This type of simulation should thus be seen as a partial step within a larger set of simulations and studies.

CONCLUDING REMARKS

The GNEX-06 simulation exposed three expert teams to a realistic crisis scenario, and proved to be an interesting and powerful tool to study crisis response capacities. The simulation was completed successfully in the sense that all three teams (Alpha, Bravo, and Charlie) were able to respond to the given scenario. Even if the teams had different configurations, communicated differently, and pursued different working procedures, they all accomplished the tasks in time. The teams used a total of nineteen different tools to accomplish the same tasks. Ten tools were COTS and nine were in-house–developed tools. On average, each team used nine tools. Three tools—all COTS—were used by all three teams. In this sense, the different team configurations and means of communication do not seem to have a significant impact on the teams' choice of tools. Unfortunately, the use of nonstandard classification schemes and vague quality and reliability statements by all three teams did not allow comparison of the simulation outcomes (products) with respect to the tools used.

The analysis of the GNEX-06 simulation also revealed that distributed teamwork and communication challenges led to problems with task handover and redundancy of products on all teams. All three teams also experienced difficulties when operating under time constraints. This resulted in the following behavior. First, the severe time constraints caused nonstandard land cover classifications to be used and cartographic visualizations made. Second, the time pressure also resulted in insufficient quality management. Third, with the increasing time pressure the teams tended to switch from advanced in-house–developed tools to COTS. Fourth, the teams were missing contingency plans even though the teams demonstrated good coping capabilities.

From the findings of this study, one area requires further attention, namely, the expertise and skills available in these types of teams. The simulation revealed that, besides capabilities in the area of earth observation data analysis, data integration and visualization, and security concepts, the teams also need expertise in general areas—data quality, data logistics, contingency planning, and process planning—as well as specific areas—cartography and ecology—with respect to this scenario. The team members need their specific technical skills, but in cases of crises it is absolutely necessary that they have additional "soft" skills in the fields of management and communication, which were seen to be missing in this simulation.

The simulation provided an opportunity to study the actual work and interaction that emerged in the collaborative processes of deploying EOT during a crisis response in relatively controlled settings. However, due to its methodological limitations, the simulation could not provide in-depth answers about why certain processes and interactions took place. Through the simulation, the participating experts gained experience in a variety of situations and courses of action relating to operational needs and deployment of future EOT. By highlighting problems that may occur under real conditions, such simulations are useful, for example, to specify training needs. The experience gained also represents an important contribution to the knowledge of what problems may be faced in real expert teams deployed in response to future crises and confronted with similar crisis-related tasks.

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PART III

CASE STUDIES

CHAPTER 6

STATPACK™

An Emergency Response System for Microbiology Laboratory Diagnostics and Consultation

ANN FRUHLING

Abstract: *This chapter presents a case study of an emergency response system called STATPack™ (Secure Telecommunications Application Terminal Package) that utilizes video telemedicine technology for microbiology laboratory diagnostics and consultation about suspicious organisms. The chapter begins with an overview of the STATPack™ system functionality and the user interface the system provides for public health laboratorians during emergencies. The chapter continues with an analysis of the current usage during emergencies and examines what lessons can be learned. Since its inception, the system has been used for emergency situations dealing with Francisella tularensis, which causes tularemia (rabbit fever), a potentially deadly disease, and Bacillus spp (anthrax suspects). In addition, STATPack™ has been used to help identify less significant but technically challenging cultures such as Clostridium perfringens, and various fungal organisms. The contribution of this research is that it is one of the first assessments of how well a medical emergency response system (ERS) met the needs of first responders in actual emergencies and what lessons were learned.*

Keywords: *Emergency Response System, Rural E-Health, Bioterrorism, DERMIS, STATPack™*

The detection and reporting of bioterrorism and the ability to maintain disaster preparedness and formulate a response continues to grow in importance, especially in the aftermath of the recent natural disaster, Hurricane Katrina. A further need for public health preparedness has become more apparent with the increased incidence of infectious diseases and antibiotic resistance that pose growing threats to public health.

In recent years, concerns about bioterrorism and emerging infectious diseases such as the West Nile virus, severe acute respiratory syndrome (SARS), and now avian influenza A/(H5N1) and the "swine" influenza (H1N1) have accelerated the efforts of state public health laboratories to establish better communication networks with private clinical and hospital laboratories in an effort to improve public health surveillance. Because the majority of infectious disease testing in the United States is done in private hospital and clinical laboratories, better integration with state public health laboratories is expected to improve both the timeliness and validity of disease reporting. During a health-related event, timely interpretation and dissemination of information are essential to reducing morbidity (the incidence of a disease) and mortality.

In a 1988 report, the Institute of Medicine identified three core functions of public health: assessment, policy development, and assurance in improving health in the United States (CDC, 1994). Public health surveillance provides an ongoing assessment of the health status of populations for the purpose of identifying and solving community health needs (Baker et al., 1994).

State health networks of clinical laboratories provide a crucial service to citizens across the nation. In the event of a public health emergency or bioterrorism event, public health clinical laboratories are the front lines in ensuring that potentially harmful substances are identified, analyzed, and quarantined quickly.

In the past, most states in the United States did not have the capability to efficiently and electronically share critical public health microbiology laboratory information in emergency situations where time is of the essence. This is a critical issue in the midwestern states, which have large geographical areas that are serviced by a single State Public Health Laboratory (SPHL).

To address this problem, the U.S. government provided a large infusion of funds to build infrastructure to ensure that the local, state, and federal entities will guarantee their population is protected by skilled public health agencies capable of detecting and responding to another bioterrorism event, should one occur. In order to do this, local, state, and federal entities must link surveillance and laboratory systems to quickly identify such an event. Public health agencies must be able to respond and detect disease outbreaks, chemical spills or leakages, food and water contamination scenarios, and animal disease outbreaks.

Several months after the anthrax incidents during the fall of 2001, the U.S. Congress appropriated funds to strengthen state and local bioterrorism preparedness. The majority of federal funds for bioterrorism preparedness programs are distributed by the Department of Health and Human Services Centers for Disease Control and Prevention (CDC) and Health Resources and Services Administration (HRSA).

The CDC has identified seven focal points to increase preparedness: (1) Preparedness Planning and Readiness Assessment, (2) Surveillance and Epidemiology Capacity, (3) Laboratory Capacity—Biologic Agents, (4) Laboratory Capacity—Chemical Agents, (5) Health Alert Network/ Communications and Information Technology, (6) Risk Communication and Health Information Dissemination, and (7) Education and Training (CDC, 2004a).

Similarly, the Health and Human Services System (HHS) has established critical benchmarks, which are described as "milestones" for public health emergency preparedness. Recipients of HHS funding for public health preparedness must demonstrate progress toward these critical benchmarks. The following is an example from the CDC Continuation Guidance, Focus Area B: Surveillance and Epidemiology Capacity:

> 1. Critical Benchmark #7: Complete development and maintain a system to receive and evaluate urgent disease reports and to communicate with and respond to the clinical or laboratory reporter regarding the report from all parts of your state and local public health jurisdictions on a 24-hour-per-day, 7-day-per-week basis." (CDC, 2004b, p. 1)

A solution to improve biosecurity and/or bioterrorism emergency and natural disaster preparedness is to leverage information technology. According to Edward Baker, assistant U.S. surgeon general, "The best public health strategy to protect the health of civilians against biological terrorism is the development, organization, and enhancement of public health prevention systems and tools, including enhanced communications mechanisms and messages" (Baker, 2001).

Several emergency response management information systems for health care initiatives are promoted at the national level. These include the Outbreak Management System, National

Biosurveillance Informatics System (NBIS), the Public Health Informatics Network (PHIN), the National Epidemiology Disease Surveillance System (NEDSS), BioNET, the Laboratory Response Network (LRN) (Snyder, 2003), a national network of public health laboratories assisting the Centers for Disease Control and Prevention to rapidly detect and determine the possible links between disease agents during terrorist attacks (CDC, 2003), the federal food regulatory agencies belonging to the Food Emergency Response Network (FERN), Health Alert Network (HAN), and the National Health Information Infrastructure (NHII) (Tang, 2002). Consequently, there is not one comprehensive system that provides the solutions to all needs of a state in terms of response to and detection of a bioterrorism event or any other emergency (Kun and Bray, 2002). Table 6.1 lists the mentioned emergency response management information systems and a synopsis of their missions.

All of these mentioned initiatives are focused at the national level and are distributed in only selected states; therefore, there are gaps in the availability of emergency health response systems at local levels, especially in rural communities. Until recently, most states in the United States did not have the capability to share critical public health microbiology laboratory information in real time and at the local levels, especially in rural communities where laboratorians serve as the front line of disease recognition. The need for rapid communication and exchange of data during an emergency is essential.

As an attempt to remedy this problem, scientists at a midwestern State Public Health Laboratory (SPHL) serving rural communities, together with information technology scientists at the University of Nebraska at Omaha, Peter Kiewit Institute, designed and developed a networked statewide video telemedicine public health ERS, called STATPack™ (Secure Telecommunications Application Terminal Package). STATPack™ provides electronic laboratory diagnostics consultation that quickly, efficiently, and electronically shares critical microbiology and pathological health information in emergency situations. The health information consists of photographic and microscopic images of organisms and descriptive text. In addition, the application provides a systematic method of alert notification and escalation, a repository of the data, and microbiology protocols. Prior to the development of the STATPack™ system, the SPHL did not have electronic intrastate connectivity to share urgent health information. In fact, they used faxes to send out an all-state emergency alert during a biosecurity event. And, until recently, many of the systems in the marketplace required manual disease reporting, which leads to incomplete, inaccurate data and slow outbreak detection, which in turn precludes a timely response.

Recently, during a Roundtable Bioterrorism Detection Discussion at the American Medical Informatics Association (AMIA), researchers agreed that to promote progress it is important to share information about systems, including origins, current capabilities, stages of deployment, and architectures as well as lessons learned during the development and implementation of systems. Furthermore, the group suggested exploring opportunities to do cooperative projects that include the sharing of software and data (Kun and Bray, 2002).

There has been limited reported feedback on how well these newly developed emergency response systems are performing during emergency situations. Hence, evaluating and understanding the usage of emergency response systems, such as STATPack™, calls for further study. There are some notable studies: using telemedicine applications for disaster situations (Garshnek and Burkle, 1999), an overview of informatics response to disaster, terrorism, and war (Teich et al., 2002), and recommendations on using telehealth to improve disaster response (Myers, 1997). However, there is a void in reporting the effectiveness of emergency response systems after implementation and measuring their performance during actual emergencies. Feedback from first responders is key to making ERS systems effective and scalable should the need arise. This study examines

Table 6.1

Selected International and National Emergency Response Management Information Systems and Agencies

System	Mission
Outbreak Management System (OMS)	OMS is a complete application that can be used to respond to a public health emergency. The software provides public health partners with a suite of tools for capturing standard data; configuring outbreak-specific vocabularies; performing analyses; and creating dynamic questionnaires, reports, and outbreak-specific packages. The application also manages case and contact investigations, records epidemiological data, allows for relationship management, and captures follow-up activities for managing exposed contacts. www.cdc.gov/phin/software-solutions/oms/index.html
BioNET	BioNET is an international not-for-profit initiative dedicated to promoting taxonomy, especially in the biodiversity rich but economically poorer countries of the world. Working via local partnerships (LOOPs), BioNET's goal is to provide a forum for collaboration that is equally open to all taxonomists and to the other users of taxonomy. www.bionet-intl.org/opencms/opencms/whoWeAre
Laboratory Response Network (LRN)	LRN is charged with the task of maintaining an integrated network of state and local public health, federal, military, and international laboratories that can respond to bioterrorism, chemical terrorism, and other public health emergencies. The LRN is a unique asset in the nation's growing preparedness for biological and chemical terrorism. LRN is the first network to link state and local public health laboratories, veterinary, agriculture, military, and water- and food-testing laboratories. www.bt.cdc.gov/lrn/
Centers for Disease Control and Prevention (CDC)	CDC's mission is to promote health and quality of life by preventing and controlling disease, injury, and disability. Further, CDC seeks to accomplish its mission by working with partners throughout the nation and the world. Specifically, CDC monitors health, detects and investigates health problems, conducts research to enhance prevention, develops and advocates sound public health policies, implements prevention strategies, promotes healthy behaviors, fosters safe and healthful environments, and provides leadership and training. www.cdc.gov
Food Emergency Response Network (FERN)	The mission of FERN is to integrate the nation's food-testing laboratories for the detection of threat agents in food at the local, state, and federal levels. This requires a comprehensive effort including chemical, biological, radiological disciplines involving the full range of food commodities. Specific objectives are (1) Prevention—federal/state surveillance sampling programs, (2) Preparedness—strengthening lab capabilities/capacities, (3) Response—surge capacity, and (4) Recovery—provide assurance to the consumer. www.fernlab.org/index.cfm
National Health Information Infrastructure (NHII)	The NHII is an initiative set forth to improve the effectiveness, efficiency, and overall quality of health and health care in the United States. It includes a comprehensive knowledge-based network of interoperable systems of clinical, public health, and personal health information that would improve decision making by making health information available when and where it is needed. It utilizes a set of technologies, standards, applications, systems, values, and laws that support all facets of individual health, health care, and public health. However, NHII is NOT a centralized database of medical records or a government regulation. NHII operates on a voluntary basis. http://aspe.hhs.gov/sp/nhii/FAQ.html

Table 6.1 (*continued*)

Health Alert Network (HAN)	HAN is a national program providing vital health information and the infrastructure to support the dissemination of that information at the state and local levels. The HAN Messaging System directly and indirectly transmits Health Alerts, Advisories, and Updates to over one million recipients. The current system is being phased into the overall PHIN messaging component. www.2a.cdc.gov/han/Index.asp
National Electronic Disease Surveillance System (NEDSS)	NEDSS is an initiative that promotes the use of data and information system standards to advance the development of efficient, integrated, and interoperable surveillance systems at federal, state, and local levels. It is a major component of the Public Health Information Network (PHIN). NEDSS's wide-ranging initiatives are to detect outbreaks rapidly and to monitor the health of the nation, facilitate the electronic transfer of appropriate information from clinical information systems in the health care system to public health departments, reduce provider burden in the provision of information, and enhance both the timeliness and quality of information provided. The vision of NEDSS is to have integrated surveillance systems that can transfer appropriate public health, laboratory, and clinical data efficiently and securely over the Internet. NEDSS will revolutionize public health by gathering and analyzing information quickly and accurately. This will help to improve the nation's ability to identify and track emerging infectious diseases and potential bioterrorism attacks as well as to investigate outbreaks and monitor disease trends. www.cdc.gov/nedss/

Source: Fruhling (2006).

one particular case on how well a newly developed ERS performed and the lessons learned from the actual users of the ERS during emergencies.

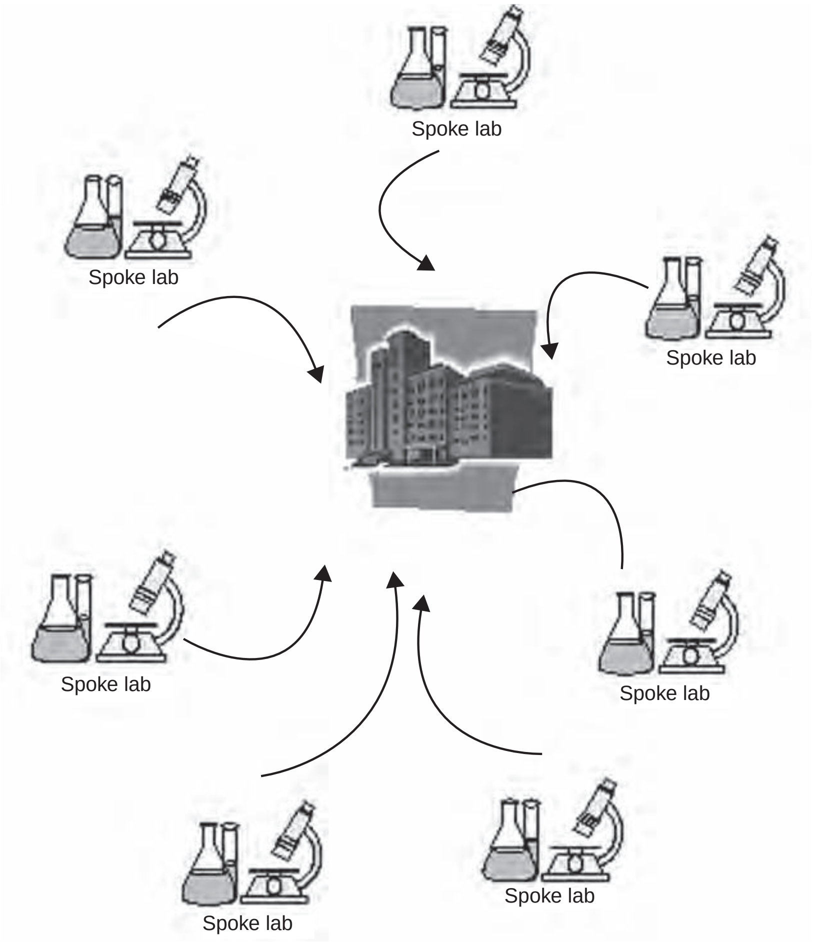
The next section presents a descriptive overview of the STATPack™ system. This is followed by a discussion of the research method, and examples of usage of the STATPack™ system in emergency and nonemergency situations, including feedback from end users. The chapter concludes with a discussion of lessons learned, limitations, and directions for future research.

THE STATPACK™ SYSTEM

Threats of bioterrorism and high-profile disease outbreaks have accelerated the efforts of public health laboratories to establish better communication networks with clinical laboratories. The intent of the STATPack™ project, which began September 2002, was to address critical health communication and biosecurity needs in Nebraska (Fruhling and Sambol, 2003). 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 (Figure 6.1).

Most recently, STATPack™ expanded its capability by connecting three SPHLs, Nebraska,

Figure 6.1 **STATPack™ State Public Health Laboratory Hub-and Spoke-Network**

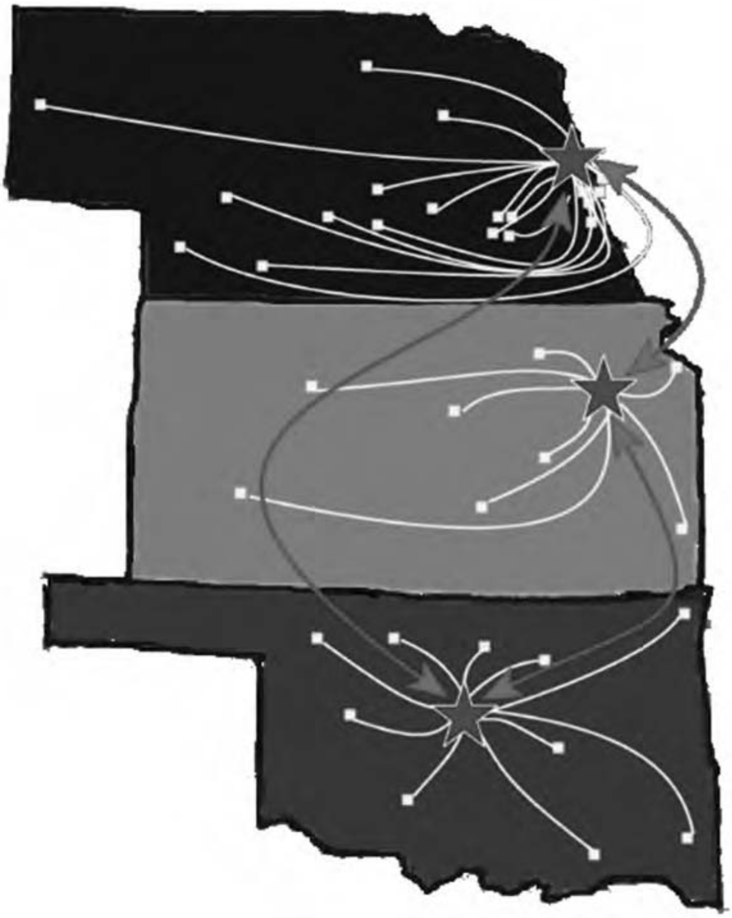


Kansas, and Oklahoma, as shown in Figure 6.2. Experts at SPHLs can now share information across state lines. This further utilizes the multistate Public Health Laboratories' state-of-the-art approaches to identifying emerging infectious diseases and tracking sources of antibiotic resistance and detecting bioterrorism agents to further support the rural public health infrastructure in states with large rural geographical areas.

STATPack™ is useful in hospital laboratory systems where much of the expertise is located in a hub lab. However, most triage occurs in smaller hospital and clinic spoke labs. Therefore, it is often at the spoke labs where decisions regarding specimen processing take place. Now that they are linked to the hub SPHL, the laboratory personnel in the spoke laboratory can send digital images of suspicious culture samples to the hub laboratory for consultation, eliminating the risks and time delay of shipping the sample by courier.

Specifically, the STATPack™ concept involves taking macroscopic (gross) as well as microscopic digital images of culture samples and sending them electronically for consultation with experts at state public health laboratories. STATPack™ enables microbiology laboratories around the state (and now the region) to send pictures of suspicious organisms to the state public health laboratory,

Figure 6.2 **Multistate Connectivity**

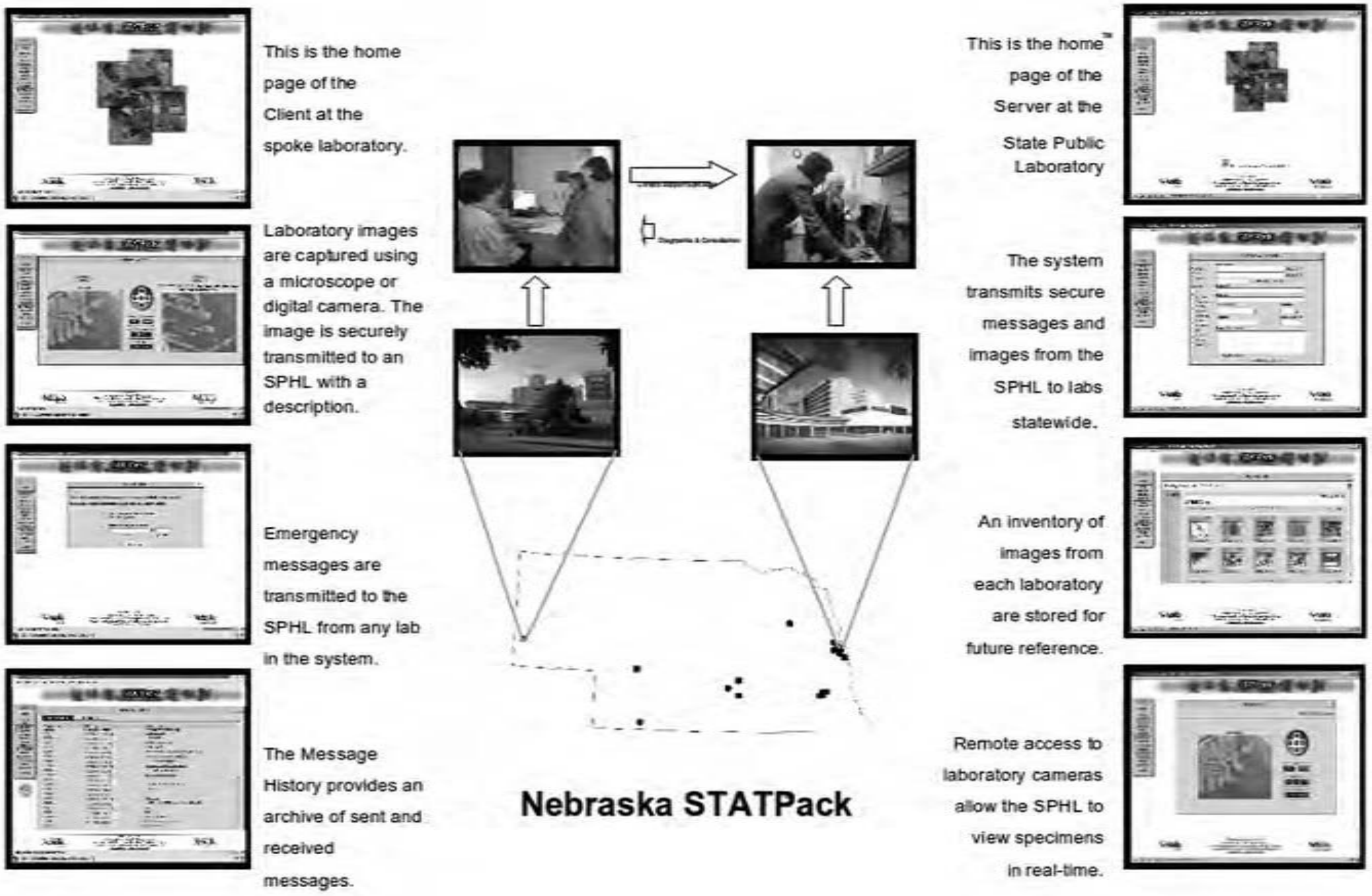


Source: Fruhling et al. (2007).

instead of the samples themselves, thus lessening the risk of spreading potentially deadly bioterror agents or infectious diseases. After seeing a sample via STATPack™, however, the state public health laboratory still could request a physical sample be sent to its lab. The system includes an alert system that is bidirectional and has various levels of priorities (emergency, urgent, and routine). Laboratory technicians at state public health laboratories can remotely and electronically zoom in on a suspicious organism, examine the organism, respond to the originating laboratory (spoke), and, if necessary, send an immediate alert to every laboratory in the network. Figure 6.3 illustrates the user interface interaction of the STATPack™ system between hub-and-spoke laboratories.

The STATPack™ system increases the availability of subject matter specialists. For example, the Nebraska Public Health Laboratory (NPHL) Biosecurity and Special Pathogens section at University of Nebraska Medical Center (UNMC) has a team of microbiologists trained in the diagnostic testing of special pathogens or agents included in the CDC's list of potential bioterrorism agents. Using the CDC's Sentinel Laboratory "Recognize, Rule-out or Refer" testing algorithm, coupled with the digital images and text, subject matter specialists can consult with the sending

Figure 6.3 **STATPack™ User Interface**



This is the home page of the Client at the spoke laboratory.

Laboratory images are captured using a microscope or digital camera. The image is securely transmitted to an SPHL with a description.

Emergency messages are transmitted to the SPHL from any lab in the system.

The Message History provides an archive of sent and received messages.

This is the home™ page of the Server at the State Public Laboratory

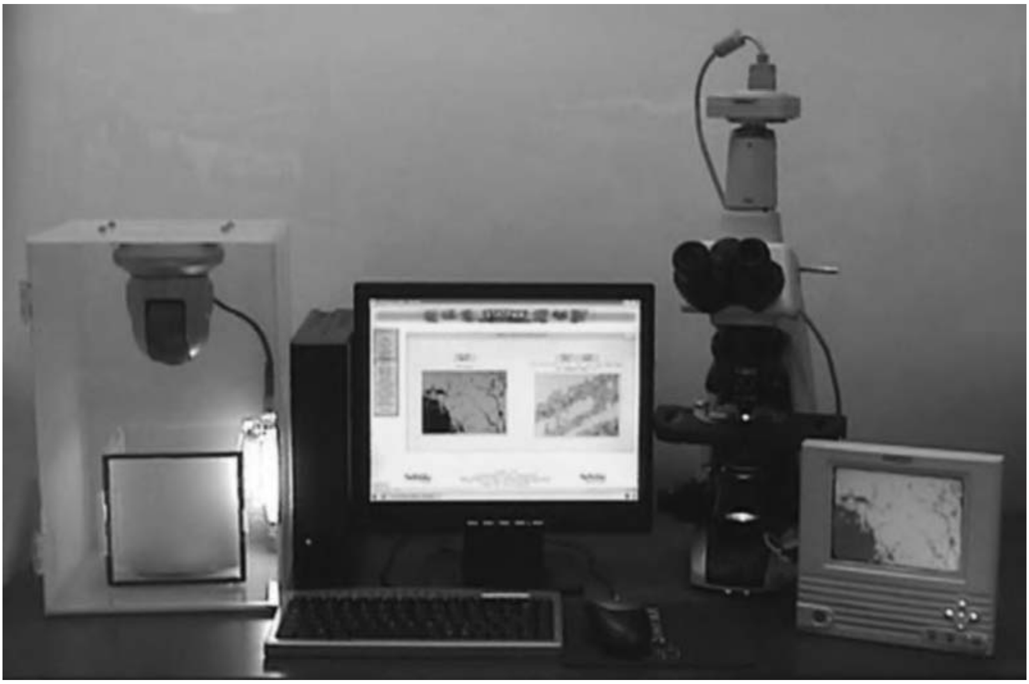
The system transmits secure messages and images from the SPHL to labs statewide.

An inventory of images from each laboratory are stored for future reference.

Remote access to laboratory cameras allow the SPHL to view specimens in real-time.

Source: Fruhling et al. (2007).

Figure 6.4 **STATPack™ System**



laboratory to determine what actions should be taken. For instance, in the case of an emergency, a pathologist or epidemiologist at a hub laboratory can remotely focus the camera in on a suspicious organism, analyze the image, and respond to the spoke laboratory where the organism is being studied. If the organism is deemed a public health threat, the STATPack™ system can be used to send an alert to every laboratory in the state public health network. For some of the outlying laboratories, it is often difficult (if not impossible) for them to describe to experts what they see in a culture sample. Prior to the STATPack™, their only option was to physically send the sample to the SPHL; it could take several hours or even a full day to arrive. STATPack™ allows experts to actually see the sample immediately and assist with the diagnosis in a matter of minutes.

STATPACK™ DEVELOPMENT BACKGROUND

The STATPack™ system was developed using an agile approach called eXtreme Programming (Fruhling and de Vreede, 2006). The project began with the investigation of enabling technologies through research and development to design a low-cost "medical information appliance" intended for use in clinical hospital laboratories that would facilitate laboratory data collection and two-way communication between local regional medical centers and the SPHL. The appliance-type device requirements were based on open standards and open source software with the intent that support would be independent of vendor reliability and technological obsolescence.

Both the hardware and software were engineered for this project. The STATPack™ system consists of a computer terminal, which includes a flat screen monitor, a mini-keyboard, speakers, a high-resolution digital camera that can capture images of culture plates housed in a biosafe container, and a hardware interface to a microscope, as depicted in Figure 6.4.

Table 6.2

Emergency Response System (ERS) Design Principles

Design principles	Description
System directory	The system will provide a hierarchical structure for all the data and information in the system as well provide a complete text search.
Information source and timeliness	All data dealing with the emergency should be identified by its human or database source, time of occurrence, status, and location.
Open multidirectional communication	The system should have a nonhierarchical communication process.
Content as address	The system will decide when the content of a piece of information is the determining factor as to where to send the information.
Up-to-date information and data	The system will have up-to-date data and information.
Link relevant information and data	The system should be designed so that an item of data and its semantic links are linked to other data and treated as one unit of information that is simultaneously created or updated.
Authority, responsibility, and accountability	This principle reinforces the need for authority in an emergency, and that authority flows down to where the action is taking place.
Psychological and sociological factors	The ERS will encourage and support the psychological and social needs of the crisis response team.
Provide alert notification redundancy	An ERS should be designed so that there is redundant alert notification.
Include nonemergency usefulness	The system should also be useful for nonemergencies.
Prioritize alerts	The system should have a method that prioritizes the messages (alerts) it sends and receives.

Source: Fruhling (2006); Turoff et al. (2004)

There are unique design principles and specifications for dynamic emergency response management information systems (DERMIS), such as STATPack™ (Turoff et al., 2004). The STATPack™ system incorporated many of the DERMIS design principles (Fruhling, 2006; Turoff et al. 2004). Turoff and colleagues (2004) proposed a set of general and supporting design principles for designing flexible, robust, and dynamic emergency and crisis response systems. They are shown in Table 6.2. Fruhling (2006) suggested the inclusion of three additional principles: (1) Provide alert notification redundancy, (2) Include nonemergency usefulness, and (3) Prioritize alerts.

Two of the major hurdles of implementing STATPack™ in rural hospital laboratories are the limited technological capabilities of the facility and the availability of information technology (IT) staff. In Nebraska, remote health care and public health institutions have limited access to high-speed networks; however, most have the option to connect through the Nebraska Statewide Telehealth Network. The STATPack™ system provides a means to integrate with this network.

The STATPack™ deployment process includes the STATPack™ team coordinating the network

Table 6.3

STATPack™ Major Uses

Major uses	Description
Emergency notification	Alerts can be sent out from the hub laboratory to all of the spokes, instantaneously alerting them to any outbreaks or emerging threats.
Suspicious organism consultation	Clinical laboratory scientists in remote labs can send magnified images of organisms to clinical laboratory scientists and other experts at the hub laboratory for interpretation of the culture growth, that is, identification and advice on processing the sample and a differential diagnosis.
Education and training	Photos of rare isolates or emerging threats can be sent to all labs in the network to teach laboratorians what to look for. STATPack™ is being used for competency testing and practice (e.g., TEREX).
Uniformity of practice	Standards of care and diagnosis can be aligned in the different labs in the network by sharing samples and diagnosis, and establishing uniform parameters.
Documentation	Interesting or rare cases can be documented in the system for future deployment for educational and training purposes.
Internal laboratory utilization	Laboratorians can save images captured on STATPack™ for local reference and use.

requirements with the local IT network administrator, traveling to the spoke laboratory to install hardware and software, and providing onsite training. After installation, the team provides ongoing technical and maintenance support as needed.

STATPack™ currently has six major uses (see Table 6.3) that help laboratorians to do their jobs better. The first two major uses, Emergency Notification and Suspicious Organism Consultation, directly support public health first responders during emergency situations. Education and Training help prepare first responders for emergencies.

The first STATPack™ prototype was deployed for field evaluation in June 2003. As the system matured, usability evaluation of the system was done using collaboration engineering techniques (Fruhling and de Vreede, 2005). The underlying code was also evaluated to help identify potential system improvements (de Vreede et al., 2006). Most recently, research was completed on the influence of affect, attitude, and usefulness on end-user acceptance of STATPack™ (Djamasbi et al., forthcoming).

To date, fifty STATPack™ systems have been placed in key clinical hospital laboratory locations throughout Nebraska, Kansas, and Oklahoma. STATPack™ systems are also located in numerous food, water, environmental, and veterinary science diagnostic testing laboratories. Additional STATPack™ system installations are planned. Now that the STATPack™ systems are fully functional and widely deployed, it is important to measure the usefulness of the STATPack™ system and its ability to meet the needs of first responders as intended during emergencies.

Method

The STATPack™ system evaluation relies primarily on subjective feedback from early adopters of the system. Interviews were conducted with the earliest adopters. Subsequently, a survey instrument was developed to assess user acceptance of this technology (Johnson and Fruhling, 2006). Appendix 6.1 contains the survey instrument itself, and later sections of this chapter describe the results and interpretation. In addition, STATPack™ usage history was also reviewed to help assess the system's performance during electronic consultations between hub-and-spoke laboratories. Finally, STATPack™ performance results during a recent NHPL-directed exercise testing statewide bioterrorism preparedness are discussed.

Interviews were conducted at the initial ten clinical and nonclinical laboratories where STATPack™ had been deployed, to better understand how well the STATPack™ system was being accepted by the laboratory technicians. This fieldwork was conducted in fall 2005 (Johnson et al., 2006; Johnson and Fruhling, 2006). During these visits, the laboratory users were asked their opinions about the usefulness of this system—for example, did they find it easy to use, was it useful, and did they have enough room within their laboratory to accommodate the STATPack™ equipment? The feedback from the interviews helped improve the system. Since that time, forty additional laboratories have been equipped with STATPack™ systems, so additional interviews may be appropriate.

In addition to personal interviews, a survey questionnaire was developed to measure user acceptance of STATPack™. Although several validated surveys for measuring user acceptance of IT systems have been published, none of the available survey instruments seemed appropriate for STATPack™ specifically (Davis, 1989; Lewis, 1995; Venkatesh and Davis, 2000; Venkatesh et al., 2003). Questions that measure perceived usefulness, for example, must take into account that STATPack™ is not intended to improve daily productivity in the workplace; the system is instead intended to be used on a weekly or monthly basis as needed. Productivity questions had to be adapted to measure the system's perceived usefulness as a diagnostic aid and as a tool for public health surveillance and emergency response. The challenge was to formulate questions to measure the perceived usefulness of a system that is not expected to be used very often, and which may not directly benefit the laboratory user. 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 would be the level of effort (ease of use) required to perform the tasks necessary for distance consultation with the NPHL.

Many of the questions were derived from published surveys for measuring user acceptance. The survey also addressed whether attitudes toward STATPack™ were associated with demographic factors such as the user's geographic distance from NPHL, capacity/type and size of the client laboratory, and frequency of computer use. A general question about the importance of being prepared for health related emergencies such as acts of bioterrorism or naturally occurring disease outbreaks was also included. This was intended to measure the extent to which perceived usefulness of STATPack™ might be associated with the user's attitudes toward emergency preparedness in general (Johnson and Fruhling, 2006).

The NPHL provided a list of primary contacts for the three nonclinical laboratories and eleven clinical laboratories using STATPack™ at the time of the survey. Introductory e-mails were sent to each of the primary lab contacts to explain the purpose of the survey. These contact personnel were asked to verify their mailing addresses and to identify first and last names of other STATPack™ users within their laboratory. The number of people actually using STATPack™ in the client laboratories was larger than anticipated. When these systems were installed, laboratorians received training from either the UNO STATPack™ team or NPHL staff, but these initial users had apparently trained others within their laboratories to use STATPack™. Next, we discuss the evaluation of the STATPack™ and the lessons learned.

STATPACK™ EVALUATION DISCUSSION AND LESSONS LEARNED

STATPack™ *User Acceptance Evaluation*

Interview Results

As part of the STATPack™ assessment process, seven clinical and three nonclinical laboratories equipped with STATPack™ were visited and the microbiology managers and technologists were interviewed. One noteworthy finding from the interviews was that there was an inconsistency in the management of passwords (Johnson and Fruhling, 2006). Network security is taken very seriously by the information technology experts, but discussions with the health care professionals using STATPack™ in the field revealed that the end users are often unsympathetic to these security concerns. Passwords, for example, are frequently written and posted in obvious locations within the client laboratory. The process of logging in with a secure password is generally regarded as a nuisance to laboratorians who may be called upon to respond quickly to a public health emergency using a system that they have not used for quite some time.

We also found that enhancing the system to include microscopic imaging was viewed as critical to perceived value of the system (Johnson and Fruhling, 2006). Informal discussions with current STATPack™ users have been encouraging. Most laboratorians have expressed confidence in their ability to get an immediate response from NPHL using the STATPack™ in an emergency situation. Others have commented that although the STATPack™ system is not used very often, it was "reassuring" to have an instant link to NPHL. Although STATPack™ is generally regarded as "easy to learn," several laboratorians have expressed uncertainty in their ability to capture and send images from the microscope interface.

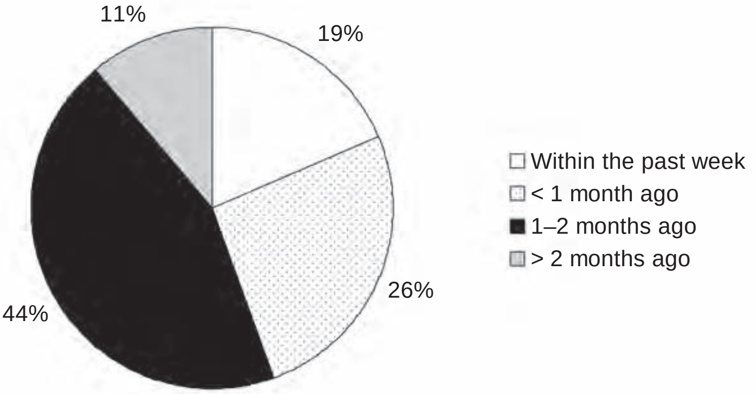
Survey Results

Surveys were mailed to thirty-nine STATPack™ users in fourteen different laboratories. Twenty-two completed questionnaires were returned within two to three weeks of mailing the survey, for an initial response rate of 56 percent. A follow-up postcard was then sent to thank those who had already responded and to encourage others to return their questionnaires. An additional five surveys were returned within two to three weeks of this second mailing, for an overall response rate of 69 percent (n = 27). Responses were received from six nonclinical and twenty-one clinical laboratorians.

The majority of survey respondents (77.8 percent) indicated that they work in hospital/clinical laboratories and most (77.8 percent) reportedly work in laboratories that are between 25 and 199 miles driving distance from the NPHL. Laboratory capacity was measured in terms of staffing and the total number of cultures performed on a weekly basis. Nearly all respondents (96.3 percent) work in microbiology laboratories staffed with one to five people and most respondents (77.8 percent) reported that their laboratory performs 100 or more cultures per week. Average computer use was quite variable, but 55.6 percent of respondents indicated that they spend more than twenty hours each week using a computer. Perhaps one of the more revealing results was that more than half of the respondents (55.5 percent) indicated that it had been a month or more since they last logged on to STATPack™. This was due to the system's being used only for emergencies and few emergencies occurred at these locations. Survey results for this question are illustrated in the Figure 6.5. This finding is consistent with STATPack™ message history.

Although the frequency (or infrequency) of use may be disconcerting to some, it is important to remember that STATPack™ is intended for consultation on suspicious or unknown organisms

Figure 6.5 **Last Time Respondent Logged on to STATPack™ (2005)**



Source: Johnson and Fruhling, 2006.

and in emergency situations. Suspicious organisms requiring consultation with the NPHL are not often encountered in Nebraska laboratories under normal circumstances. Several STATPack™ users have commented, however, that even though the system might not be used very often, it is "reassuring" to have an instant link to the NPHL.

Survey responses to the Likert portion of the survey were tabulated and are presented in Table 6.4. Overall, survey participants responded favorably to questions about perceived usefulness and ease of use of the STATPack™. For example, 85.1, 2.2 percent of respondents either agreed or strongly agreed with the statement, "I feel that 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." These results were consistent with comments received during field visits with STATPack™ users.

Survey respondents were less comfortable using the system to send images from their microscopes than using it to send macro images of colony growth. This was somewhat expected, based on comments received during field visits. Several users mentioned that the optical resolution observed through the microscope is different than that of the digital image produced through the STATPack™ interface and that it is difficult for them to focus the digital image.

The system developers have apparently been successful in minimizing the footprint of STATPack™ within the client laboratory. Only 7.4 percent of respondents agreed or strongly agreed with the reverse-worded statement "The STATPack™ takes up too much space in my work area." Most respondents (92.3 percent) agreed or strongly agreed with the statement "I believe it's important to be prepared for health related emergencies such as acts of bioterrorism or naturally occurring disease outbreaks," while 88.9 percent agreed or strongly agreed that "the STATPack™ is a useful tool for emergency response to acts of bioterrorism or naturally occurring disease outbreaks in Nebraska." It was interesting to note that while seven respondents (26.9 percent) were neutral or disagreed with the statement "This system has all the functions/capabilities I expect it to have," none of them took advantage of the opportunity to write additional comments or suggestions.

Emergency Notification Evaluation: TEREX Exercises

Emergency notification response functionality was measured during TEREX 2005, a Nebraska statewide bioterrorism exercise. In an emergency, laboratorians are instructed to log on to STAT-

Table 6.4

Summary of Survey Responses

Statement	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
I received adequate training to use the STATPack™ system.	10 (37%)	13 (48.1%)	3 (11.1%)	1 (3.7%)	0 (0%)
It was easy to learn how to use the STATPack™ system.	10 (37%)	13 (48.1%)	3 (11.1%)	1 (3.7%)	0 (0%)
It takes too long to use the system to make it worth the effort.	0 (0%)	2 (7.4%)	2 (7.4%)	13 (48.1%)	10 (37%)
In an emergency, I could effectively complete the tasks.	10 (37%)	14 (51.9%)	1 (3.7%)	2 (7.4%)	0 (0%)
In an emergency, I would get a quick response from NPHL.	12 (44.4%)	12 (44.4%)	1 (3.7%)	2 (7.4%)	0 (0%)
The STATPack™ is a reliable tool for consulting with NPHL.	11 (40.7%)	14 (51.9%)	2 (7.4%)	0 (0%)	0 (0%)
I believe it's important to be prepared.	17 (65.4%)	7 (25.9%)	1 (3.7%)	0 (0%)	1 (3.7%)
The STATPack™ is a useful tool for emergency response.	14 (51.9%)	10 (37%)	1 (3.7%)	0 (0%)	0 (0%)
The STATPack™ takes up too much space in my work area.	1 (3.7%)	1 (3.7%)	9 (33.3%)	10 (37%)	6 (22.2%)
I feel comfortable sending macro images.	7 (25.9%)	15 (55.6%)	3 (11.1%)	2 (7.4%)	0 (0%)
I feel comfortable sending micro images.	2 (7.4%)	8 (29.6%)	6 (22.2%)	2 (7.4%)	1 (3.7%)
I feel that STATPack™ is a useful system to have in my laboratory.	10 (37%)	13 (48.1%)	3 (11.1%)	1 (3.7%)	0 (0%)
Overall, I am satisfied with how easy it is to use the system.	8 (29.6%)	16 (59.3%)	2 (7.4%)	1 (3.7%)	0 (0%)
This system has all the functions/capabilities I expect.	5 (19.2%)	14 (51.9%)	4 (15.4%)	3 (11.11%)	0 (0%)
I like using the STATPack™.	4 (15.4%)	15 (55.6%)	7 (25.9%)	0 (0%)	0 (0%)

Source: Johnson and Fruhling (2006).

Pack™ when they hear the system's audible alarm or notice a visual notice on the screen and reply to the accompanying message from the Nebraska Public Health Laboratory (NPHL). The STATPack™ component of this exercise consisted of an emergency notification sent from the NPHL to nine clinical (spoke) diagnostic laboratories.

During the TEREX 2005 exercise, the alert notification was successfully sent from the NPHL and received by all nine participating laboratories. All laboratories responded to the message within fifteen minutes; however, two of the labs were unable to reply through STATPack™ and some replies contained incomplete information. This was corrected by adding a simplified "Reply" button to all STATPack™ systems. Alternative password/log-in procedures were also considered because one of the laboratorians was simply unable to log on to STATPack™. This problem was due to the num-lock key being on and the user did not realize it. To alleviate the problem, a system enhancement has been made that allows multiple log-ins at each laboratory. This enables the NPHL consultant to guide STATPack™ clients through the log-in process over the phone if they have forgotten or misplaced their passwords. There were also some network issues. Because the response was not as good as desired, a second TEREX 5.5 was scheduled.

STATPack™ was again evaluated in the TEREX 5.5 exercise in May 2006, for thirteen of the fifteen locations that had the system up and running. One location was not included because it was experiencing network issues, and another location was waiting for replacement hardware. Twelve out of the thirteen spoke locations (92.3 percent) successfully completed the exercise. The two locations that were most recently installed had problems. Those at one location had their monitor turned off and did not see or hear the notice. Those at the other location had the volume on the speaker very low so they could not hear the audible notification; however, they did respond within an hour. Overall, the mean turnaround time was 7.17 minutes and the median was 5 minutes. Future TEREX exercises are planned.

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). For example, the CDC has issued guidance on public health surveillance and detection capabilities for recipients of CDC funding. The CDC urges them to assess, at least annually, 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). Funding recipients are asked to assess these capabilities, but what level of completeness and timeliness is necessary? How are completeness and timeliness even measured? No studies tell policy makers the answers to these questions (Asch et al., 2005). It seems reasonable to conclude that the use of STATPack™ will improve the timeliness of disease reporting. But because all suspect samples are eventually submitted to the hub laboratory for confirmation testing, with or without STATPack™ consultation, it seems unlikely that completeness would be enhanced by this system.

Suspicious Organism Consultations

In 2005, the first year of STATPack™'s introduction, there were ten documented cases where spoke laboratories successfully used STATPack™ to consult with the hub laboratory about suspicious biological agents. (At that time, nine systems were deployed in spoke laboratories.) In each of these cases, the spoke laboratory technicians were able to capture and send images, send text messages, and receive guidance from hub laboratory experts for further testing or sample submission. The microorganisms most frequently encountered were *Francisella tularensis,* which causes tularemia (rabbit fever), a potentially deadly disease, and *Bacillus spp* (anthrax suspect).

In addition, STATPack™ was used to help identify less significant but technically challenging cultures such as *Clostridium perfringens,* and various fungal organisms.

The number of cases in Nebraska increased to twenty-five in 2006, and the number of systems deployed increased to eighteen. Several planned training exercises were conducted during the implementation of the STATPack™ system, and this helped the laboratorians become more familiar with the system on a routine basis.

Figure 6.6 shows a graphical representation of the usage of STATPack™ in Nebraska. As easily seen in the chart, the most common activity seems to be messages sent to and from the spoke-and-hub laboratories. However, spoke laboratories are also using STATPack™ for documentation of local or internal cases (denoted as stored.)

STATPack™ has also been used for consultation in Oklahoma and Kansas. The installation of the twenty STATPack™ systems placed in these states has only recently been completed, however, and therefore the number of cases that occurred in the past year is not representative.

A summary of the system usage by all message activity (e.g., emergency, consultation, training/educational) by state is shown in Table 6.5. Since the inception of STATPack™, over 2,800 messages and images have been processed in the three states. Messages are distinguished by activity—received, sent, or messages that store images locally for reference. Nebraska completed installation of their twenty systems in January 2007, Oklahoma completed installation of their eleven systems in May 2007, and Kansas completed installation of their nine systems in July 2007.

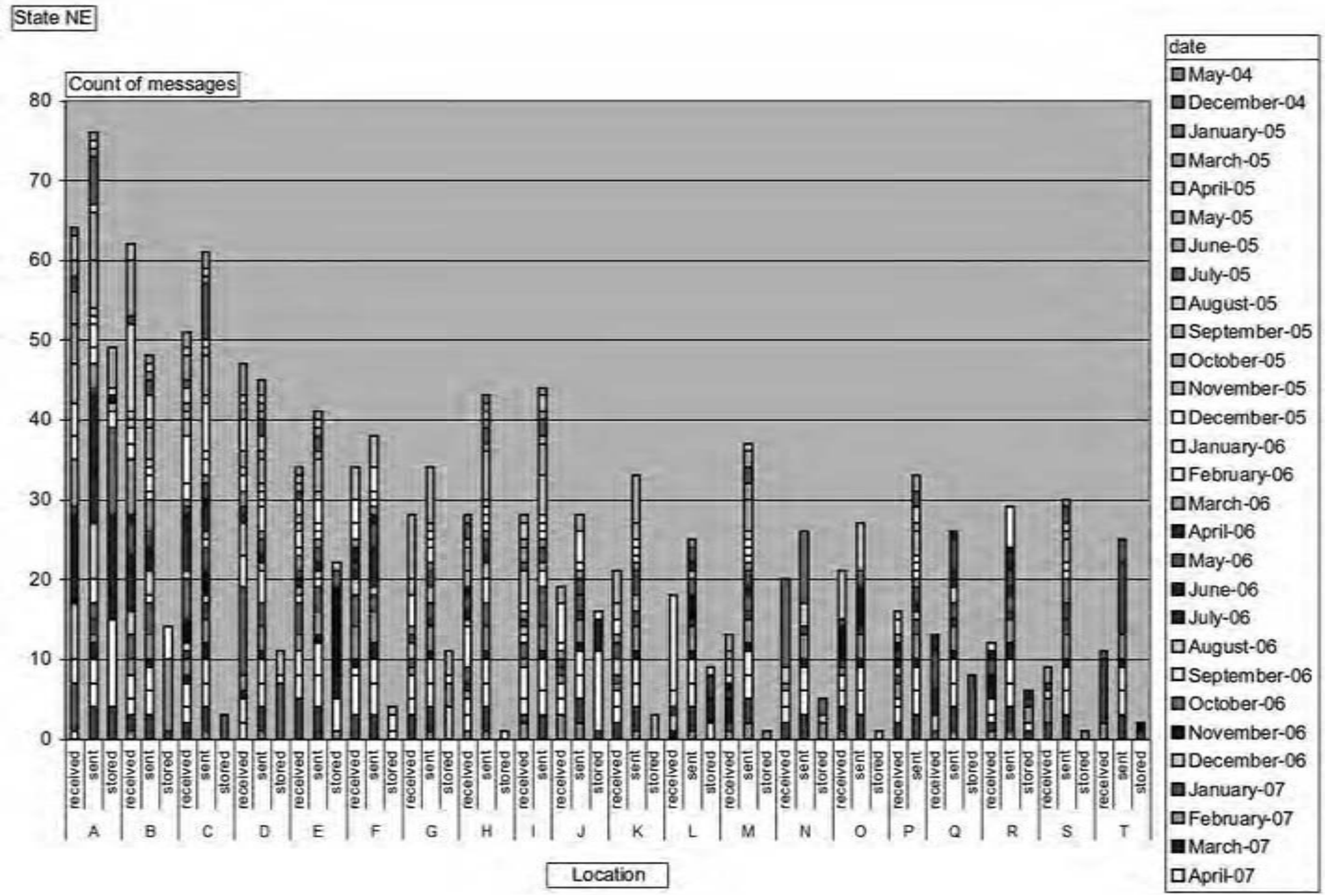
A recent example of how the STATPack™ was used for suspicious organism consultation follows. Shortly after the STATPack™ system was installed at a medical center in Oklahoma, a medical technician was doing tests on a patient's blood. The technician saw something unusual—malaria (*Enid News,* 2006). The laboratory technician found a malaria parasite on a patient but was unsure which of the four malaria-causing organisms s/he was viewing—a critical factor in determining the proper treatment. (Malaria had not been seen in the laboratory for the past ten years.) One of the four malaria-causing organisms can be deadly. Using the STATPack™ system (see Figure 6.7), the laboratory technician sent an image to the hub parasitologist expert and received an answer in minutes, saving the several hours it may have taken to hand deliver the sample to the state public health laboratory facility. The medical staff at the medical center were able to get help in determining which form of malaria it was, and, therefore, they were able to prescribe proper treatment quickly.

This example clearly illustrates the importance and usefulness of STATPack™ by utilizing specialists who are always available, through a beeper system, 24/7. It also demonstrates that if the state laboratory microbiologist is not at the hub laboratory, s/he can securely log on to the STATPack™ system through the Internet wherever s/he is and provide his or her expertise. In the case mentioned above, the parasitologist was on the road and within a short period of time, he was able to log on remotely to view the laboratory microscopic images and provide immediate consultation.

STATPack™ has also been used for bacteria consultation on potential *Bacillus anthracis* samples, an unusual fungal colony, *Stachybotrys,* suspicious Gram-negative *Bacillus cocci,* suspect *Neisseria,* tiny Gram-negative rods including *Francisella tularensis,* and large Gram-positive *cocci.* Examples of some of the cases and images are shown in Figure 6.8.

Perhaps the results are best summed up by a microbiology supervisor at a rural community hospital in Nebraska who said that using the STATPack™ "has opened up the lines of communication" between labs. It has created cohesiveness between the state Public Health Laboratories and the laboratories like hers in outlying areas. She adds, "I feel more secure having the technology. If something were to occur, communication with the state Public Health Laboratory would be

Figure 6.6 **Nebraska STATPack™ Usage from Inception**



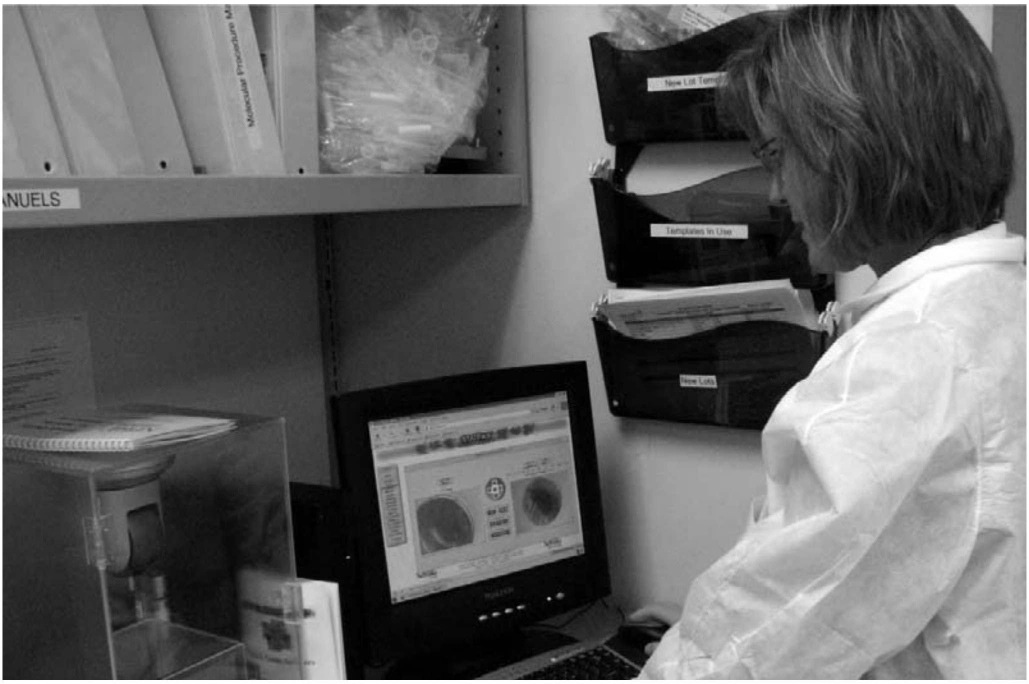
Note: Letters indicate town/city in Nebraska.

Table 6.5

Summary of Message Usage

	Count of Messages			
	State			
Message Type	Kansas	Nebraska	Oklahoma	Grand Total
Messages Received from Hub Laboratory	83	604	233	920
Messages Sent from Spoke Laboratory	84	863	230	1177
Messages Stored at Spoke Laboratories for Education and Training	64	183	521	768
Grand Total	231	1650	984	2865

Figure 6.7 **Medical Lab Technician Accessing STATPack™**

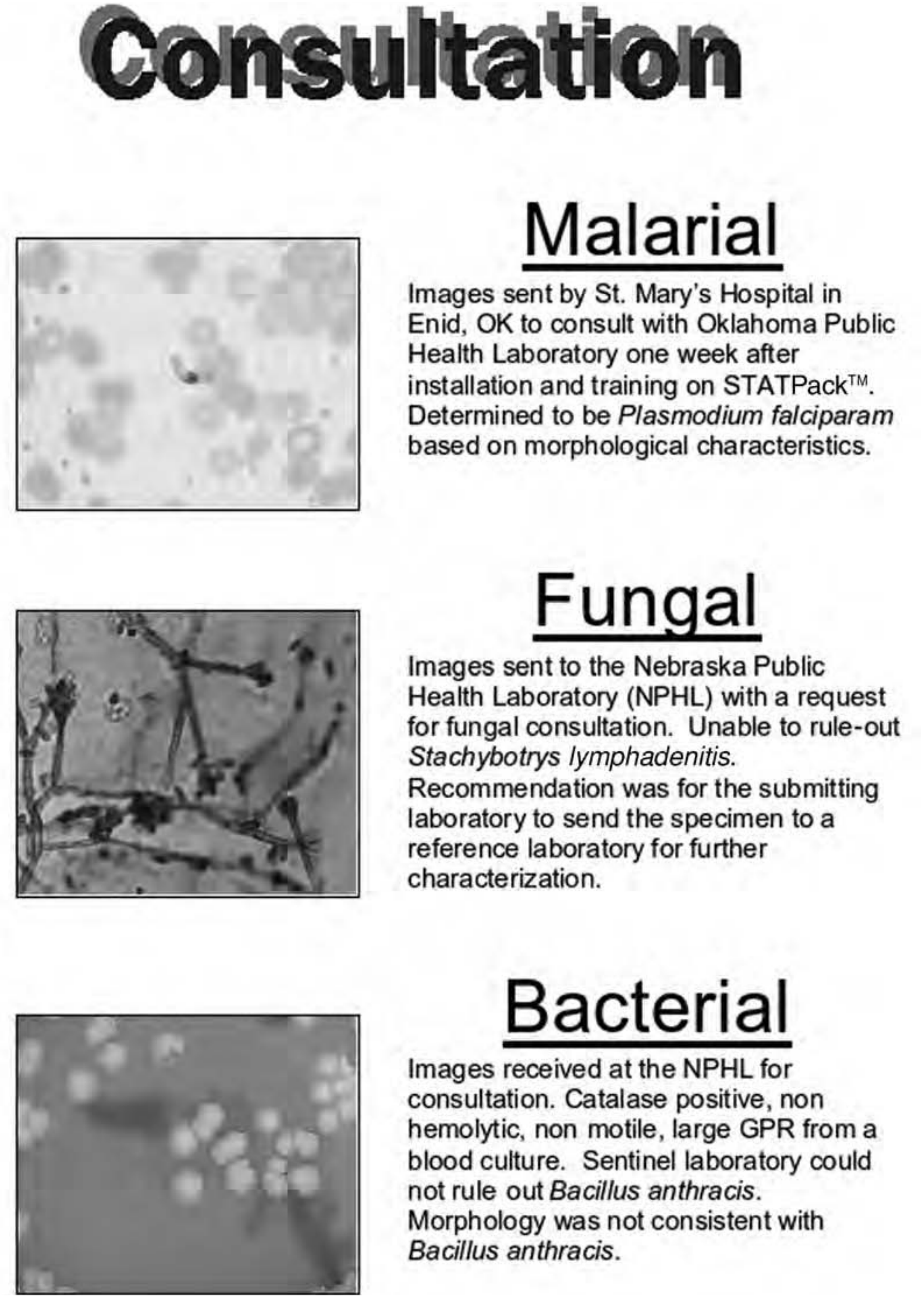


immediate." State Health Department medical technicians have twenty-four-hours-a-day, seven-days-a-week direct consultation services available through the STATPack™ system.

Education and Training Uses

STATPack™ has also been used frequently for nonemergency purposes such as education and training. For example, the Oklahoma Veterinary Laboratory uses the STATPack™ system on a daily basis for a variety of reasons. The laboratory manager shared the following:

Figure 6.8 **Examples of Cases**



Consultation

Malarial

Images sent by St. Mary's Hospital in Enid, OK to consult with Oklahoma Public Health Laboratory one week after installation and training on STATPack™. Determined to be *Plasmodium falciparam* based on morphological characteristics.

Fungal

Images sent to the Nebraska Public Health Laboratory (NPHL) with a request for fungal consultation. Unable to rule-out *Stachybotrys lymphadenitis*. Recommendation was for the submitting laboratory to send the specimen to a reference laboratory for further characterization.

Bacterial

Images received at the NPHL for consultation. Catalase positive, non hemolytic, non motile, large GPR from a blood culture. Sentinel laboratory could not rule out *Bacillus anthracis*. Morphology was not consistent with *Bacillus anthracis*.

Source: Fruhling et al. (2007).

> We do use the STATPack™ on a somewhat routine basis. I am the laboratory manager in the bacteriology/mycology area. We have found it useful for a number of things. We are writing new SOP's in our area, and using photographs from "real" cases for this and for training new employees have been great. We have used the system for documentation of some of our interesting bacteriology cases. This has been great for future training on case types we do not get often. We have been documenting many of our mycology cases for routine as well as interesting/unusual cases. The images can be inserted into a Word document and filed with the case. We also occasionally have someone ask us if we have photographs for cases that they are going to write up for publication. This is the main reason we started documenting almost all of our mycology cases, because the pathologist would be asking us for photographs 2 to 3 months after we had disposed of the cultures, of course. These are some of the things we have used the system for so far. So far I have not asked for consultation on any of the images produced by the system, but that is of course what the system was designed to do, and we do keep that option in mind.

Examples of images used for education and training are shown in Figure 6.9.

Lessons Learned

Several insights were discovered. First, remembering log-ins and passwords can be a barrier for emergency response systems that are not used often. Second, training and practice on the system are essential, especially when using specialized equipment such as a microscope digital imaging interface control unit. Additional practice helps improve confidence during an emergency. This finding is congruent with the observation that an emergency system that is not used on a regular basis before an emergency will never be of use in an actual emergency (Turoff et al., 2004).

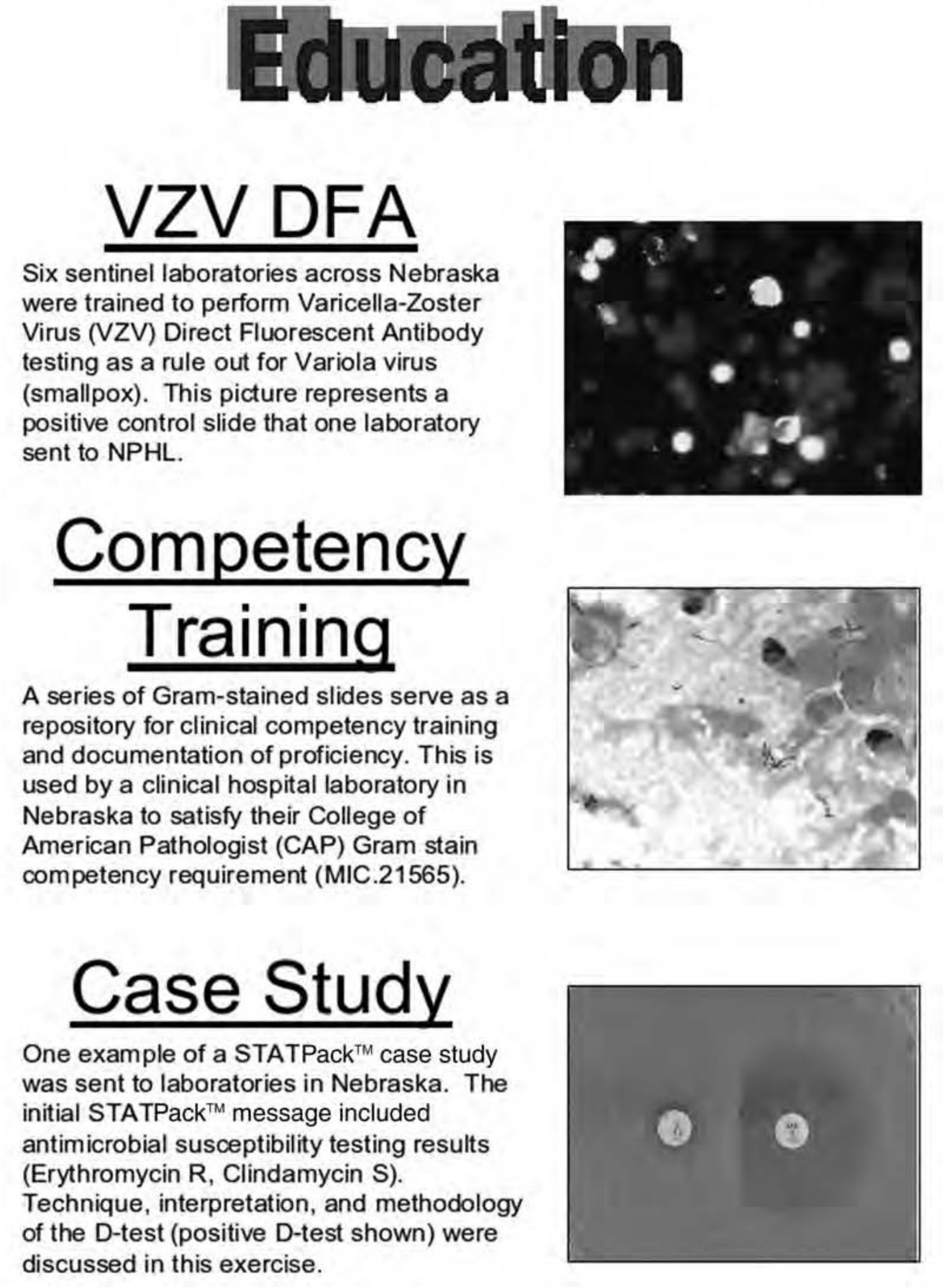
Third, communications using emergency response systems between the hub-and-spoke laboratories should be practiced in nonemergency situations. Also, because of turnover of staff, refresher training should be offered routinely. Fourth, network issues need to be managed. In the case of the STATPack™ system, system maintainers are notified if a network connection is down more than fifteen minutes.

The evaluation of the STATPack™ during actual emergencies confirmed that the digital images sent to experts were of the quality that they could provide consultation. It was also confirmed that the STATPack™ system does save time and provide medical assistance when experts are on the road. An unforeseen result from the implementation of the system was the amount of usage by some locations for internal documentation and reference. The STATPack™ has also improved communication between hub-and-spoke laboratories as reported by several users.

STATPack™ performed as expected in recent emergency situations for various individual labs and after the first TEREX exercise it has performed satisfactorily in a planned training exercise involving all labs in the network. It was evident from the results of the malaria case that it is an easy-to-use system; the laboratory had the system in place for less than ten days but nevertheless laboratory technicians were able to use it easily in an emergency.

We also saw that STATPack™ improved the timeliness of patient care and overall has positively impacted public health surveillance of reportable diseases to the CDC. In addition, end users found other productive uses for the STATPack™ system that improved their day-today activities, such as documenting interesting cases and supporting local training and education. Building system

Figure 6.9 **Examples of Education Uses of STATPack™**



Education

VZV DFA

Six sentinel laboratories across Nebraska were trained to perform Varicella-Zoster Virus (VZV) Direct Fluorescent Antibody testing as a rule out for Variola virus (smallpox). This picture represents a positive control slide that one laboratory sent to NPHL.

Competency Training

A series of Gram-stained slides serve as a repository for clinical competency training and documentation of proficiency. This is used by a clinical hospital laboratory in Nebraska to satisfy their College of American Pathologist (CAP) Gram stain competency requirement (MIC.21565).

Case Study

One example of a STATPack™ case study was sent to laboratories in Nebraska. The initial STATPack™ message included antimicrobial susceptibility testing results (Erythromycin R, Clindamycin S). Technique, interpretation, and methodology of the D-test (positive D-test shown) were discussed in this exercise.

Source: Fruhling et al. (2007).

use into routine operations is important for maintaining its ability to be used in emergencies, and should be encouraged.

In the future, it is expected that the evaluation of the STATPack™ system will include communications among state public health laboratories, now that they are connected.

CONCLUSION

Threats of bioterrorism and high-profile disease outbreaks have accelerated the efforts of public health laboratories to establish better communication networks with private clinical laboratories. The STATPack™ system is designed to support distance consultation, integrate statewide laboratory-based disease surveillance, and to facilitate prompt response to public health threats such as bioterrorism.

Since 9/11, multiple agencies have worked at improving emergency readiness in the United States. The federal government has provided several funding sources for state and local governments, academia, and private business to analyze, design, and create emergency response systems for public safety. Much has been published on what problems need to be addressed and on proposed solutions. Less has been reported on actual systems and even less on actual usage of such systems. This chapter reported on the actual day-to-day and emergency usage of an emergency response system for bioterrorism preparedness for public health laboratories that has been implemented in three midwestern states.

There are several contributions from this research. First, it described one of the few, if not the only, video telemedicine consultation system that is available for state public health labs to consult and help identify suspicious organisms with the outlying laboratories they support. Second, the study described actual emergency cases in which the system was used for immediate consultation and how well the system worked. Finally, the lessons learned from a post-implementation perspective are reported.

A limitation of this research is that the emergency response system examined in this study was specifically developed for electronic laboratory diagnostics consultation and response to public health emergencies. Thus, generalization of the research results is restricted.

This study demonstrates that an SPHL serving geographically dispersed rural communities was able to effectively, efficiently, and electronically share critical microbiology and pathological health information in emergency situations using a newly developed statewide networked of computerized public health ERS known as STATPack™ . STATPack™ is proving to be a valuable tool for SPHLs and has the potential to impact public health systems worldwide. For example, according to J. Rex Astles, Ph.D., senior health scientist at the CDC’s Laboratory Systems Development Branch in Atlanta, few people are trained in China for public health issues. The country is so big geographically; STATPack™ could be used by someone in a public health agency in Beijing to look at a culture that is under a microscope in a laboratory clear across the country.

ACKNOWLEDGMENTS

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APPENDIX 6.1

STATPACK™ SAMPLE EVALUATION

For each of the following questions, please circle the response which best describes the laboratory in which you work:

1. Hospital clinical laboratory
2. Non-clinical laboratory

The driving distance from my laboratory to the Nebraska Public Health Laboratory in Omaha is approximately:

1. 25 miles or less
2. 25–100 miles
3. 100–200 miles
4. 200–300 miles
5. Greater than 300 miles

The total number of people who work in my microbiology lab during a typical day shift is:

1. 1 or 2
2. 3–5
3. 6–8
4. 9 or more

The total number of cultures performed in my laboratory in a typical week is approximately:

1. 0–50
2. 50–100
3. 100–150
4. 150 or more
5. I don't know

During the course of a week, I typically spend approximately _____ hours using a computer (work and personal use combined).

1. 0–5 hrs
2. 5–10 hrs
3. 10–20 hrs
4. More than 20 hrs

The last time I logged on to the STATPack™ system was:

1. Within the past week
2. Less than a month ago
3. 1–2 months ago
4. More than 2 months ago

To what extent do you agree or disagree with each of the following?	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
	1	2	3	4	5
I received adequate training to use the STATPack™ system.	1	2	3	4	5
It was easy to learn how to use the STATPack™ system.	1	2	3	4	5
It takes too long to use the system to make it worth the effort.	1	2	3	4	5
In an emergency, I could effectively complete the tasks required to consult with the Nebraska Public Health Laboratory (NPHL) using STATPack™.	1	2	3	4	5
I feel confident that I would get a quick response from NPHL using the STATPack™ in an emergency.	1	2	3	4	5
The STATPack™ is a useful tool for emergency response to acts of bioterrorism or naturally occurring disease outbreaks in Nebraska.	1	2	3	4	5
I believe it's important to be prepared for health-related emergencies such as acts of bioterrorism or naturally occurring disease outbreaks.	1	2	3	4	5
The threats of bioterrorism and natural disease outbreaks have been greatly exaggerated. These are unlikely to occur in Nebraska.	1	2	3	4	5
The STATPack™ takes up too much space in my work area.	1	2	3	4	5
I feel comfortable using the system to capture and send (macro) images of colony growth.	1	2	3	4	5
I feel comfortable using the system to capture and send images from the microscope (please circle N/A if your STATPack™ is not equipped with a microscope interface).	1	2	3	4	5 or N/A
I feel that the STATPack™ is a useful system to have in my laboratory.	1	2	3	4	5
Overall, I am satisfied with how easy it is to use the system.	1	2	3	4	5
This system has all the functions and capabilities I expect it to have.	1	2	3	4	5
I like using the STATPack™.	1	2	3	4	5

Please use this blank page if you would like to offer any additional comments or suggestions about the STATPack™ system.

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CHAPTER 7

COORDINATION OF EMERGENCY RESPONSE

An Examination of the Roles of People, Process, and Information Technology

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Abstract: *Coordination management plays an important role in emergency response as it resolves the complex and dynamic interdependences among actors, resources, information, and decision making. Review of current emergency response practice suggests that emergency coordination is an understudied research area and new knowledge in this area is of high importance. In this chapter, we examine the roles of people, process, and information technology and their impacts on emergency coordination. Through a case study of Snowstorm 2006 in western New York, we demonstrate their practical operation and evaluate their individual performance. Further, we summarize the important lessons learned in the management of these factors and propose solutions. Also included in the chapter is a detailed discussion of one cutting-edge emergency response system named DisasterLAN, through which we demonstrate how modern response systems are designed and in what ways they facilitate emergency coordination.*

Keywords: *Emergency Response, Coordination Management, Case Study, People, Process, Information Technology*

Increased attention has recently been directed toward extreme events and their response management. Emergency events such as natural disasters and man-made accidents are characterized by their rare occurrence and the high risk of negative consequences if decisions in response to the emergency are slow, uninformed, or inadequate (Ajenstat et al., 2007). As emergency management typically involves a complex network of tasks, resources, and actors, coordination emerges as a critical management aspect that should be used to address the embedded interdependences for smooth and efficient response operations (Turoff, 2002).

Coordination is a specific form of decision making wherein the problems associated with the different possible responses are interdependent; Malone and Crowston, 1990, 1994). Challenges ranging from limited information, unpredictable development, short time windows, and high risks all threaten the response organizations in their ability to make rapid and sound coordination decisions. The governmental reports of coordination in recent rare events, such as the 9/11 attack and Hurricane Katrina, reveal enormous failures, calling for further research to improve coordination practices (Executive Office of the President, 2006).

This chapter investigates research questions, including:

1. How is coordination managed in extreme events?
2. What procedures and mechanisms are typically utilized for coordination decision making?
3. What are the current practices of information systems for coordination support?

Utilizing a case study of response coordination in one large-scale natural disaster, this chapter provides a rich account of organizational coordination in extreme events with in-depth details on coordination problems, management structures, coordination processes, and the role of technology in supporting decision-making processes.

The next section reviews the existing literature on emergency coordination. Then, we introduce the case research methodology employed for data collection, followed by a detailed description of coordination management in the case under study. Next, we discuss the lessons learned in coordination decision making, and end by summarizing the contribution of this study.

BACKGROUND

This section summarizes the coordination literature and prior, related research on information systems. Coordination is "managing dependencies between activities" (Malone and Crowston 1994, 90). By focusing on the flow of work, materials, and objects, Thompson (1967) defines interdependence in terms of workflow in the forms of being pooled, sequential, and reciprocal. Van de Ven and colleagues (1976) and Rao and colleagues (1992) further suggest *team* or *concurrent* interdependence, which refers to situations wherein the work is undertaken jointly by unit personnel who diagnose, solve problems, and collaborate in order to complete the work.

Emergency responses typically represent the above interdependences as they involve complex response tasks, resources, responder personnel, and information flows. These entities are likely to be physically dispersed across geographical boundaries and/or jurisdictional municipalities. Unlike a normal event, the interdependence in an emergency context undergoes rapid changes when new entities join the response organization or when existing entities are dismissed, modified, or restructured throughout the course of the response to cope with incident development.

Prior studies have identified a rich volume of mechanisms addressing the interdependences. The mechanisms may include standardization, planning, mutual adjustment, and routine (Galbraith, 1973; Malone and Crowston, 1994; Thompson, 1967). These mechanisms, static or dynamic, prescribe how the decisions will be made to solve the problems associated with interdependences. From the perspective of information processing, these mechanisms vary in their information bandwidth and richness (Galbraith, 1973). Considerations of social structure, conflict, information quality and quantity, cost, technology, and task all have a role in determining when individual mechanisms may be preferred (Galbraith, 1973; Shapiro, 1977; Van de Ven et al., 1976; Victor and Blackburn, 1987).

Despite increasing interest in the organizational coordination of extreme events, little is known about how to effectively make coordination decisions in trying conditions. It remains unclear whether, and to what extent, the conventional wisdom is still valid in abnormal circumstances (Petrescu-Prahova and Butts, 2005). Although recent studies have explored coordination decision making in contexts such as software development, new product design, and supply chain management, where there exist moderate levels of velocity of change, uncertainty, and pressure, further research is necessary (Montoya-Weiss et al. 2001; Piplani and Fu, 2005; Raghu et al. 1998; Simatupang et al. 2004; Van de Walle and Turoff, 2007, 2008). Moreover, there is a lack of awareness

Figure 7.1 **Snowstorm 2006 Affected Areas: Erie, Niagara, Orleans, and Genesee Counties**

Source: Excerpt from FEMA 2006. "FEMA-1665-DR New York Disaster Declaration (10/24/2006)," M.A.C. Center (ed.), Federal Emergency Management Agency, Washington, DC.

about the current practice of information technology in emergency management coordination. Aside from a few attempts (Chen et al., 2005; Mendonça et al., 2007; Shen and Shaw, 2004), emergency coordination support has not been the focus of information systems (IS) research (Currion et al. 2007; Fiedrich and Burghardt, 2007; Manoj and Baker, 2007; Simon and Turoff, 2007).

RESEARCH APPROACH

Case research is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (Yin 1994). As a solid research methodology, case research is widely adopted by IS researchers (Dube and Pare, 2003). The abundance of case research has developed a systematic methodological framework. We follow the work of Benbasat and colleagues (1987), Eisenhardt (1989), Lee (1989), Yin (1994), and Dube and Pare (2003), all of whom have a strong influence on the conduct of case study research in the IS field. The research reported here takes a single-case study approach. Despite the typical criticism, the single case study is by far the most frequently utilized format of case research (Dube and Pare, 2003) and it is deemed rigorous when the relevant methodological concerns are addressed properly (Bonoma, 1985; Ragin, 1999; Yin, 1994). In this regard, we follow the guidelines

Table 7.1

Summary of Risks in the October 2006 Snowstorm

Large-scale impact	Over 73 local municipalities in western New York with a population of over 1 million people were affected
Huge damage	Estimated loss of more than $500 million as estimated to date. A total of 17 storm-related deaths, 151 hospitalizations, and 177 injuries were reported
Multiple hazards	Snowstorm, power outage, water outage, water pollution, disrupted traffic, and floods
Critical infrastructure interdependence	Hospital, food, shelter, power, communication, and transportation

proposed by Lee (1989), who demonstrates how to make controlled observations and deductions as well as how to allow for replicability and generalizability when using a single case. That is, natural controls or verbal propositions, among others, are practiced whenever possible.

The current research is an intensive study of coordination decision making in response to the October 2006 snowstorm in western New York. The case study involves an entire configuration of individuals, organizational structure, and advanced information technology inside the Incident Command System (ICS) set up in Erie County, New York. From a site selection standpoint, the October 2006 snowstorm proves to be an ideal case to study as it meets the general site selection criteria for a single-case design proposed by Dube and Pare (2003). The tremendous media coverage of this particular incident, the unique attributes of the disaster and its complex impacts, and the fact that key actors can be located for interviews all point to the necessity to study this particular case site. As suggested by Yin (1994), the authors conducted a pilot case study four months prior to the launch of the main case study. Through interviews and onsite observations, the pilot case helps the authors determine the appropriate unit of analysis, refine data collection instruments, and familiarize researchers with the phenomenon.

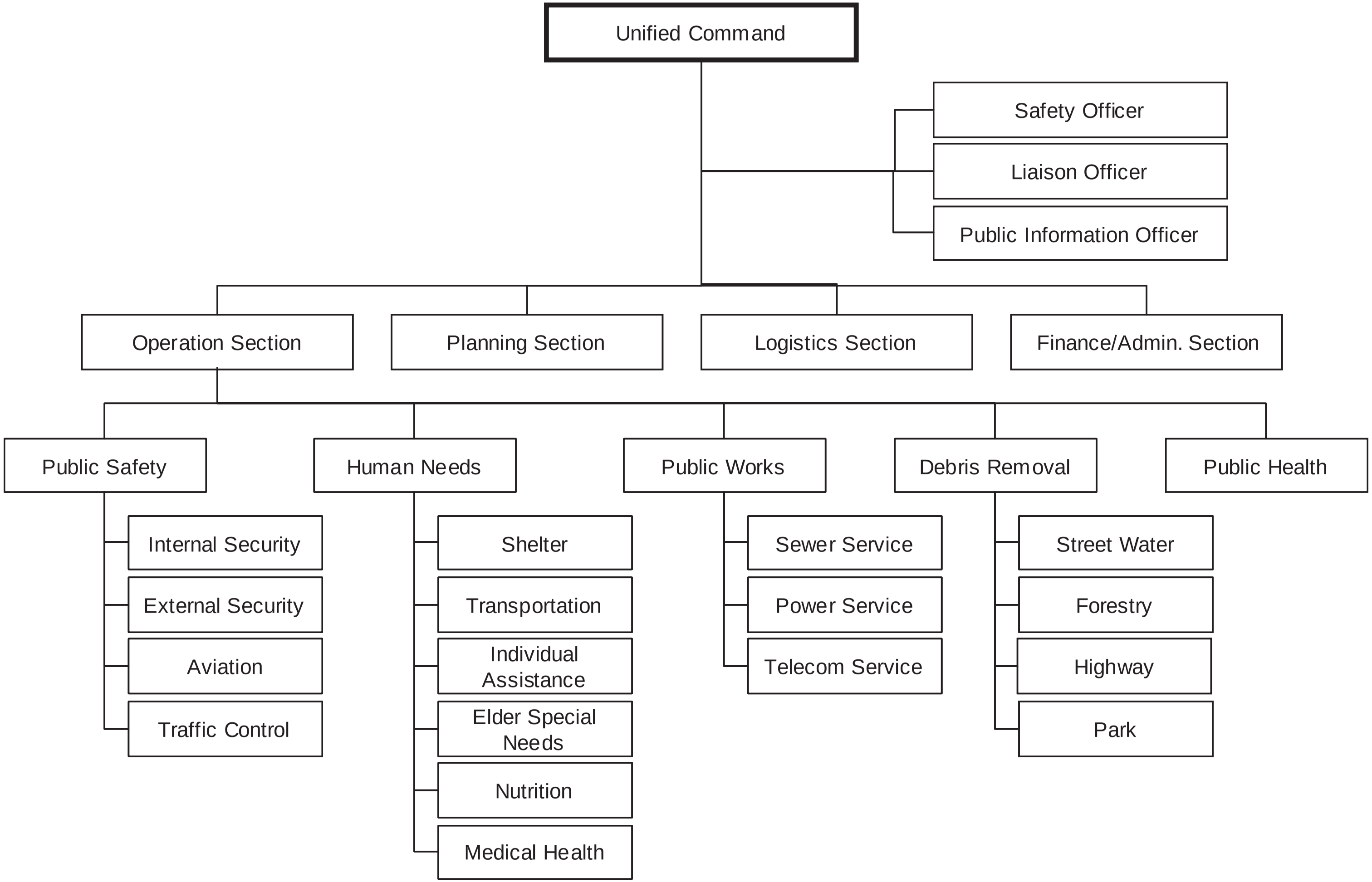
To begin our data gathering, we first consulted published reports on the October 2006 snowstorm. We found more than 100 articles published in national and local media, either online or paper-based printouts. We also contacted the ICS managers who assumed key decision roles for incident coordination during the response to the incident. These contacts are executives (e.g., chiefs and commissioners) of emergency services from multiple municipalities as well as across county, city, town, and village levels of government. Over a two-month period, we conducted multiple rounds of field research in the form of onsite observations, semistructured interviews, and further document reviews. The collected data include 500-plus pages of internal reports, action plans, fact sheets, e-mail correspondence, and 100-plus pages of interview transcripts.

THE OCTOBER 2006 SNOWSTORM AND INCIDENT COORDINATION

This section presents background information about the organizational coordination of the response to the October 2006 snowstorm. It highlights the major coordination problems, organization structures, and coordination process in decision making.

On October 12, 2006, an unseasonable lake-effect snowstorm hit the western New York area with record-breaking snowfalls while leaves were still on trees. The snowstorm downed thousands of tree limbs and toppled power lines, leaving about one million people in western New York

Figure 7.2 **A Partial Illustration of Incident Command System Organizational Structure**



without electricity for up to ten days (Fairbanks, 2008). The combination of melting snow and rain showers overnight also resulted in flooding hazards. Flood watches were issued and a response was launched in multiple counties. On October 13, Governor George Pataki declared a state of emergency for Erie, Genesee, Niagara, and Orleans counties. On October 20, President George W. Bush signed a Major Declaration for Individual Assistance (IA) and Public Assistance (PA) for the above four counties along with Health and Medical (HM) for all counties in New York State. A 105-mile stretch of the New York State Thruway from Rochester to Dunkirk was closed on the morning of October 15 because of the snow. Local municipalities also issued numerous traffic bans. This incident was a devastating event. See Figure 7.1 on page 152.

Erie County was the most impacted area in the October Snowstorm. This case study is focused on incident coordination inside Erie County. Erie County specifically plays a regional role in managing and supporting countywide emergency responses through interactions with local, State of New York, and federal government agencies (Whetham, 2006). In the event of the October 2006 Snowstorm, Erie County set up an Incident Command System to oversee and direct the countywide (one city, seventeen towns, and six villages) incident management. The command staff was located at Erie County Emergency Operations Center (EOC) with an emergency response team, at full operation, which totaled in excess of 200 individuals (ibid.). The response organizational structure is captured in Figure 7.2. For the sake of simplicity, we delineate only a small portion of the complete organizational structure, yet this chart still sufficiently reveals the complexity involved which highly challenged coordination decision making at Erie County.

- Agencies under coordination: all the local response organizations at the levels of county, city, town, and village, State Emergency Management Office, State Health Department, State Highway Authority, Federal Emergency Management Agency, Coast Guard, Activity Military Duty, Army Corps of Engineers, National Guard, National Grid, New York Electricity & Gas, and Red Cross, National Weather Service, Southern Baptist Disaster Relief, and AmeriCorps
- Tasks under coordination: public safety and security, transportation, food and shelter, information and telecommunications, public works and engineering, public assistance, individual assistance, environment protection, resource support, public health and medical services, hazardous materials disposal, energy restoration, public information dissemination, and education
- Resource under coordination: strike teams, food, water, medical supplies, shelters, snowplow, water tankers, debris removal tools, and generators
- Information under coordination: situation report, resource request, incident action plan, weather forecast, public announcement and advisory

The command staff deemed the Incident Command System (ICS) [now part of the National Incident Management System (NIMS)] as the foundation to emergency coordination as it provides the overarching structures (Whetham, 2006). Evolving from the 1970s, ICS is now a national standard for emergency management (National Wildfire Coordinating Group, 2004). As we observed from the case of the 2006 snowstorm, ICS facilitated the response coordination through five major schemes:

1. it constructed a clear organizational hierarchy that directed both information and decision structures;
2. it broke down organizational goals into microstructures where specialized personnel might excel in operations and decision making;

3. it prescribed general roles, responsibilities, and accountabilities for decision makers at each organizational layer and position;
4. it standardized the skills, functions, and input/outputs of internal structures to allow for smooth and interconnected operation; and
5. it established the protocols of reporting, meeting, and cross-boundary adjustments for fast coordination.

More detailed response operations were coordinated through the use of incident action plans (IAPs), which outline the measurable strategic operations to be achieved. During each of the operation periods (06:00–18:00 and 18:00–06:00), the Planning Section of ICS developed an IAP that was to be implemented for the next operation period. Key components of the IAPs designed for this incident included control objectives for the incident (sometimes alternatives as well), the weather forecast for the period, safety messages, organization assignment lists, division assignment lists, communications plans, medical plans, incident maps, and traffic plans. Through IAPs, response operations were coordinated in the following ways: (1) the same overall assumptions, goals, and objectives were set straight for all the participating agencies, (2) a situational awareness of the incident progress and predictions, (3) a mutual awareness of the contact, status, and operations of other agencies in supportive roles, and (4) detailed task assignments, workflow schedules, resource allocation schemes, and dedicated communication channels in place.

To manage the heavy interdependency such as those of critical infrastructures, ICS established complex decision-making processes that strongly emphasized a high level of collaboration. Between ICS and external key stakeholders, the command staff made conference calls to all the towns, mayors, and supervisors twice a day for all those involved to communicate about the situation and their progress. Through consensus-building processes, the meeting established the overall direction of the response and prioritized the critical operations. Inside ICS, all the sections joined together for decision making on critical issues. Take IAP development, for example. The chief of Planning section met with representatives from Operation, Logistics, and Finance/Admin. sections at least once per each operation period to discuss IAP development. During the meetings, representatives discussed the plans, shared opinions, and made note of individual concerns or needs so that the plans could consequently be improved with advocacy. Once updated, the IAP was submitted to the Unified Command, which discussed and argued its pros and cons before finalizing it for implementation. Decision-making rules in these meetings included reliance on protocols, contestation, joint sense making, cross-boundary intervention, and voting.

TECHNOLOGY SUPPORT FROM DISASTERLAN

The organizational coordination at the EOC was leveraged by advanced information systems such as DisasterLAN (www.disasterlan.com). DisasterLAN is a work-flow-based, commercial, off-the-shelf software purchased by the state of New York and made available to all the municipalities including Erie County. It replaced the conventional "paper-pencil"-based management approach to digitalize information flow and semiautomated decision support; and thus it assisted the EOC in coordinating the management of the entire incident. Key functions of DisasterLAN include call center service, incident status board, integrated message broadcasting system, asset management tool, contact management tool, and numerous reporting and task management tools (Buffalo Computer Geographics [BCG], 2007). These modules offer a wide range of support for coordinating the emergency management efforts.

DisasterLAN exemplifies cutting-edge emergency management systems. In the remainder of this section, we discuss its key design features along with their respective performance in the management of Snowstorm 2006. The discussion attempts to acquaint the readers with advanced emergency management systems through the example of DisasterLAN. A short summary of DisasterLAN features and issues is presented in Table 7.2.

Call Center

The call center module logged, routed, and tracked calls for assistance, offers of donations, and reports of information. During Snowstorm 2006, a bank of call takers was deployed at the Erie County EOC to answer daily incoming phone calls from the local response agencies, external supportive organizations, general public, and media. For each phone call received, information such as message content, caller contact, call type, call kind, and associated events were directly recorded into the DisasterLAN system. Following the call center operating procedures, the call takers also added to each phone-call record control settings such as the message routing information, priority value, and due date so as to ensure that the calls would be properly and timely handled by the relevant agents in the EOC. The call center also allowed query of reports and statistical summaries. This feature allowed the EOC emergency managers to review phone calls of certain nature, time period, priority, or status through predefined or custom report templates. The statistics and summaries generated helped the managers to comprehend the up-to-minute emergency situation and to track the progress of reported issues.

The call center module was used extensively during the snowstorm management and deemed as critical support to coordination management by the emergency managers. First, it provided a centralized information repository to enable global situational awareness. Acting as the "single-point" contact, the call center module collected information on incident development, demand of response operation, and support of incident mitigation. All the task-critical information was entered and stored in DisasterLAN databases, providing a consistent and comprehensive view of the entire incident situation to all of the emergency managers.

Second, the call center module transformed data to reduce logic, semantic, and structural inconsistency. Prior literature points out that emergency information is of low quality due to factors such as limited data sources and cognitive bias of the witness (Chen et al., 2007). As a consequence, the emergency information collected is likely to be incomplete, inconsistent, and inaccurate. The call center module was designed and operated to identify inconsistent, duplicated, and correlated reports, which were then reconciled and corrected by the staff or supervisors. Meanwhile, the call center module recorded information following existing standards to reduce semantic and structural consistency. For example, it recorded the resource information using NIMS Resource Typing definitions (Federal Emergency Management System, 2006b).

Third, the call center module routed information only to relevant agencies so as to reduce information overload. Rather than broadcasting all the new information to the entire management team at the EOC, the call center module sent information to selected destinations based on pre-incident planning. Emergency literature suggests that unnecessary information increases information overload of the recipients and consequently gives rise to cognitive stress and degraded productivity (Turoff et al., 2004). The design of the routing scheme in the call center module helped minimize the above issues.

However, the contribution of the call center module was challenged by a number of issues that emerged during the snowstorm response. An example is the unexpected change to the information routing policy, which introduced unnecessary delays in the system operation. When DisasterLAN

Table 7.2

DisasterLAN Support for Coordinating Emergency Management at the Emergency Operations Center

Module	Level of support	Performance highlights	Emerging issues
Call Center			
Logs requests, offers, and reports; prioritizes, assigns, and tracks calls; searches and generates reports	High	Provided a centralized information repository to enable global situational awareness; transformed data for reduced semantic and structural inconsistency; routed information only to relevant agencies so as to reduce information overload	Unexpected changes and ambiguity of information routing policy introduced unnecessary delays in system operation
Status Board			
Presents up-to-date incident information, messages, weather, photo, and video	High	Provided a common operational picture of the current emergency management for all agencies involved; presented comprehensive information for decision makers; aided evaluation process of disaster management effectiveness so far	Lack of integration support of data such as power grid and geographical information systems
Streaming Video			
Captures Internet protocol–based video from the scene of the incident and provides critical infrastructure	Low	Provided visualization (rich medium) of incident development and response operation status for monitoring and analysis	Lack of sources for video data; limited bandwidth of video stream transmission
Reference Library			
Stores reference documents, response plans, and images of supportive Web sites	High	Provided domain specific knowledge to improve decision-making quality in a timely manner; established the foundations for decision improvisation	Lack of preloaded data, missing certain reference materials
Security Management			
Manages user/group account and privilege	High	Achieved data access control by implementing “need-to-know” policy for information security	Lack of intuitive ways to manage user/group accounts
Contact Management			
Manages organizational and personnel contact	Medium	Provided centralized repository for permanent and temporary response personnel/group; aided establishment of communication among personnel	Lack of preloaded data; lack of enforced policies for periodical contact updates

(continued)

Table 7.2 *(continued)*

Module	Level of support	Performance highlights	Emerging issues
Preplanning			
Manages organizations and personnel needs	Medium	Provided predesigned plans for emergency mitigation and recovery	Lack of preloaded data; lack of plans for long-term operation
Weather Center			
Presents weather bulletins and radar imagery	Medium	Aided the analysis and planning of weather-dependent operations such as power restoration and environment	Lack of data richness of weather information
Chat and Broadcast			
Enables instant messaging for one-to-one or broadcast	Medium	Facilitated internal information sharing and exchange; improved interpersonal/group communication for decision making	Abandoned by some managers who prefer face-to-face or phone communication
Incident Action Plan			
Develops, distributes, and archives incident-specific operation plans	High	Ensured clear management objectives by using ICS-informed planning schemes; aided decision making through information infusion and integration techniques	Implemented during the response process and was not available to the managers at the beginning
Situation Report			
Develops, distributes, and archives incident-specific situation reports	High	Assisted the internal information sharing among related stakeholders; reduced the development effort and expedited the information sharing	Interface not easy to use

was initially deployed at Erie County, the call center module was configured, at the request of the local emergency management authority, to route all important information to the EOC manager when an incident strikes. In the case of Snowstorm 2006, however, the EOC manager at Erie County did not follow this plan. The EOC manager became overwhelmed by the overload of information and task management as the incident kept escalating. Consequently, he revised information routing protocol and requested that the critical information be routed to other sections where sufficient manpower was available. While this revision of information routing protocol was legitimate, it required a significant reconfiguration of the DisasterLAN and hence interrupted the system operation for a period of time.

It is therefore important that the emergency management systems be designed with a high level of flexibility to allow ease of customization and reconfiguration. As unexpectedness is inherent in emergency management, the user requirement analysis is more challenging for software engineering than it is in other normal contexts (Chen et al., 2007). As a result, flexibility in a form such as customization may serve as a good remedy to offset the low quality of user requirement analysis. It provides the users with capabilities to improvise the way any emergency system functions.

In addition, it is important that specific design features be offered to decision makers who assume critical roles (Turoff et al., 2004) in the emergency management. As manifested through the example of the EOC manager, design features such as information filtering, emotion detection, automated load balancing, and role transfer (ibid.) may be employed to help the key decision makers maintain productivity before they themselves become the victims of emergency incidents.

Status Board

The status board module provided the ability to display text, graphics, photos, real-time streaming video, and animated weather imagery on a computer screen or an LCD video projector. During Snowstorm 2006, the status board was used to display targeted weather alerts and warnings, traffic updates, mitigation progress briefs, meeting synopses, and incident planning summaries.

During Snowstorm 2006, status board module provided critical support to the emergency coordination in the following way. First, it established a common operational picture of the current emergency management for all agencies involved. A common operational picture is pivotal to ensure that all the agencies are on the same page in terms of collective response operations. It further built the “shared mental model,” which measured the extent to which organizational members shared the same understanding of the task, the tools, the team, and the situation (Majchrzak et al., 2007). Due to the escalated size of Snowstorm 2006 and the fact that a portion of the emergency managers were participating in incident management outside the EOC through remote access to DisasterLAN, the status board helped in establishing an integrated viewpoint of the overall incident management, thus allowing the individual agencies to make movements in line with the overall disaster mitigation strategy.

Second, the status board directly fostered coordination mechanisms such as community narratives (Boland and Tenkasi, 1995). Community narrative is a running narrative of the actions taken, the decisions made, and the theory in use. It therefore does not represent a single shared understanding of a domain but the multiplicity of events and actions a community is taking (Majchrzak et al., 2007). Coordination literature suggests that community narratives provide an observable record of others’ actions that may help members recognize opportunities to which they might contribute (Bechky, 2006; Feldman and Pentland, 2003). Further, community narratives may facilitate collaborative group behavior such as “implicit coordination” (Rico et al., 2006). During Snowstorm 2006, the status board allowed the emergency managers to observe and actively coordinate with the other agencies for synergy in disaster mitigation.

However, the contribution of the status board feature to coordination of Snowstorm 2006 was limited due to issues including the lack of integration support on data such as power grid and geographical information systems (GIS). During typical emergency response, information on the power grid is required for the analysis of infrastructure interdependence, which itself becomes the input to the strategic planning on mitigation and recovery. While power grid information was available through agencies such as National Grid and New York State Electricity and Gas, the information was not able to be integrated into the DisasterLAN due to the lack of system integration plans in place. Future efforts to integrate critical information from supportive agencies are therefore necessary.

In addition, operation of the status board during Snowstorm 2006 did not utilize GIS technology. GIS technology allows the emergency managers at the EOC to visualize, among others, the locations of incident activities and resource deployment (Goodchild et al., 1997). While GIS technology was supported by DisasterLAN, it could be used only if the information to be displayed was GIS-coded. Unfortunately, the operators at the call center did not geographically code the emergency information they received. As a consequence, not all the information stored in the DisasterLAN was GIS-readable, leaving the decision makers unable to present it through GIS technology. It was suggested by emergency managers that an enforced policy be in place that requires all raw information to be GIS-coded in future operations.

Reference Library

The reference library module stored reference documents, response handbooks, and images of supportive Web sites to allow quick retrieval of decision references during the crisis. The reference documents included materials such as information on biological and chemical agents, the *Emergency Response Guidebook, 2004* (U.S. Department of Transportation et al., 2004), and Erie Country emergency-preparedness plans. The reference library also allowed the EOC emergency managers to build cached versions of Web sites such as the Centers for Disease Control and Prevention for reference in case the Internet connection went offline.

The emergency managers considered this module a critical support to the Snowstorm 2006 coordination management as it provided domain-specific knowledge to improve decision making quality in a timely manner. For example, the county disaster response plans in the reference library allowed the emergency managers to quickly lay out mitigation arrangements following the predefined operating procedures. In addition, it helped establish the foundations for decision improvisation (Mendonça, 2007). In order to develop innovative solutions for incident mitigation, the emergency managers were able to consult on the reference materials in the DisasterLAN and to create new response tactics based on proved strategies and prior experience.

While the reference library module was found useful, its operation was criticized for issues including the lack of preloaded data and the absence of certain reference materials. While the reference library module came with a set of prepared reference materials at the time of deployment, there was little documentation on response management of snowstorm-related crises. As a consequence, the level of contribution from the reference library was limited during Snowstorm 2006. The managers had to resort to other alternatives for information retrieval on reference materials. It is therefore important for the emergency responders to carefully prepare all-hazard, or even customized, reference documents for the emergency systems that they adopt. Regular update and maintenance are also necessary.

Security Management

The security management module allowed the emergency managers to easily create new users/groups, manage security levels of task-critical information, and limit access to particular areas within the DisasterLAN systems. The user management approach in this module resembles the “role”-based approach that has always been a key part of structured group systems (Turoff et al., 1993, 2001, 2004). During Snowstorm 2006, the composition of the emergency personnel and management team altered frequently due to changes in organizational structure, roles and responsibility, and task assignment. The role-based design of the security module therefore allowed the system to function smoothly in the face of personnel changes. Individuals who joined the incident management team were granted with appropriate levels of security and those who left were deactivated immediately by the system administrators. To protect the sensitive information flow, end-to-end encryptions were used to ensure information confidentiality, integrity, and accountability. The user feedback on the security management module suggested that this was a very important feature for coordination management during Snowstorm 2006 as it implemented a “need-to-know” policy for information security. The “need-to-know” policy influenced the flow of information in the ICS and consequently coordinated decision making and task management. The security management module proved to be well developed despite comments on the interface design: the emergency managers expect more intuitive approaches to manage user/group accounts.

Contact Management

The contact management module managed organizational and personnel contacts, including contact information, training and certification records, photographic credentials, printed phone books, and mailing labels. In Snowstorm 2006, this allowed the EOC managers to search for individuals with special skills and for organizations with certain resources (e.g., snowplows) that matched the incident mitigation demand.

The emergency managers found that the contact management module provided medium support on coordination management as it supported knowledge coordination. Knowledge coordination theories such as transactive memory systems theory suggest that it is important for individuals in a collaborative relationship to know “who knows what,” and further, to use that knowledge to coordinate the work, resulting in more efficient and effective individual and collective performance (Majchrzak et al., 2007). The use of the contact management module in Snowstorm 2006 established a centralized repository that captured the individuals and organizations with their expertise and resources. It therefore allowed the incident managers to identify the expertise and resources among the candidates and consequently to utilize the personnel and resources in a coordinated and optimal way.

With regard to this module, the interviews with the responders revealed that a number of problematic issues emerged in the Snowstorm 2006 response. Like the reference module, the contact management module was also criticized for a lack of preloaded data. It was reported that the contact information of many responders was not available in the system, partially due to the lack of data preparation. An establishment of enforced data preparation and entry policy must therefore be in place during a preplanning phase before any incident strikes.

Second, the responders complained that the contact information kept in the contact management module was not useful since much of it became outdated quickly once the incident took place. A reason for this problem is that during a typical incident response, the personnel contact information may change when the communication infrastructure (e.g., landlines) is broken or when the individuals are relocated. As many responders did not update their contact information during the incident, their contact information stored in DisasterLAN became obsolete and hence introduced serious difficulties in interpersonal communication and interagency coordination. To cope with such challenges, an enforced policy that requires responder personnel to regularly update their personal contact information during the incident mitigation is vital.

Preplanning

The preplanning module allowed the DisasterLAN users to log detailed information on incident planning during the preplanning phase. Information mainly included critical infrastructure such as chemical production facilities, schools, and power stations that were vital to the design of response strategy. It was found that this module provided a medium level of support to the emergency coordination of Snowstorm 2006 because the information on critical infrastructure affected how the emergency managers prioritized the overall mitigation operations.

The emergency managers pointed out several issues regarding the operation of the preplanning module. For example, the preplanning module had not been properly prepared prior to the onset of the incident and some portions of the local emergency response plans were not available in the DisasterLAN system. The contribution of the preplanning module was also limited as a result of the lack of preparedness at the Erie County level. It was found that the county did not have detailed plans in place for a crisis as large as the prolonged snowstorm of 2006. Many of the plans developed by the local emergency community and consequently stored in the DisasterLAN system deal with small to medium incidents. As this lesson suggests, the utility of the information systems relies greatly on system management and maintenance of the operators. Members of the emergency response community must improve their practices before they can fully leverage the potential benefits of advanced emergency response systems.

Streaming Video

The streaming video module captured, integrated, and displayed video information from the scene of incidents, roadway traffic cameras, airborne surveillance units, and virtually all types of Internet protocol-streamed video. During Snowstorm 2006, a number of video sources were employed and they were primarily utilized to monitor roadway traffic.

While this module has great potential to support incident coordination with rich-media information (Dennis and Kinney, 1998; Dennis and Valacich, 1999) regarding incident development and management, the actual performance of streaming video during Snowstorm 2006 was unsatisfactory. Interviews with the emergency managers found that the utility of the streaming video module was significantly hampered due to the lack of support from the underlying infrastructure: (1) the video streaming through airborne surveillance was seldom employed, since the county did not have sufficient financial resources to operate the sheriff helicopters on a regular basis, and (2) the bandwidth of the network connecting the variety of video sources and the EOC was low, due in part to the huge network consumption of other emergency-management-related information sharing and communication activated during the snowstorm. Increased investment in the communication infrastructure is therefore important.

Chat and Broadcast

The chat and broadcast module allowed instant messaging among emergency managers. The communication was secured through encryption technologies, and it supported both one-to-one and broadcasting modes. The chat and broadcast module was found to provide a medium level of support to emergency coordination, primarily because it established direct communication among decision makers and facilitated internal information sharing (Turoff et al., 2004). During the response to Snowstorm 2006, interpersonal and interorganizational communication allowed the EOC managers to mutually adjust and share feedback with each other for coordinated incident mitigation. Communication in turn further enabled “dialogic coordination” through practices such as joint sense making and contestation (Faraj and Xiao, 2006).

It was interesting to find out that the emergency managers held mixed attitudes toward this module. Through the interview, we found that younger managers tend to favor and use this feature more than their older colleagues. As this chat and broadcast module resembles third-party instant messaging systems (e.g., MSN Messenger, Yahoo! Messenger, AOL Messenger) that are popular among young generations, we posit that one major reason for the above discrepancy is the level of personal experience with third-party instant message systems. That is, the more an emergency manager uses instant message systems, the more he or she will accept and utilize the chat and broadcast module. On the contrary, the managers who use instant message systems less, and indeed computer systems in general less, prefer face-to-face or phone conversations to which they are more accustomed. The emergency system designers therefore have to carefully study the end-user population and better understand the requirements from the practitioners. This implies that many software design premises (e.g., technology savvy) that are valid in normal contexts must be discarded when emergency system development is concerned. Rather, the designers may consult on emergency-specific design premises as proposed by Turoff and colleagues (2004).

Incident Action Plan

The incident action plan module developed, distributed, and archived incident mitigation plans. This module was used primarily by the Planning Section of the Erie County EOC. For each incident action plan, the EOC organizational structure and key individuals were recorded along with the operation scheduling details.

This module was found to be of high importance for emergency coordination. First, it ensured clear management objectives by using ICS-informed planning schemes. ICS promotes the concept of making management decisions based upon clearly defined objectives (BCG, 2007). The design of the incident action plan module followed the ICS forms (e.g., ICS-202, ICS-203, ICS-207) to guide the response planning, thus allowing planning objectives to be specified. Second, this module aided decision making through information infusion and integration techniques. While the Planning Section of the EOC managed the overall development for incident response plans, it usually subtasked the completion of specific ICS forms to Operational, Branch, Sector, and Division personnel (BCG, 2007). When used in Snowstorm 2006, the incident action plan module allowed the Planning Section to disaggregate the planning tasks to the supportive staffs and aggregated the collective input accordingly.

While the module proved to be useful, its operation was not without problems. It was reported that this incident action plan module was installed in the DisasterLAN system at the onset of Snowstorm 2006. According to DisasterLAN Inc., the incident action plan feature was included in the DisasterLAN system deployed at Erie County. However, the operators of the DisasterLAN system did not initiate the incident action plan module. This issue was further complicated as the target end users (i.e., personnel at the Planning Section of the ICS) were not aware of this feature when they first joined the ICS. As a consequence, the Planning Section worked on a “paper-pencil”-based approach for a long time before they recognized and started using the incident action plan module that ultimately increased work productivity.

Situation Report

The situation report module developed, distributed, and archived incident-specific updates. During Snowstorm 2006, this module was used to provide situation reports to government officials (e.g., village, town, city, county, state, and federal), the media, the general public, and supportive agencies on a daily basis. This module was found important to coordination management in that it (1) assisted internal information sharing among related stakeholders, and (2) reduced the development effort and expedited information sharing. These updates are critical to ensure that information timeliness is achieved and collective memory is synchronized (Turoff et al., 2004). Regarding the sophisticated functionalities available in the situation report module, the emergency managers indicated that they would expect more intuitive ways to navigate and operate it. For example, the design of pull-down screens for functions and information on specific topics is suggested.

Through the discussion, we found that DisasterLAN provided good performance in supporting coordinated emergency management during Snowstorm 2006. Its design features are comprehensive and include design principles (e.g., directory, timeliness, and multidirectional communication) suggested by the literature (Bui and Sankaran, 2001; Chen et al., 2007; Turoff et al., 2004). It establishes a collaborative platform for distributed individuals/groups/organizations to share information, make decisions, and consequently to synergize response capabilities. While there were many successful aspects of DisasterLAN, a few issues remain that are valuable for research analysis and practice design. An important observation is that many of these issues are not with the technology itself; rather, they are the results of lack of user orientation and training on the system.

As our discussion suggests, future improvements are needed in organizational process/policy design, infrastructure support, system maintenance, ease of use, and user adoption. It is, however, important to note that some issues (e.g., organizational issues) are inherent in the nature of emergency responses and are unlikely to be fully anticipated and addressed by any system design. Others, such as infrastructure-related issues, require investment for a supportive computing environment by the local government.

LESSONS LEARNED FROM THE OCTOBER 2006 SNOWSTORM

The incident coordination of the October 2006 snowstorm is concluded to be a success (Whetham, 2006). Through further review of the incident's management, we summarize the lessons learned in decision processes and decision making for organizational coordination. These lessons provide valuable opportunities to reflect on the current practice and to improve the design of management strategy as well as information system development. To facilitate the discussion, in Table 7.3, we summarize the key lessons learned along dimensions of people, process, and technology (Kim et al., 2007). In the remainder of this section, we discuss some important issues in detail.

Lessons on People Management

Expertise and Qualification of Decision Makers

Where people issues are concerned, one important lesson revealed in the October 2006 snowstorm is that key decision makers lacked task-critical knowledge and expertise. An example is demobilization coordination by the Unified Command (UC) who assumed the ultimate decision-making role in the ICS. Demobilization is the process of releasing and sending back external response agencies and resources when they are no longer needed. It is a standard response procedure for large-scale incident response and has a direct impact on other core response processes such as operations and logistics.

In the case of the snowstorm, several members of the Unified Command did not understand the concept of demobilization and they looked upon it as a defeating term. The chief of the ICS Planning Section recalled,

> The command staff absolutely refused to implement the demobilization plan. They did not understand what it means. It had been explained several times and until that time some of them were still saying "how can we be sending people back when some citizens are still without power?"

Table 7.3

Summary of Lessons Learned About Decision Making in Coordination

Lesson	Example	Primary cause	Preventative solution
		People dimension	
Key decision makers lacked task-critical knowledge and expertise	Command staff refused to implement demobilization process in the overall plan	Appointment was made by county executives who were not familiar with emergency operations	Expertise-based personnel selection scheme; pre-incident plans for personnel nominees; database of candidate expertise
Difficulty for decision makers to shift across contexts	Finance/Administration personnel experienced prolonged learning period for working in disaster scenario	Agencies were well trained in normal contexts but not in disaster scenarios	Quick instructions and training to reduce learning; drills of potential participants and stakeholders
Decision makers with incompatible personalities	A few agencies were in conflict over their attitudes toward the ICS and certain operations	Agencies were gathered from multiple municipalities	Scheduled orientation process for mutual understanding and opinion exchange; leadership
		Process dimension	
Slow decision-making process and ambiguity in decision-making roles	In the initial stage, the ICS operated with insufficient staff for two days	Inaccurate damage assessment; insufficient planning of decision making	Quick disaster damage and risk assessment; all hazard plans for ICS activation and operation
Negligence of situational awareness for decision making	Multiple municipalities built up twenty-six shelters at one time without having been coordinated; they soon ran out of resources	Lack of reporting from the subordinates; lack of situational awareness and supervision of the entire incident response	Enforcement of reporting policies and standard of reporting process; real-time monitoring
Insufficient communication of the decision-making process and purpose	The general public once misunderstood the power restoration operation as unfair and politically biased	Ineffectiveness of channels for public information dissemination; lack of feedback mechanisms	Strengthen the process of public information distribution; enhancement of trust toward government

(continued)

Decision making for coordination tasks therefore suffered significantly and a comprehensive response plan could not be established until this issue was addressed.

The interview suggested that this problem was rooted in the appointment process of key decision makers. County legislation states that county executives are authorized to appoint incident commanders. As elected officials, the executives were not equipped with sufficient knowledge of emergency response. They made the final decisions on ICS formation using their own criteria and personal preferences.

To eliminate this problem, a number of solutions are suggested by emergency managers. For example, it is important to have pre-incident plans for nominees for command personnel in typical

Table 7.3 *(continued)*

Lesson	Example	Primary cause	Preventative solution
		Technology dimension	
Decision makers were unable to use advanced decision support systems	Many agencies did not know DisasterLAN or did not know how to use it for help	Unawareness of available technologies; underestimation of the role of information technology; low level of technology self-efficacy	Sufficient education and training; enhancement in easily used decision support systems
Insufficient technology investment	Available computers in the EOC met only 75 percent of the demand	Low priority of technology investment; insufficient financial resources	Increase in the amount and priority of technology investment
Degraded and unfaithful appropriation of technologies	Many used DisasterLAN for purposes other than decision making; the full capability of DisasterLAN as a decision support was not achieved	Lack of appreciation of the computer systems; unfamiliarity with the technology's functions	Sufficient training on information system; standardize information usage and put it into plans
Unnecessary technology redundancy	Fax was used for information exchange while DisasterLAN was available; fax resulted in many missing/delayed requests	Lack of financial resources for some agencies; unawareness of alternative technologies	Improvement in the level of technologization
Insufficient technological "readiness" of decision support	Important decision support modules in DisasterLAN were not installed before the incident	Lack of planning; lack of prediction on what decision support will be needed	Timely maintenance and updates on software; use best-of-breed technology with full modules
Excessively tight control of technology and restraints on technology contribution	DisasterLAN was managed by the EOC; individual municipalities could not alter its usage to support decision making for their own disaster activities	Inaccurate estimate of the incident's magnitude; lack of mechanisms to manage user privileges; "local mindset"	Relaxation of system management policy with the appropriate control and oversight

disaster scenarios. Second, the nomination criteria should be expertise-based but not rank-based or title-based. Third, it is important to maintain a knowledge base of local response experts from whom the command staff can be selected when the preferred nominees become unavailable.

Transition of Decision Maker from Normal to Trying Conditions

One unique characteristic that distinguishes the coordination of emergency organizations from that of normal organizations is that the organization under coordination is typically formed on a task-oriented basis (Chen et al., 2007; Turoff et al., 2004). In the response to Snowstorm 2006, a great number of personnel were called in to serve the ICS at the Erie County EOC. While many of these individuals were emergency-management specialists (e.g., Fire, Police, EMS), others were not. For example, the Finance/Administration section of the Erie County ICS was formed primarily of individuals who worked for the Department of Finance of Erie County. These individuals rarely worked in an emergency-management context, and they were called in only to help the financial management of the ICS. With regard to this population, which possessed little experience in working in an emergency response context, we found that they experienced difficulties in adapting to the trying conditions. Unlike normal contexts, emergency response is typically characterized by a high level of uncertainty, stress, and risks. As most of the nonemergency specialists were not trained and had not been exposed to emergencies before, they could not cope with the psychological challenges and high workloads typical in medium- to large-size disaster response (Chen et al., 2007; Turoff et al., 2004).

The solution to the above issue may include (1) the establishment of a training program to help nonemergency specialists with contextual transition, and (2) regular drill and practice involving potential participants and stakeholders so as to acquaint them with emergency management challenges.

Lessons on Process Management

Decision Process and Roles

Where process issues are concerned, a valuable lesson learned was related to the slow decision making and ambiguity in decision roles at the onset of the incident. Soon after the snowstorm hit Erie County on Thursday night, the ICS was activated; however, it was severely understaffed and most positions were unfilled. In the event of a large-scale incident such as this, a curtailed ICS is simply unable to meet the huge demand for collaborative and complex decision making. Effective incident management at the initial stage of a disaster is critical to control the situation and minimize losses. With many important decision-making positions (e.g., chief of Finance/Admin.) empty, the ICS was functioning at low capability and missed significant opportunities for mitigation of the situation. It was not until Monday that the county requested additional assistance and a hundred personnel started to arrive at the EOC. The chief of the Planning Section commented that

> Everybody knows that on Thursday night things are bad, but somebody needs to push the button and say, “Look, Friday morning we need all these people to come.” The next time it happens, we hope they will push the button much quicker and the people come here much quicker.

The interview suggests that this problem is a result of both ambiguity in decision roles and incomplete information on incident damage assessment. The ambiguous role of decision makers is reflected by the fact that there exists no clear decision-making scheme for the local authorities to initiate the response operation. That is, the establishment of decision-making roles for a quick response in extreme events was missing from the response plans and from the governmental structure. On the other hand, critical input to decision making such as damage assessment was not fully available during the snowstorm. In Erie County, it is a required procedure that all affected cities, towns, and villages submit a preliminary damage assessment (including dollar loss estimate) in the first twenty-four hours after disaster strikes. This assessment information helps the county to determine the incident’s magnitude and to develop a response strategy accordingly; however, they did not come in as quickly as they were needed.

A number of solutions are proposed by the emergency managers in this regard. The solutions include, first, quick disaster damage assessment through policy and information technology enablers such as sensor networks. Second, it is important to establish all hazard plans for ICS activation processes and to assign clear decision-making roles to the related authorities.

Negligence of Situational Awareness

As part of the "home-rule" state (i.e., state of New York), Erie County manages the local disaster response through a bottom-up approach. That is, each city, town, or village within Erie County manages its own incidents; it requests additional supervision and support from Erie County only if it runs out of local resource or becomes incapable of meeting the scale of mitigation. During any incident, it is therefore important for the local municipalities to correctly assess the impact of the emergency situation in each territory and decide whether to handle it alone or to resort to Erie County instead. The sooner the local municipalities identify the facts of insufficiency of response capability and turn to the county, the better the latter can handle the regional disaster in a coordinated manner. That is, the county may be able to allocate available resources quickly to those in need and may further maximize the utility by allocating the available resources in an optimal way among multiple requests.

It was unfortunate that many of the local municipalities failed to manage the emergency properly during Snowstorm 2006. They did not accurately assess the level of incident impacts and wrongly decided to manage the incident on their own. For example, the local municipalities in Erie County built up twenty-six shelters at one time and ran out of supportive resources soon after. A lot of local resources (e.g., manpower and equipment) were wasted during the process of building, operating, and maintaining the local shelters. The interviews with the emergency managers suggested that a coordinated sheltering plan under the supervision of Erie County would better serve the needs of sheltering of the region.

The solution for this issue may include an enforced policy that requires the local municipalities to report their emergency management actions on a regular basis. This allows the establishment of basic supervision at the county level. In addition, the aggregated information from the local reports will help the county to better analyze the incident situation and detect any inappropriate management practices undertaken at the local levels.

Lessons on Technology Management

Technology Competence

In terms of the technology used, the snowstorm revealed that many decision makers were unable to use the advanced decision-support systems. In Erie County, DisasterLAN is the backbone system designated for ICS operation and decision making. During the disaster response, it was found that many of the agencies that joined ICS were not familiar with this decision-support system. Most of these personnel had to spend the first day learning the system with help from DisasterLAN technical support staff. As the chief of the ICS Operation Section put it, "So, *technology is only as good as the training of people who are using it*." Sadly, prior emergency research has already highlighted similar issues and cautioned about the negative consequences of the lack of system training. Turoff and colleagues (2004) point out that "an emergency system that is not used on a regular basis before an emergency will never be of use in an actual emergency."

The interview revealed that the reasons for this lesson are threefold. First, some responders greatly underestimated the role of information technology. Although DisasterLAN provided free access and training to the local responders, not many people took advantage of it. Second, the lack of appreciation of the necessity of computer technology was also a result of low technology self-efficacy, as most of the responders were not technology-savvy. Third, DisasterLAN is not a mandated software for the local municipalities to adopt. In a "home rule" state, this may certainly result in situations where there is not a uniform awareness of the available technology across the local communities.

Potential solutions include an increased awareness of technology, sufficient education and training through dry runs and scheduled meetings, and enhancement in the ease of use of decision systems.

Technology Investment

Despite increasing awareness of information technology and its role in emergency management, technology investment tends to be insufficient for many communities. In the case of Snowstorm 2006, we found that Erie County was short of financial resources in supporting advanced computer systems. For example, the responders at the Erie County EOC could not find enough computers on which to work during the snowstorm response. The data showed that the EOC met only 75 percent of the total demand for computers. As a result, the responders had to resort to conventional approaches in collecting and processing information, which degraded their productivity and efficiency.

Our study suggests that the reasons for this technology investment shortage may include lack of appreciation of information technology by the local authorities and thus a low priority for technology investment in county budget plans. Potential solutions could include improved assessment of technology cost (direct and indirect) and better communication between the emergency response community and the local authorities regarding technology importance and prioritization.

Technology Appropriation

Adaptive structuration theory points out that the use of advanced information technology is largely influenced by the end users (DeSanctis and Poole, 1994). User perceptions and cognitive styles influence the way a given technology acts and further limits the potential contribution it may make. As to DisasterLAN, we found that this system was not utilized to the full extent in the incident mitigation of Snowstorm 2006. The interview with the emergency managers revealed that many responders did not use the full features of DisasterLAN. Rather, they used a very limited set of modules for simple tasks such as making personal notes. Despite the fact that certain DisasterLAN modules are for specific groups in ICS (e.g., the module of incident action plan is mainly for the Planning Section), many features of DisasterLAN, such as status board, streaming video, and situation report, are useful to all emergency managers.

The interview with the responders suggests that the primary reason for the "unfaithful appropriation" of the DisasterLAN system is a lack of appreciation of the computer system. Some responders indicated that they were not aware of the utilities of the modules due to lack of training; others preferred the conventional "paper-pencil"-based management approach due to a low level of computer competence. Still, some others were not advocates of innovative information systems due to "inertia" (Akgun et al., 2003). The solution for this issue may therefore involve increased training programs on emergency computer systems. To ensure the expected utility of advanced information systems, it is also preferred that the local emergency response community enforces policies that encourage the adoption and usage of computer systems.

Managerial Control over Technology Usage

During Snowstorm 2006, DisasterLAN was used not only by emergency managers at the Erie County EOC but also by the local municipalities. As DisasterLAN is a Web-based application, the local emergency managers logged on to the system from remote locations and utilized the system for individual information and decision support. While the local managers benefited from the system in managing Snowstorm 2006, they suggested new approaches regarding the management policy of the DisasterLAN operation.

The interviews revealed that DisasterLAN posed strong limitations on the local emergency managers concerning their capabilities to customize the system operation. DisasterLAN functions under the concept of "event." That is, the system administrator first creates individual emergency events inside DisasterLAN and then grants admission to the related management personnel who consequently log on to the system and work for that specific incident event. In the case of Snowstorm 2006, DisasterLAN was configured to operate for one single event named "Buffalo Snowstorm." In addition, the system administrator did not allow the end users to create other localized events. This setting facilitated the regional coordination of the snowstorm if the entire Erie County was concerned; however, it did not allow the local emergency managers to leverage the DisasterLAN system for incident management of their own municipalities. For example, this system setting did not allow the local emergency managers of the City of Amherst, New York, to set up a subevent of "Amherst Snowstorm" under the top-level "Buffalo Snowstorm" for managing the unique response issues solely pertaining to Amherst.

The interviews with the local emergency managers suggested that there were both pros and cons regarding such a system setting. On the one hand, the single event configuration and the constraints on user privilege of event creation maintained strong control by regional emergency management and further facilitated the coordination of Erie County's response. On the other hand, the setting reduced the utility of the DisasterLAN system and also introduced unnecessary information overload. That is, much of the local specific incident information and communication could have been kept within the boundary of local municipalities and thus reduced the volume of information delivered to other DisasterLAN users who were from other municipalities of Erie County.

While the debate is likely to continue inside the local emergency community, a compromise system setting is likely to be favored by both sides: relaxed local emergency manager-privilege policy with appropriate county-level supervision in place.

CONCLUSIONS

Coordination in extreme events such as natural disasters plays a critical role in achieving organizational goals and operational efficiency. The current body of knowledge about coordination, however, is mostly limited to normal contexts. While conventional wisdom provides limited predictions, the extent to which these beliefs are in fact accurate remains largely unknown. Through case study of coordination in one large-scale incident, this chapter presents some intriguing findings. It shows that decision making for extreme event coordination is mainly facilitated through (1) organizational structures, (2) collaborative decision-making processes, and (3) the contribution of advanced decision-support systems. The discussion of lessons learned provides opportunities to extend the coordination literature and also helps system developers to better design emergency response systems.

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CHAPTER 8

THE CHALLENGES FACING A HUMANITARIAN MIS

A Study of the Information Management System for Mine Action in Iraq

DANIEL ERIKSSON

Abstract: *After the March 2003 Iraq invasion, the international humanitarian community entered the country with a new set of methods, including management information systems (MIS). Mine action is the sector within the humanitarian domain that is tasked with reducing the impact of the explosive remnants of war on the local population. The MIS adopted by the Iraq Mine Action Program (MAP) was the already globally tested Information Management System for Mine Action (IMSMA), developed by the Swiss Federal Institute of Technology (ETHZ) and the Geneva International Centre for Humanitarian Demining (GICHD). This chapter presents the main MIS tools applied in the mine action domain and moves on to explore the challenges that were faced in the use of the tools in Iraq. The lessons learned from the Iraqi mission included: the importance of a national authority to provide governance of the information management; the impact on successful MIS usage by the deteriorating security situation; and the importance of making the applications robust and intuitive in order to increase the resilience of the national staff and reduce dependence on expatriate experts.*

Keywords: *MIS, Humanitarian, Environment, Iraq, Mine Action, Demining, OASIS, IMSMA, GOTS, E-Governance, Nationalization*

Kreger (2003) describes how the international mine action humanitarian community entered Iraq on a large scale shortly after the March 2003 Iraq invasion. They brought with them new methods for managing the massive humanitarian efforts. Tools that were developed and tested during a set of humanitarian missions in the preceding decade, including the interventions in Bosnia, Kosovo, and Afghanistan, accompanied these methods. A particular group of tools were the management information systems (MIS) used to analyze large sets of data collected on the ground through surveys and other instruments. In the case of the mine action program (MAP), that is, the removal of the explosive remnants of war (ERW), the Information Management System for Mine Action (IMSMA), developed by the Swiss Federal Institute of Technology (ETHZ) and the Geneva International Centre for Humanitarian Demining (GICHD), was launched as the countrywide solution for information management and MIS for mine action. IMSMA is the standard system in use in the majority of ERW-affected countries.

The United Nations coordinated the humanitarian efforts on the ground through its centers in the south in Basrah, in the center in Baghdad, and in the north in Erbil. In the mine action sector, this approach resulted in the use of a relatively complex IMSMA installation with distributed regional databases being synchronized using CDs.

This study presents the situation of IMSMA in Iraq in 2007, four years after the system was introduced, and highlights the challenges that prevented a more successful implementation of the system in the particular national context. The identified challenges include: the lack of governance, the inadequate stability and resilience of the system, the lack of remote management functionality, the reliance on the support of expatriate experts, the lack of understanding of the system role and functionality among national stakeholders, and the lack of functionality centered on the needs of field users.

RESEARCH METHOD

The aim of this chapter is twofold. The first is to familiarize readers with the domain of MIS for humanitarian aid in the specific case of mine action in Iraq; the second is to discuss the lessons learned from the introduction of IMSMA in Iraq. This chapter is intended to serve as a reminder to developers of MIS that the context of the applications in the humanitarian domain is fundamentally different from that of conventional MIS—that is, those applied in commercial organizations in developed countries.

The author has been closely involved in the rejuvenation of the MIS resources in Iraq. In January 2007, he started as an information management consultant with the Vietnam Veterans of America Foundation (VVAF), visiting current and potential future users of the IMSMA software in Iraq over the course of February to April the same year. In April, he transferred to become the mine action e-governance adviser with the United Nations Development Programme (UNDP) for Iraq—a position that he currently holds. The main objective of the two positions was the same: to revitalize the use of MIS in Iraq, with emphasis on the Mine Action Program (MAP). This chapter can partly be seen as a narrative of that participatory observation.

In June 2007, the author was part of a team that organized a two-week conference in Petra, Jordan, titled “Information Management in Mine Action Planning.” The event was attended by seventeen Iraqi mine action professionals—representing the majority of the mine action community. The conference was interactive and included several workshops on the subjects discussed in this chapter. Several participants had been part of the mine action community since the start of activities in Iraq, and their institutional memory provided an important input to the role of the e-governance efforts in the mine action sector. In that regard, the event forms an empirical basis for the chapter for the time preceding the author’s engagement in the Iraq mission. Another primary source that provides a less central input to the research is the April 2007 Iraqi mine action donor conference in Amman, Jordan, attended by implementing organizations, funding organizations, and the United Nations. This event provided insight into the interest of field-based MIS in the donor community.

BACKGROUND

Mine Action

Mine action is defined by the International Mine Action Standards, set up by the United Nations Mine Action Service, as “activities, which aim to reduce the social, economic and environmental impact of mines and ERW” (UNMAS, 2007, 04.10). The tools available to the organizations to achieve those aims are:

- Mine Risk Education (MRE) of the affected communities through mass media, schools, and other channels;
- Humanitarian demining, that is, mine and ERW survey, mapping, marking, and clearance;
- Victim assistance, including rehabilitation and reintegration;
- Stockpile destruction; and
- Advocacy against the use of antipersonnel mines.

MIS can play a vital role in each one of these business areas of mine action. With appropriate baseline data, MIS can help in setting up priorities and dividing resources within and between the business areas. The IMSMA system described in this chapter provides some decision support functionality for this.

The mine action community is not a homogeneous entity. The stakeholders in mine action are many and diverse: starting with the affected communities, extending to organizations with global interests, such as policy advocacy groups and donors that fund mine action operations. This chapter focuses on the segments in between those extremes. These segments include regional and national mine action coordination centers, and implementing partners—that is, organizations conducting mine action operations on the ground, as defined in the first three bullets above. The main reason for this limitation is that the author's involvement on the ground in Iraq was centered on those user segments and that the participants in the Petra conference came from those user segments.

Decision Support in Mine Action

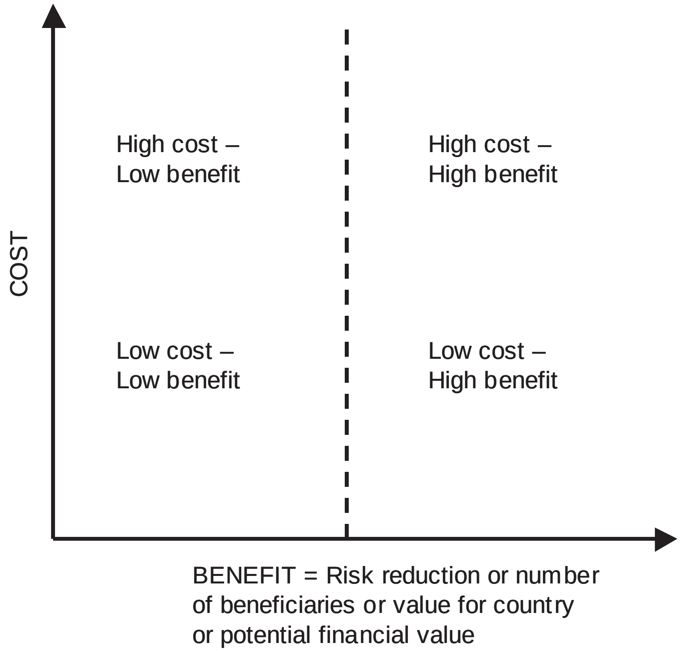
For an outsider, mine action is often equated with mine clearance. However, as mentioned above, mine action includes many other activities. Physical mine clearance, that is, demining, is the slowest and most costly method of solving a contamination problem. The available resources are rarely sufficient to conduct timely simultaneous mine clearance on all areas posing a threat to the population of concern. In this situation prioritization becomes pivotal. The prioritization practices in mine action and the alternatives to mine clearance are discussed in this section.

The prioritization of contaminated areas rests on two broad factors: *cost* and *benefit*. The cost varies depending on the selected solution, but if clearance is selected, the cost would be based on indicators such as: soil type, vegetation, metal contamination, expected type and quantity of mines, slope, infrastructure access to the area, and so on. The indicators of benefit can take many shapes. The most tangible benefit is potential financial income from using the land after clearance, for example, for commercial agriculture. Less tangible indicators of benefit include, but are not limited to, risk reduction, improved infrastructure, and increased self-sufficiency in terms of food and water supplies. Figure 8.1 illustrates the decision alternatives in the prioritization of individual contaminated areas.

At first, the decision maker should strive to address contaminated areas and communities that would provide high benefit at a low cost—that is, the lower right quadrant in Figure 8.1. The last contaminated areas and communities to be addressed should be those with low benefit at a high cost—that is, the upper left quadrant.

The VVAF (Benini 2002) has published a retrospective analysis of the use of MIS for prioritization in the Kosovo mine action program from 1999 to 2002. In Kosovo, the prioritization was made both for communities and for contaminated areas. Impacted communities were classified into one of three categories (low-, medium-, and high-impact), and contaminated areas were given a numerical impact score based on calculation of their level of impact on what VVAF termed "social space"—defined by them as space that people are likely to use. Using available spatial data and

Figure 8.1 **Cost vs. Benefit in Clearance Prioritization**



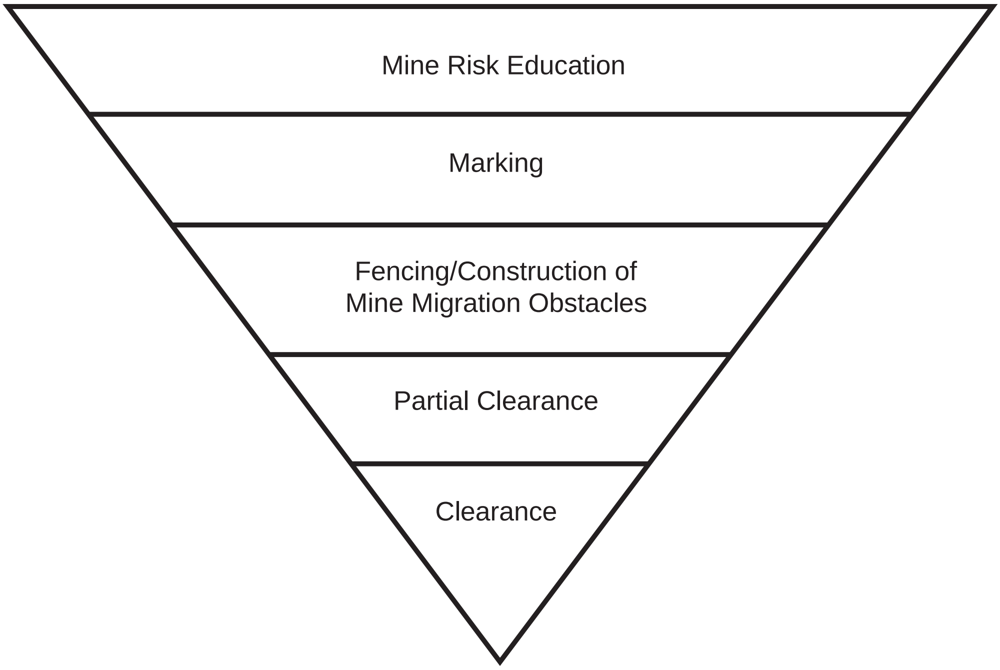
geographical information systems (GIS) analysis, the VVAF project assigned cumulative scores to contaminated areas that intersected with or were close to, among other aspects, roads and community structures, such as hospitals, voting stations, and schools. A similar impact analysis was made in Iraq. This will be explored later in this chapter under the heading: “The Setup in Iraq.”

Sadly, the level of contamination in many countries is so high that successful prioritization does not distill the contaminated areas into a set small enough to be targeted with complete mine clearance. Fortunately, mine clearance is not the only solution to a contamination problem. The model in Figure 8.2 was presented by Kent Paulusson, mine action adviser with the UNDP in Iraq, during the Petra conference. This and other similar models later inspired the development of the land release model in the international mine action standards (UNMAS, 2007).

The model in Figure 8.2 attempts to illustrate the preference that should be given to the less costly mine action methods. On a vertical axis, a threat should be dealt with from the top and down. Correspondingly, complete clearance is the last option, which should be reserved for as few cases as possible. Mine risk education, on the other side of the spectrum, can be applied liberally where it is deemed suitable because of its relatively low cost. MIS can be of great support in selecting the theoretically optimal solution, considering that decision makers in many large mine-affected countries, including Iraq, are confronted with tens of thousands of contaminated areas and communities that need prioritization in ways described above.

It is easy to assume that all mine action decision makers are alike and that their requirements on the MIS vary little from country to country. On the contrary, the requirements differ greatly even within countries. Every affected country possesses an array of decision makers, each being concerned with a specific segment of the mine action environment. This is valid for individual roles such as program managers, operational planners, and mine risk education coordinators.

Figure 8.2 **Order of Preference of Threat Addressing Mine Action Methods**

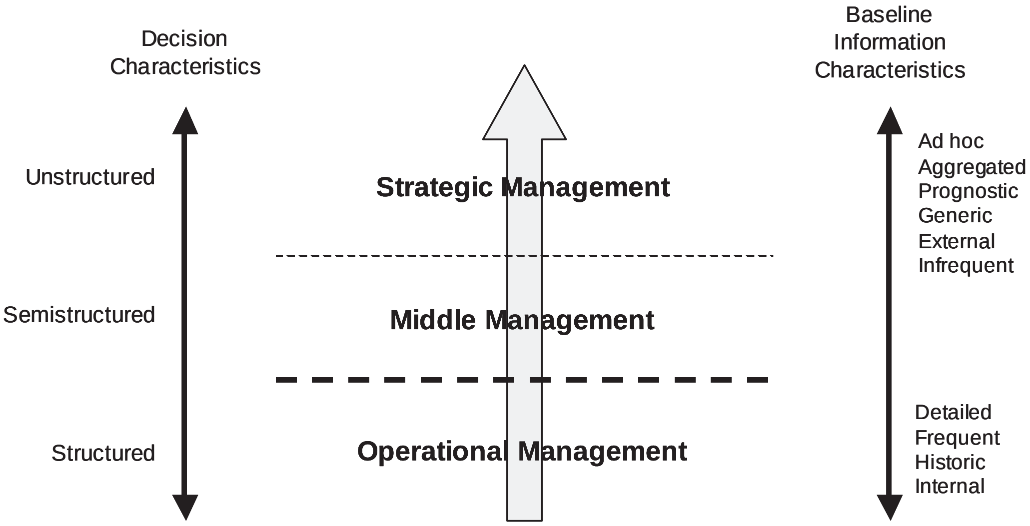


Source: Adapted from UNMAS (2007).

Another factor is the hierarchical level of the organization within which a role is located. There are, for instance, differences in the requirements between the *national* program manager and the *regional* program manager. The decision makers in each of these roles and organizations will all have different requirements on an MIS. O'Brien (1999, p. 456) suggests the use of the model in Figure 8.3 to illustrate the various types of decision makers and decisions in a commercial organization. The model supports the analysis of the decision support needs of the various roles in the mine action community.

By applying O'Brien's model to the mine action community, the organizations can be positioned along a figurative vertical axis. National organizations, such as a host governmental mine action authority, would have its center of gravity toward the top of Figure 8.3, whereas implementing partners active only in parts of the country would have their emphasis on the lower end of the figure. Furthermore, individual decision makers in the organizations would also have a location on the vertical axis. For example, the decisions facing an operations manager in the government national mine action agency could include which regions of the country to prioritize, or which methods from Figure 8.2 will be needed for the upcoming year—that is, strategic decisions. On the opposite end of the vertical axis, a clearance site manager of an implementing partner would make decisions on how to structure the work for a given task, such as choosing a safe place for a deminer resting area, or setting up a list of alternative hospitals in the area—that is, operational decisions. These roles and their locations in Figure 8.3 were discussed in a focused manner with the author as the moderator in a two-day workshop that was part of the Petra conference.

Figure 8.3 **The Relation between Decision Makers and Decisions**



Source: Adapted from O'Brien, 1999: 456.

The Information Management System for Mine Action

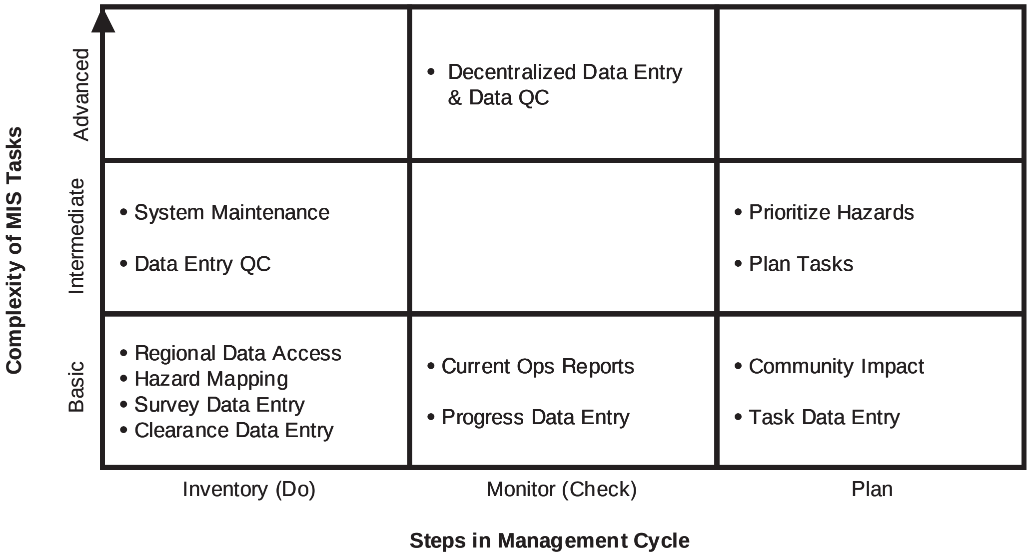
The mainstay MIS of the global mine action community is the Information Management System for Mine Action (IMSMA). This system consists of two modules: the *field module* and the *headquarters module*. The field module is intended to assist in-country stakeholders in most aspects of the mine action activities. The *headquarters module* is intended to provide global overview through comparative analysis of countries affected by ERW. Through the author's discussion with participants in the Petra conference, it was clearly the consensus that the field module is targeted at strategic and tactical decision makers on a national level. Few users in the affected countries have been exposed to the headquarters module. It is targeted at strategic decision makers with global interests, such as the donors that fund the mine action programs. None of the users at the Petra conference had experience with the headquarters module. The case was the same with the participants in the donor conference in Amman.

The attendants of the Petra conference made clear that although the use of IMSMA does provide some benefits to the operational decision maker, this user group is not well covered by the application—particularly not with regard to decision support functionality.

IMSMA was developed by the Center for Security Studies and Conflict Research at the Swiss Federal Institute of Technology Zurich on behalf of the Geneva International Centre for Humanitarian Demining. The GICHD provides the IMSMA Field Module free of charge to the international mine action community. IMSMA is the UN-approved standard for information systems supporting humanitarian demining activities. The intent of the system is to collect *standardized* mine-related data and manage it in a *standardized* system using numerical and spatial decision support functionality. When set up as a networked multiuser system, IMSMA enables several users to enter and evaluate their data simultaneously.

Technically, IMSMA is a relational database built on a Microsoft SQL Server Desktop Engine (MSDE) platform and connected through a data dictionary to an ESRI ArcView Geographical

Figure 8.4 **Increments of Complexity of IMSMA Implementations**



Complexity of MIS Tasks	Inventory (Do)	Monitor (Check)	Plan
Advanced		• Decentralized Data Entry & Data QC	
Intermediate	• System Maintenance • Data Entry QC		• Prioritize Hazards • Plan Tasks
Basic	• Regional Data Access • Hazard Mapping • Survey Data Entry • Clearance Data Entry	• Current Ops Reports • Progress Data Entry	• Community Impact • Task Data Entry

Steps in Management Cycle

Source: ETHZ (2002a).

Information System user interface (Swiss Federal Institute of Technology, 2002b). The data can be accessed through two user interfaces: (1) the database user interface, which is used for entering and manipulating the stored data, and (2) the GIS user interface, which is used for browsing the data in a user-friendly spatial environment that allows the production of maps.

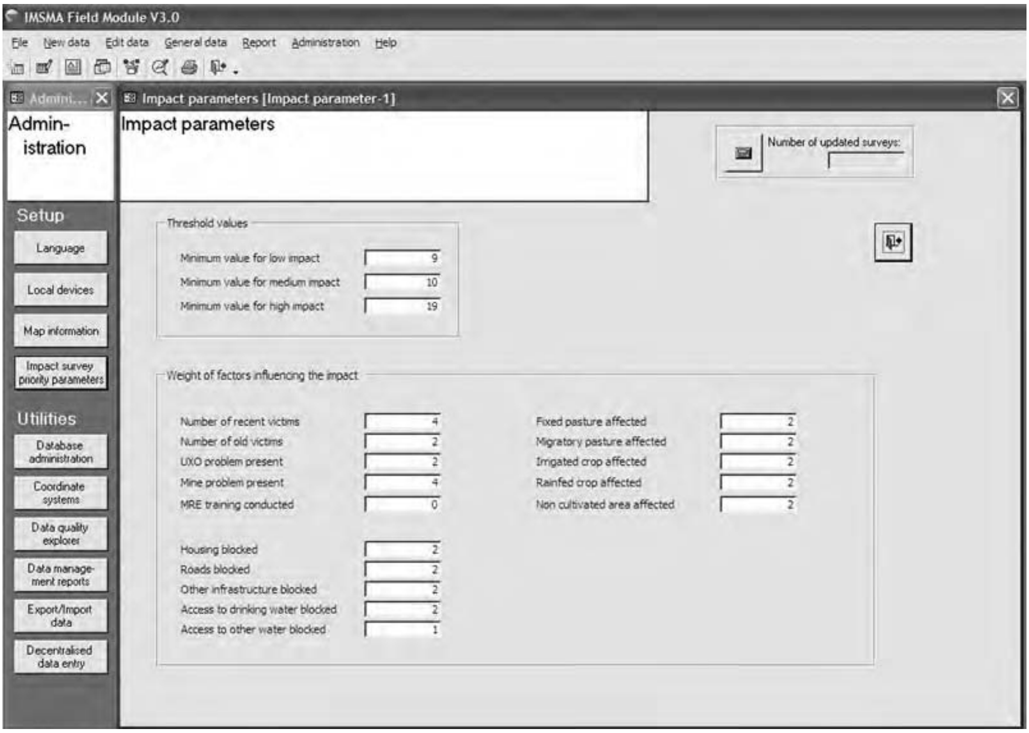
GICHD has recently released parts of a new version of IMSMA. It should be clear that all references to IMSMA in this chapter are to what is referred to as version 3. Version 4 is not in use in Iraq. According to marketing material from the GICHD, version 4 will be fundamentally different from version 3. Unfortunately, experiences drawn from version 3 in Iraq can therefore not be seen as fully valid for a future version 4.

IMSMA incorporates several decision support functions. The use of IMSMA in an organization does not imply, however, that any decision support functionality is used. Figure 8.4 is an excerpt from the IMSMA operations manual (Swiss Federal Institute of Technology, 2002a). It shows how IMSMA can be used in one of several increments of complexity where complete decision support usage is one extreme. When applied to its full extent, IMSMA provides decision support through both its user interfaces mentioned above.

When used to its full extent the GIS interface provides support in the form of visualization and overview to tactical decision makers. It also includes a support function for creating tasks, that is, sets of several contaminated areas to be addressed. The tasks are then combined with relevant contextual information such as past civilian accidents, nearby hospitals, and previous work. The result is a task dossier containing the bulk of the information required by an implementing partner for successfully addressing the contaminated community through whatever set of mine action activities is required.

The database interface provides decision support in several forms. The user interface provides access to statistical reports generated from the back-end database. These numerical reports provide help to inform a decision maker on the current status and achievements of the MAP,

Figure 8.5 **IMSMA Screenshot of the Prioritization-Weight-Setting Interface**



Threshold values

Minimum value for low impact 9
Minimum value for medium impact 10
Minimum value for high impact 19

Weight of factors influencing the impact

Number of recent victims 4
Number of old victims 2
UXO problem present 2
Mine problem present 4
MRE training conducted 0

Housing blocked 2
Roads blocked 2
Other infrastructure blocked 2
Access to drinking water blocked 2
Access to other water blocked 1

Fixed pasture affected 2
Migratory pasture affected 2
Irrigated crop affected 2
Rainfed crop affected 2
Non cultivated area affected 2

for example, how much has been cleared, where most accidents are occurring now, and how they happen.

A central decision support feature is the community impact scoring functionality, which calculates a socioeconomic impact score for individual communities based on information collected on the ground through a landmine impact survey (LIS). The LIS is conducted by survey teams in meetings with community leaders and citizens in their villages. The resulting community impact score helps tactical and strategic decision makers in planning their approach on a national or even regional level. Parts of a country or region that contain higher impact communities are likely to require greater assets based closer to them. Properly applied, the community impact score provides a convenient way of tracking the progress of mine action activities (GICHD, 2004). As the data collected during the LIS are static, the impact calculation will remain unchanged. The GICHD suggests that proper usage in relation to progress monitoring would hence include return visits by the LIS teams. Thus, when the contamination is dealt with, the impact score would be reduced.

Each impact indicator that is collected as part of the LIS is grouped with similar indicators and linked to a factor for which the user can set the weight. These factors are shown in the screenshot in Figure 8.5. If the necessary data are not collected as part of the LIS, GIS analysis can be applied to find additional blockages using remote sensing. The GIS analysis will never achieve the same detail as an on-site visit by a survey team, but it is likely to be faster and to lower cost. Figure 8.5 shows the weights that a decision maker in the Iraq MAP has assigned to the various factors. The weights, and to a limited extent, the indicators can be changed as the priorities of the decision maker change.

When applied in large countries, such as Afghanistan, Iraq, or Sudan, the IMSMA application allows for distributed data entry. This functionality was introduced in version 3 of IMSMA and has caused some technical and organizational challenges where it has been put to use. In distributed data entry mode, regional centers have ownership of the data in their region—thus preventing a central overseeing agency from entering or changing regional data. An additional challenge is that the database synchronization between central and regional databases often results in a corrupt database—something that the author has experienced repeatedly in both Afghanistan and Iraq. When a database becomes corrupt, the national operators seldom have sufficient expertise to repair it. The solution is to send an expatriate database expert to resolve the issue. In the case of Iraq, this is expensive, dangerous, and sometimes impossible.

The benefit of distributed data entry is twofold: (1) the burden of data entry can be shared with regional centers, and (2) the data entry occurs closer to where the data are collected, which benefits from the data entry clerks' awareness of local geography and operations.

The Operational Activity Security Awareness System

The Operational Activity Security Awareness Information System (OASIS) is the solution to some of the problems faced in the use of IMSMA. The OASIS, developed by a nongovernmental organization (NGO) called Veterans for America, is being installed in Iraq during the summer of 2007. Once operational, the system will allow for data exchange of spatial data over the Internet and provide a simplified user interface that can be likened to that of Google Earth (ESRI, 2006). OASIS will not replace IMSMA, but enhance it by enabling users with limited computer literacy to browse the data. It will also encourage users outside the mine action community to upload and exchange data from their domain of interest. An example of this would be spatial data on agriculture or refugee movements that could supply input to impact calculations by providing indicators of potential benefits. Spatial data on the boundaries of potential agricultural fields can be used to detect areas that could be released for agricultural use. Spatial data on the refugee movements can be used to highlight areas with an influx of refugees—which increases the risk of civilian accidents.

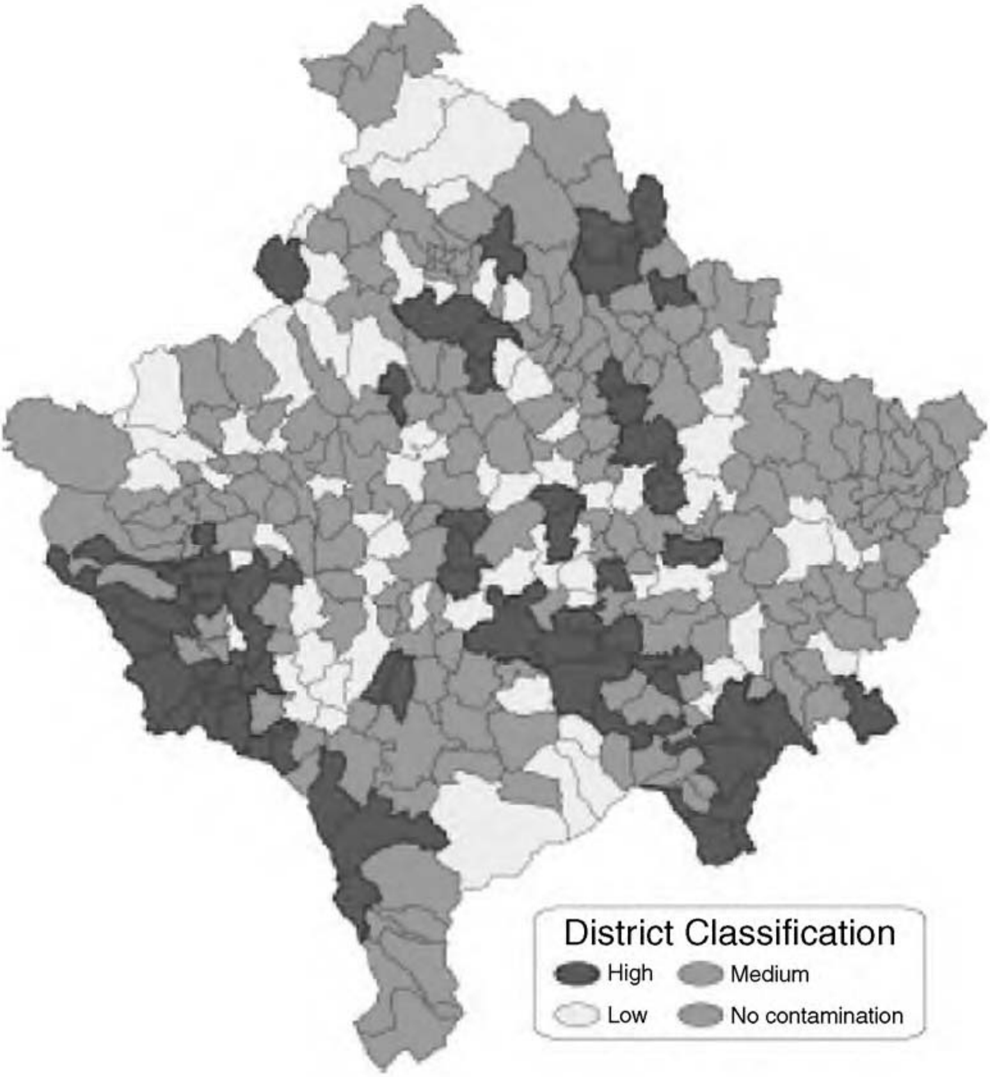
The OASIS system was developed to increase sharing of information in the NGO community, specifically with reference to security-related data (ibid.). The system includes functionality to calculate security trends using raster-based methods. The same methods could theoretically be applied to mine action data. A raster method would allow for impact analysis of greater detail than the traditional ”administrative area” method applied by the VVAF (Benini, 2002) in Kosovo (see Figure 8.6).

THE SETUP IN IRAQ

The original set-up of IMSMA in 2003 divided the country into three areas: the south, the center, and the north. This was a relatively complex installation, with distributed data entry being made in one central office and two regional offices. The regional offices were to synchronize their data to the central office on a regular basis. As the UN withdrawal started following the August 2003 bombings of its headquarters in Baghdad, this complicated setup was put to the test without the on-site support of expatriate experts. The fact is that when the author arrived in Iraq in February 2007, only one out of the three regional IMSMA systems installed before the bombing was functional and the most recent countrywide synchronization had been made in the summer of 2005.

The intention of the international community was to build capacity in the Iraqi government to manage the national mine action activities. Correspondingly, the IMSMA systems were installed

Figure 8.6 **Impact of the Explosive Remnants of War on and Administrative Level in Kosovo 2002**



Source: VVAF (2006).

inside the relevant government organization. This process of nationalization or transition of a national mine action body is nothing new. It has occurred on several occasions with varying levels of success in countries like Kosovo (Meador, 2005) and Lebanon (Cox and Ressler, 2006). Barlow (2006) writes that although the global process to national ownership is difficult, the only alternative for the host countries is an indefinite dependency on international expertise.

For Iraq, the National Mine Action Authority based in Baghdad managed the center database, while the Regional Mine Action Centre South based in Basrah managed the south database. The situation in the north in terms of politics and the maturity of the mine action activities was at the time of installation in 2003 completely different from that of the center and south. Whereas the databases and organizations hosting them in the south and center were created in 2003, mine action organizations in the north had been active since 1992. A different database developed in-house by the United Nations Office for Project Services (UNOPS) was already in use in the north. In addition, there were political struggles inside the Iraqi north that resulted in two entities inside the north, out of which neither could fully live up to the role of regional leader for information management. The result of this power vacuum was that the international implementing partners active in the north had to resort to developing their own databases for managing mine action data. In addition to desktop applications developed out of necessity, there were consequently three IMSMA databases in use in the north that have seen only partial synchronization. Several attempts were made to amalgamate the various databases, but complete success has not yet been achieved. Consequently, the information management in the north has become fragmented and undisputed information on the contamination is hard to come by.

In Iraq, the main decision support functionality applied, so far, is the calculation of community impact by the ERW. Iraq's relatively large size makes it unsuitable for impact analysis based on administrative area as implemented by the VVAF (2006) in Kosovo and shown in Figure 8.6. Instead, impact is allocated to individual populated places using the built-in functionality of IMSMA and user-defined weights as shown in Figure 8.5. The resulting community-based impact is shown in Figure 8.7.

Figure 8.7 delivers a partial snapshot of the country impact as it was when the bulk of the LIS was conducted from 2003 to 2005. Some of the provinces in the center of the country remained too insecure to allow a visit by the survey teams, hence the central gap in the map. One of the areas that has not been fully surveyed is the border between Iraq and Iran. It is widely expected that this area will be very heavily contaminated by the ERW—something that Figure 8.6 fails to convey due to the incomplete survey.

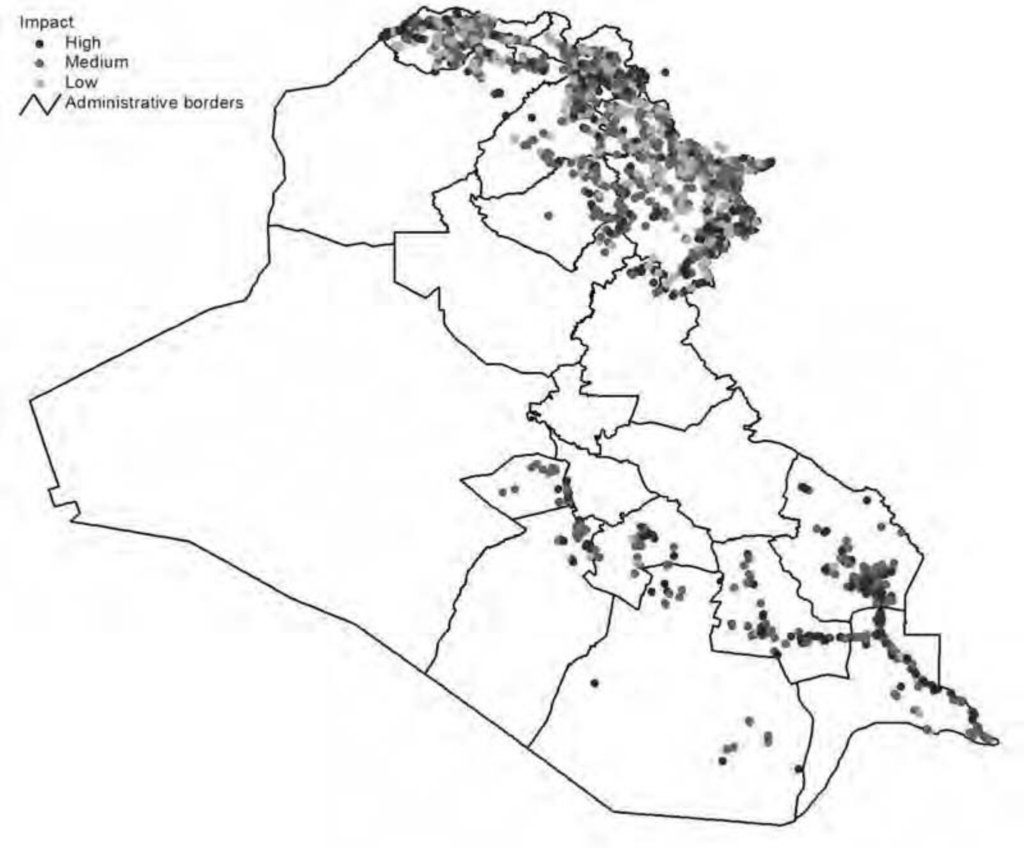
Current Challenges

The MAP in Iraq is currently faced with serious challenges, not only in the information management sector but also politically and operationally. In the context of a constant struggle to maintain a functioning government, mine action is not a political priority of the Iraqi government. Focusing on the information management challenges in the MAP, the author identified several challenges preventing complete and successful adoption of MIS in the wider MAP. These challenges were: the security situation, the lack of central governance, staff retention, user understanding of the MIS, and the lack of decision support functionality incorporated into IMSMA for the operational decision makers working on the ground.

Security Situation

The deteriorating security situation following the 2003 Canal Hotel bombing was the main obstacle confronted in the early stages of the introduction of IMSMA in Iraq. This continues to be an obstacle. As an example, in the case of the previously mentioned community impact analysis, IMSMA allows for continuous updates of the community impact score. But due to the inadequate security, the data collection on the ground in the south and center has been stalled. In the north, where the security situation allows for continued data collection, the updates and successful use of the impact score have been hampered by the lack of expertise on all levels of decision making in the involved organizations. The impact score could have been recalculated without data from

Figure 8.7 **Community-based Impact of the Explosive Remnants of War in Iraq**



Source: IMMAP (2008).

continuous impact surveys. The weights in Figure 8.5 could have been changed when the strategic objectives changed. However, the lack of central governance, combined with insufficient expertise in the IMSMA software package, led to a reluctance or inability to act. In the opinion of some users, this caused decision support to be of inadequate accuracy.

Information Management Governance

The insufficient central governance of the information management activities has led to de facto information anarchy. Organizations collecting and analyzing data do so with disparate standards and methods, resulting in data redundancy and producing conflicting advice, which leads to reduced efficiency in the operations. The individual organizations do, however, have a clear picture of the contamination and mine action efforts in their local areas of operations, which enables them to operate efficiently. The inefficiencies are located on the regional and national levels where economies of scale could be applied, but are not due to the lack of a central authority.

With no authority tasked with the verification of data and to ascertain data quality, the databases have been fed with low quality data for several years. The databases consequently contain numerous instances of obvious inaccuracies and entry duplications: minefields are entered with erroneous grid references, ending up not only outside Iraq but also on other continents; the figures for civilian victims of mine accidents in the north vary between 6,000 and 28,000. However, the most serious discrepancy is the divergence of the gazetteers in the databases. The Joint Humanitarian Information Centre (JHIC) managed by the United Nations in 2003 ran a project to assign numerical database keys to populated places in Iraq—similar to a postcode system (Benini, 2005). This is required for two reasons: (1) because places are used for linking other types of spatial data when a grid reference is not available, and (2) because populated places often go by several names. Spatial data on its own is not sufficient to identify a populated place, especially not in areas where populated places are close to each other. The P-code project, as the JHIC project was referred to, provided a solution to these challenges. The project was, however, finished prematurely due to the unsatisfactory security situation. Many populated places, particularly in the center of the country, were thus not surveyed by the project. In the absence of an up-to-date central gazetteer, organizations active in Iraq had to revert to creating their own database keys for locations that were not assigned a P-code by the JHIC. Consequently, as the number of populated places went into the tens of thousands, it became harder to correctly identify new populated places entered in the various databases. This, in turn, made it harder to establish links between the data in the databases.

National Staff Retention

The organizations that run the IMSMA application have a problem retaining their national database operators. When their staff has developed the necessary database management skills, they become very attractive on the local labor market. Being offered higher salaries by commercial organizations, the national employees soon choose to leave. The difficulty of retaining national staff covers all areas of information technology expertise; although database management and GIS are the most sought-after skills, conventional network administrators are also hard to hold onto. The increased turnover of staff has reduced sustainability in the organizations. When the author toured Iraq to visit the organizations using the IMSMA, some did not even know the passwords of their database; others had not started the system for many months; and only a couple of organizations had made backups as a result of the lack of skilled network administrators.

Comprehension of Decision Support Functionality

Contrary to its purpose, the decision support system risks replacing the human decision maker in some organizations. By not understanding how the decision support function in IMSMA calculates the community impact score, the score, which should be supporting decisions, is instead incorrectly taken as fact by some users. The fallacy of this is that because the input data are out of date, incomplete, and approximate, the community impact score cannot be exact. When the discrepancy between the system output and reality was discovered, the users became understandably skeptical. This caused many organizations to stop usage of the decision support functionality and, in some cases, to distance themselves from using information systems altogether. By not using the information at all, those organizations entered a vicious circle. When data were not corrected and new data were not entered, the quality of the decision support functionality was reduced, as was the quality of the data that could be printed on maps using the GIS functionality. When the data quality was reduced further in this manner, the users became even more reluctant to use the system. Important data on threats and progress will be lost without an authority to provide guidance and enforcement of the proper information management practices.

Top-heavy Decision Support

It is the author's opinion that MIS in the mine action community so far has been unsuccessful in incorporating all levels and types of decision makers. Looking at Figure 8.3, the functionality in IMSMA is focused on the strategic and tactical decision maker. Those collecting the information on the ground and the operational decision makers get little decision support from the system beyond the maps and database printouts. In a country as large as Iraq the organizational distance between the policy-centered national institutions and the implementing partners working in the minefield is vast. Even with a fully functional information system, the data collection necessary to achieve optimal strategic decision support is likely to fail due to a lack of understanding of data's relevance by those who collect it. In the best of cases, data collection will be the secondary task of the staff working with mine action activities on the ground, possibly with the exception of the survey tasks. If the mine action professionals are not fully aware of the potential use and importance of the data that they should collect, it is inevitable that whatever data actually are collected will be incomplete or irrelevant. Several examples of this were encountered during the author's time in Iraq. Professionals working on the ground saw data collection as a burden and filled in the fields on the forms to get the paperwork completed as soon as possible, rather than trying to convey an accurate representation of the item reported, for example, a minefield or a mine accident.

On a positive note, the professionals attending the Petra conference changed their mindset immediately when they realized how the data that they collected were reflected in the IMSMA database.

LESSONS LEARNED

The primary lesson learned in the Iraq mission is that functional central governance is at least equally important to functional information systems on the ground. Without the guidance of a central authority, anarchy ensues—the quality of data is reduced and economies of scale are not achieved. Without information standards and enforcement of them, the cost of maintaining MIS is greatly increased as database operators will struggle to connect databases in order to achieve useful decision support. The lack of central information management governance in Iraq is a result of political struggles that will not be further investigated here. The argument presented is that the absence of such governance is central to the current demise of the Iraqi mine action MIS.

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.

The complexity of the IMSMA system has led to the necessity of at least intermittent visits by expatriate information management experts. In the cases where national staff has achieved a level of knowledge to solve most complex information management tasks themselves, the staff is invariably recruited by better-paying commercial organizations. Had the IMSMA system been easier to operate and maintain, it would have ameliorated the problems of reduced expatriate presence and national staff retention. Local information management staff should have to work only through the predefined user interfaces and should not be expected to have to edit software code or to access back-end databases using Select Query Language (SQL). Instead, a national authority, or an expatriate agency located outside the mission area, could have provided these highly specialized services. A technical solution to increase the stability of the data would be to store the back-end databases on a managed server located outside of the mission area. This would obviously require a fast and stable Internet connection in order for the users to be able to access the data. Even so, having to rely on an Internet connection could be less awkward than to live with the risk of all the data going missing due to lost passwords, insufficient backups, or operator mistakes.

Where the community impact scoring is applied in Iraq, it is evident that the users are not fully aware of what it means, what its limitations are, or how the scoring is calculated. This lack of knowledge sets the scene for inappropriate use of the decision support output. The calculated impact will either be relied upon too much, because the decision maker can counter those who question his decision by stating that he acted on what the computer told him, or the decision support is ignored because the decision maker has lost his trust in the system after having identified cases where the impact score is inaccurate. The Iraq context of IMSMA has shown that these two extremes of user cases are common. By making sure that the decision maker who uses the decision support understands the underlying manual processes leading up to an impact score, his ability to question the output and apply the decision support in a successful manner is ensured. In the words of the *IMSMA Operational Handbook* (Swiss Federal Institute of Technology, 2002a): “IMSMA can be an effective planning tool for users who have a solid basis of skills in planning and prioritization, but it is not a substitute for planning and management training.”

RESTORING THE USE OF MIS

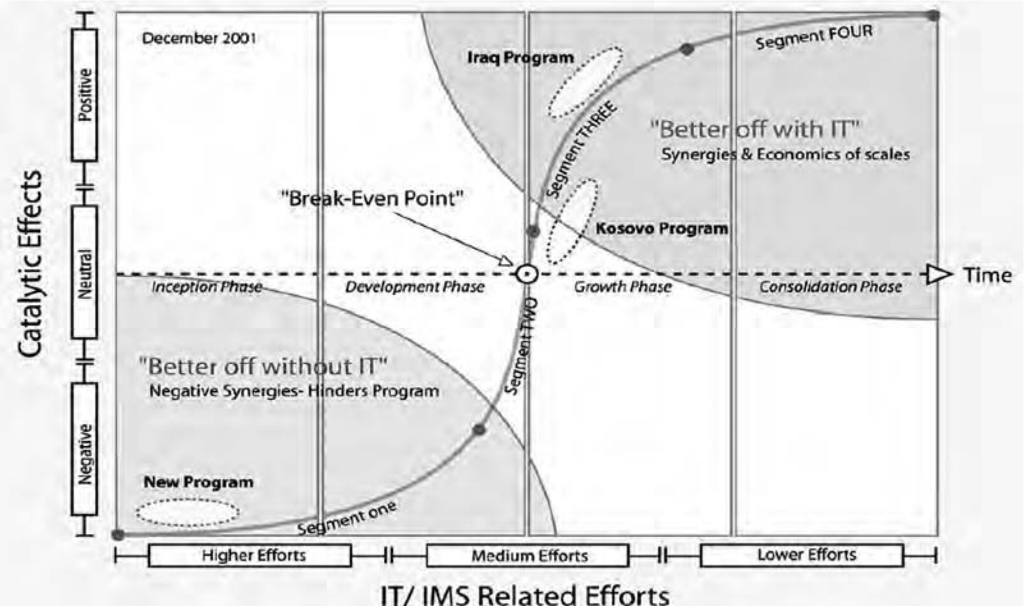
Figure 8.7 was developed by the UNOPS in December 2001. At that time, the bulk of the mine action activities were in the Iraqi north. The information management aspects of the program were, as depicted in the graph, considered mature and well functioning. Since then UNOPS has departed from Iraq and handed over responsibility for governing the mine action program to the national authorities. Nationalization of the mine action program is positive for the host country, but if it is rushed, it can hurt the capacity building of the national governance structure. It is not clear whether a rush to hand over the MAP to national authorities took place in northern Iraq. However, based on visits to the organizations using IMSMA in Iraq, it is the author’s opinion that after Figure 8.8 was assembled in 2001, the mine action information management in Iraq regressed to “segment one.”

So, what is required in order to return the information management sector in Iraq to the state in which it was in the Iraqi north in 2001? The disparate databases currently in use have to be amalgamated into one database, and the data that it will contain have to be standardized. The disparity mainly exists in the north of the country. With tens of thousands of records in the two largest databases in the north, a substantial effort will be needed to combine all of them—something that could have been avoided through smoother transition to national ownership of the MAP.

The rectification of the databases will have to be coupled with institutional development of a national authority for mine action. This authority will have to be closely involved in the development and enforcement of national mine action standards, including those for information management. The methods applied by decision support systems should be clearly understood by the national authority. Before being confronted with computers, operators and decision makers should be trained in applying the decision support methods manually.

Where possible, the existing systems, particularly IMSMA, will have to be made more intuitive for end users and administrators. Installations should be made so as to allow for remote management of the computers via the Internet. The current top-down emphasis of IMSMA should be reverted by introducing functionality that will benefit the operational users on the ground. The introduction of OASIS will target some of the issues, such as usability, Internet support, and increased benefit and accessibility to the system for field users.

Figure 8.8 **The Catalytic Effect of Information Systems versus the Maintenance Effort in Two Mine Action Programs in 2001 ETHZ (2002a.)**



Source: Fruhling et al. (2007).

CONCLUSION

The domain of mine action represents a tangible example of a case where there is scope for MIS to be applied to enhance humanitarian business effectiveness; two such existing MIS tools for mine action were presented. Although the domain is very suitable for MIS in theory, the case of MIS in Iraq has proved that it is much harder to implement in practice—even when applying ready-made tools such as IMSMA. The MAP in Iraq was explored to highlight the information management challenges that it has confronted since its inception. The specific lessons learned from the Iraqi MAP are:

- The sustainability of the MIS was hampered by the *absence of a functional central governance* entity for information management to coordinate and standardize the data collection and analysis. More time and effort should have been invested to ensure continuity of governance in the transition to the national government. A consequence of the inadequacy of governance is that the various databases in the mine action community, particularly in the Iraqi north, contain low quality data that are conflicting, corrupted, or incomplete. In order to resolve this, considerable resources will be required to clean and amalgamate data. The long-term solution is to identify and develop a national institution for mine action;
- A *complex administrative interface and lack of remote management functionality* repeatedly threatened the project. The deteriorating security situation in Iraq following the 2003 Canal Hotel bombing was a major obstacle in all aspects of the creation and maintenance of the MIS. Had it been foreseen, measures could have been taken to make the MIS sturdier, for instance, by storing data outside of the country or making it possible to administrate the databases remotely;

- In relation to the previous point, the *reliance on expatriate expert support* to maintain the complex IMSMA system operational hampered its successful application. A sturdier application with a more intuitive user interface would have allowed for local staff to be more resilient to application crashes and less dependent on external support;
- The *lack of understanding of the output of the decision support system* resulted in inaccurate decisions. As a consequence, the community-impact score calculated by the IMSMA system was interpreted literally by the users. The strengths and limitations of the decision support were hence ignored, which resulted in either overreliance on the output or complete alienation of the system by potential users. The users of decision support systems should be adequately trained in the manual processes underlying the decision support systems before they can be expected to use the system output;
- The *lack of decision support functionality targeted at operational decision makers* might have reduced their understanding of the relevance and impact of the data that they collect for the IMSMA database. More decision support functionality targeted at this group of users could improve the quality of the collected data.

Some of these lessons learned might come too late for the Iraqi MAP, but will certainly be relevant in future mine action programs in other countries. In hindsight, all the setbacks experienced in Iraq have solutions, as presented above, that could have mitigated their impact or avoided them altogether.

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CHAPTER 9

USER PERSPECTIVES ON THE MINNESOTA INTERORGANIZATIONAL MAYDAY INFORMATION SYSTEM

BENJAMIN L. SCHOOLEY, THOMAS A. HORAN, AND
MICHAEL J. MARICH

Abstract: *The emergence of wireless communications technologies (e.g., cell phones) has allowed for faster emergency incident notification. New wireless technologies on board automobiles, such as automatic crash notification (ACN), provide yet another method to reduce emergency notification times and provide valuable information to emergency responders. This chapter presents a case study of the Minnesota Mayday system, a service-oriented architecture-based information system that automatically pushes select General Motors (GM) OnStar emergency data to preauthorized emergency response and transportation stakeholders (e.g., dispatch centers, law enforcement, ambulance providers, health care facilities, traffic management centers, and the traveling public). 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 time-critical information services (TCIS) sociotechnical framework is utilized as a guiding framework to extract end-user perspectives, perceptions, and issues related to the end-to-end performance impact of the Mayday system. Interview responses from GM OnStar, Minnesota State Patrol, Department of Transportation, and Mayo Clinic representatives are organized along operational, organizational, and governance dimensions of interorganizational information exchanges. Findings include "timeliness" and "quality of care" performance benefits that resulted from the information technology (IT) and business process changes implemented to support interorganizational emergency services; the need to design information systems to "fit" both organizational and interorganizational performance goals; and the critical role of an oversight organization in the success of interorganizational emergency response information systems. Additional system needs and requirements are discussed and implications presented for decision makers and system designers for both day-to-day and crisis situations. The Mayday system architecture is also discussed in terms of how it informs the development of an end-to-end national model for incident information exchange.*

Keywords: *Emergency Medical Services, Emergency Response Information Systems, Interorganizational Systems, Performance Improvement, User Perspectives*

INFORMATION SYSTEMS FOR EMERGENCY MEDICAL SERVICES SYSTEMS

Nearly four decades ago, the National Academy of Sciences (NAS) released a pathbreaking report titled *Accidental Death and Disability.* The report was largely responsible for the creation of the first widespread 911, Trauma, and Emergency Medical Services (EMS) systems in the United States. One important recommendation in the report charged the medical field and public sector services and agencies to build modern communications systems to enable efficient and effective coordination of services across police, fire, dispatch, ambulance, and hospital organizations (NAS, 1966). As a result, the federal government responded by funding two-way radio infrastructure development projects across the United States. Since that time, emergency medical communications systems in the United States have largely remained a “voice-centric” infrastructure.

A little over a decade ago, the National Highway Transportation Safety Administration (NHTSA) (1996) identified the importance and need for a more “data-centric” communications infrastructure for EMS. It discussed a need to update communications systems to better utilize data to improve EMS processes and enable an infrastructure for performance analysis and reporting. This report, and other more recent studies and reports, have concluded that multiorganizational EMS continues to operate without a sufficient research basis to support many of its operational and information systems decisions and thus needs better data collection, analysis, and reporting systems (IOM, 2007; NHTSA, 2001; McLean et al., 2002; Sayre et al., 2003). Such an infrastructure would enable information sharing across the range of emergency response organizations and was thus identified as an important precursor to improving EMS research and systemwide services (IOM, 2007; NENA, 2001; NHTSA, 2001).

THE MOTIVATION FOR NEW AND BETTER EMS IT SYSTEMS

Of course, the need and motivation to improve EMS systems stems from a long-standing and noble cause: to reduce death and disability and the costs associated with doing so. Significant financial and human resources, for example, are dedicated to reducing traffic-related deaths. In 2005 alone, there were over 43,000 traffic-related deaths that resulted in an economic cost estimated at approximately $50 billion (National Safety Council, 2008). Common sense and the general public perception is that a faster emergency response will decrease the likelihood of death or disability consequences for an automobile crash victim. It is not difficult to imagine a stranded, unconscious driver unable to dial 911 after crashing a vehicle. Cell phones used by passing travelers and new automatic crash notification (ACN) systems on board vehicles provide innovative solutions. However, only a few empirical studies have demonstrated that faster emergency response times reduce the likelihood that a trauma patient will experience disability or death consequences. One of these studies found that rural crash victims are seven times more likely to die if emergency medical services response time is more than thirty minutes (Grossman et al., 1997). Another study found that approximately 50 percent of trauma victims could benefit significantly from faster arrival at a trauma center, while the other 50 percent would not (Trunkey, 1983). Data from the Federal Highway Administration’s Fatality Analysis Reporting System (FARS) shows that over 60 percent of fatal automobile crashes occur on rural roads largely due to the additional time required to respond and care for a patient located in a faraway rural or remote location. The FARS data analysis shows that the length of time for an emergency response, including the time to answer the 911 call, arrive on scene, and transport a patient to a hospital, is approximately fifty-two minutes in rural areas compared to thirty-four minutes in urban areas (USDOT, 2007. The logical assumption is often made that these longer emergency response times in rural areas result in increased fatality rates.

A concerted focus on timely emergency medical service often translates into what is referred to as a “scoop and run” service, or the idea that the job of an ambulance is to pick up a patient and speed to a hospital as fast as possible with lights and sirens blaring. More recently, there has been a shift toward applying a higher level of quality health care and treatment at an incident scene and during the ambulance ride prior to a patient’s arrival at a trauma center. This practice is largely motivated by the belief and experience of trauma physicians and care givers that providing a higher level of care at the scene is better for the patient than providing a “scoop and run” service. There exists little empirical evidence in support of or against this perception. As a result, it remains largely unknown whether faster response times and higher quality pre-hospital care improve patient outcomes (Carr et al., 2006; Pons and Markovchick, 2002). There is a need for additional research to better understand the benefits and trade-offs of these two approaches to system improvement. There is a parallel need for more advanced interorganizational information systems to allow for such evaluation to occur.

More research and better data collection systems are needed to better understand the correlation between emergency response times and patient outcomes. And not just from a “fatality” perspective but also including disability consequences, length of hospital stay, severity of injury, and other outcomes associated with community, patient, provider, and payer costs of care delivery. This need for a more evidence-based approach to EMS performance evaluation and improvement is one major motivation for developing new end-to-end information systems for EMS. Department of Transportation (DOT) motivations for building information technology systems for Emergency Medical Services include the need to:

- Reduce emergency response times.
- Provide data to decision makers to make better resource allocation decisions.
- Provide data to EMS and trauma center decision makers to enable higher level of quality care to patients.

The Minnesota Mayday system was originally construed as a working test project motivated by the needs described above for more advanced IT systems in EMS. The goal was to build an advanced data-centric system in the State of Minnesota for the purpose of reducing emergency response times to automobile crashes. The case study reported herein refers to this innovative technical information system and interorganizational business process change that occurred, and how it influenced interorganizational information sharing. The analysis comes from the perspective of Mayday system users from a series of roundtable discussions and interviews with Mayday stakeholders.

Below we describe the methodology used in this study and the guiding analytical framework. The Emergency Medical Services (EMS) context is then discussed as background to summarize the current state of IT in EMS. We explain the performance motives for building advanced IT systems and describe the Minnesota Mayday case study. Findings from end-user interviews and focus groups are presented followed by a discussion of the utility, needs, and design considerations for end-to-end EMS systems.

STUDY METHODOLOGY AND GUIDING FRAMEWORK

The Mayday project implementation was conducted from October 15, 2004, to September 30, 2005. A test project technical evaluation was written and published by the Minnesota Department of Transportation (2006) as well as by Linnell and colleagues (2006) on behalf of the Minnesota Department of Transportation. It reports test results such as the system’s ability to send, route, and receive data; data reliability, throughput, and latency performance; and data storage and retrieval capabilities. The research team writing this report did not participate in the implementation and technical evaluation of the Mayday system. Rather, at the conclusion of the Mayday test project, the research team conducted an evaluation to understand benefits and challenges of the Mayday system from an end-user perspective. While the Mayday system project evaluation focused on the technical capability of the operational system to function as intended and designed, this case analysis focuses on end-user perspectives and perceptions about the utility, effectiveness, challenges, and future opportunities of the system. Researchers accomplished this through a series of interviews and roundtable discussions with individuals from each participating organization (State Patrol, GM OnStar, Mayo Clinic, and Minnesota Department of Transportation).

The importance of extracting end-user needs and perspectives has been articulated in the information systems literature for several years (Fahy and Murphy, 1996; Gunton 1988; Taylor et al., 1998). Integrating end users into the design of information systems has been shown to increase the creativity of a solution, incorporate a greater degree of specialized organizational knowledge into a solution, and produce additional opportunities for new and innovative strategic information systems (Davenport, 1994; McBride et al., 1997). When the end-user needs are well understood, organizations can expect greater levels of acceptance and diffusion of technology, greater levels of satisfaction, and systems that are more effectively aligned with organizational needs (Katz and Kahn, 1978; Robson, 1997; Zinatelli et al., 1996). By understanding end-user perspectives, we gain a better understanding about how to integrate technology into the design and operation of sociotechnical systems such as EMS—thus, the need for and focus of this chapter on understanding user perspectives about the Mayday system.

The end-user evaluation utilized on-site visits with each participating organization as well as individual interviews and roundtable discussions with participants. Participants included personnel from both management and nonmanagement positions and included call center operators, medical dispatchers, State Patrol officers, paramedics, physicians, hospital administrators, and nurses. Appendix 9.1 includes a list of participant job titles and organizations involved. In particular, we were interested in understanding issues related to system usability and improvement, as well as performance implications that affect service timeliness and service quality from end to end. The types of questions asked are also listed in Appendix 9.1.

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, and performance reports, interorganizational agreements including formal and informal contracts, as well as field notes and supplemental interviews. These 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. Interview and roundtable discussion participants were selected based simply on whether they interacted with the Mayday system and whether they were willing to participate. Semistructured interview questions sought to understand dimensions to information sharing. In particular, we were interested in understanding operational, organizational, and governance issues related to system usability and improvement, as well as performance implications that affect service timeliness and service quality from end to end. The intention of the interviews was 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.

Guiding Framework

The overall study methodology and research process 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, some of which are performance-based, technological, time-dependent, and so forth, and frame them into an analytical lens for interorganizational systems (IOS) analysis. The conceptual model includes several levels of analysis for TCIS, both in regard to EMS specifically and other public services generally. These levels, shown in Figure 9.1, include (1) the time- and information-critical elements of a sequential public service process, (2) the interactions and information exchanges across multiple cooperating service organizations that include both qualitative organizational elements and "hard" information flow elements, (3) the end-to-end elements that consider performance metrics within and across the process flow, and (4) context variation elements such as normal versus peak conditions (in terms of service demand) (Schooley and Horan, 2007). The utility of TCIS has been demonstrated as a heuristic to analyze EMS systems from a patient-centered approach (see Schooley and Horan, 2007).

Defining the Three Dimensions of Information Sharing

This study focuses on the interorganizational information-sharing dimensions of TCIS (Figure 9.1, second row from the top). This framework proposes a structure for understanding operational, organizational, and governance dimensions of interorganizational information sharing and integration to gain a deeper understanding about how information sharing influences the design and improvement of time-critical public services, EMS service delivery, and information systems to support these services.

These three dimensions were defined in more depth in Schooley and Horan (2007) and are also summarized below. These include:

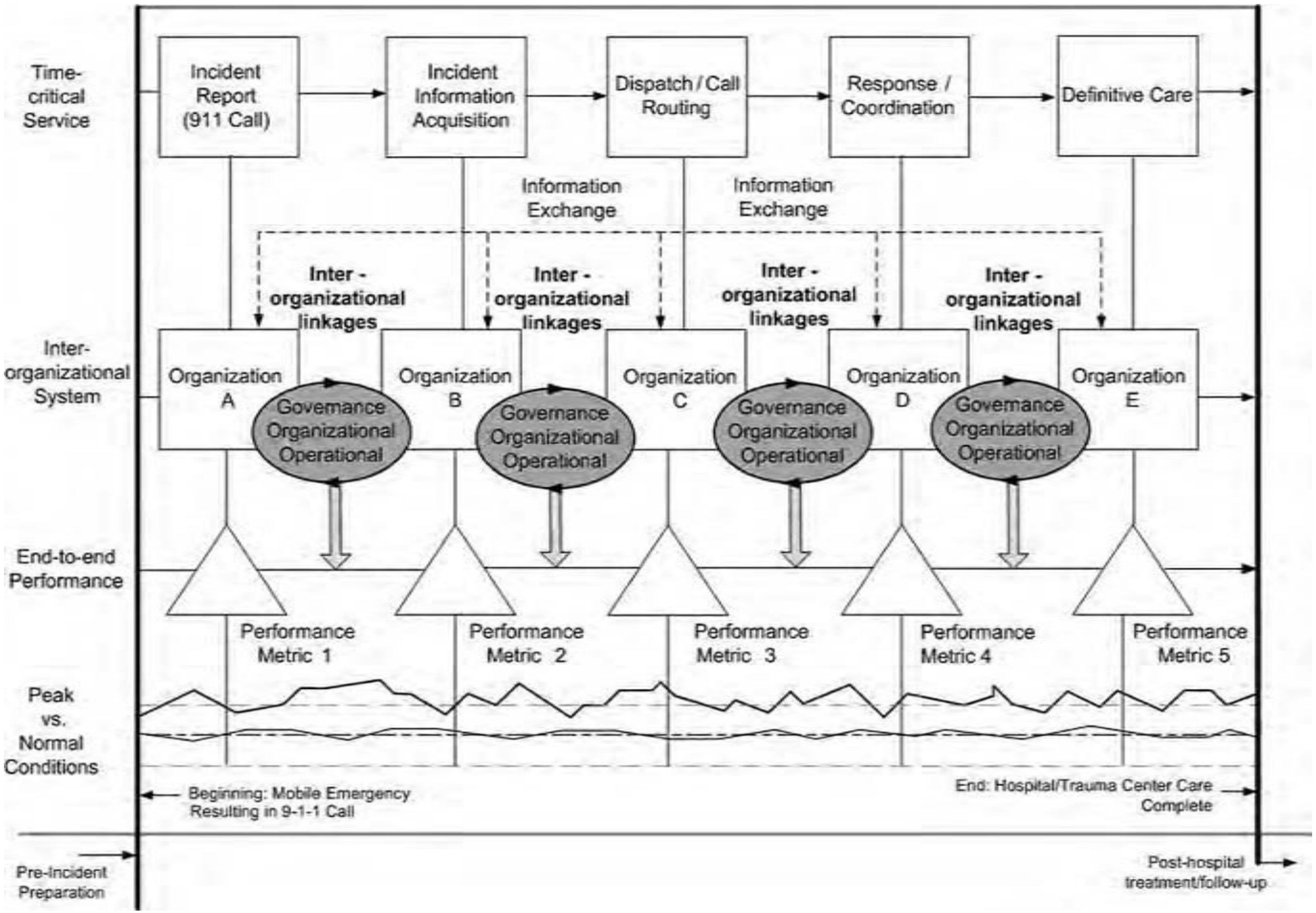
Operational dimensions
- Technical systems (software and hardware)
- Business processes (who, what, where, how)
- Communication flows (voice and data)

Organizational dimensions
- Power relations
- Level of participation
- Cultural, subcultural differences/similarities
- Resistance to change
- Trust

Governance dimensions
- Participant roles
- Rules and regulations
- Decision-making processes
- Political/legal
- Fiscal

The first of these dimensions, the *operational/technical* dimension of information sharing, includes technological resources, business processes, and communications flows related to sharing information and data across organizational boundaries. The *organizational* dimension includes issues

Figure 9.1 **Time-Critical Information Services Framework**



Source: Horan and Schooley (2007).

related to power relations, level of participation, cultural and subcultural difference and similarities across organizations, the tendency toward organizational resistance to change and finally issues of trust, or lack of trust between organizations. The *governance* dimension includes participant roles, rules and regulations, decision-making processes, legal, political, and fiscal issues surrounding an interorganizational information sharing system. These three dimensions were explored within the end-user interviews conducted by researchers. The findings from interviews are reported below and are organized along these lines.

CURRENT STATE OF IS IN EMS: AN OVERVIEW

A general complaint among users of EMS systems is that supporting information technology lags far behind private sector business capabilities. Nonetheless, significant technological changes have taken place in EMS over the past decade and continue to take place. Two-way radio systems continue to be an integral and important part of communicating during both day-to-day and large-scale incidents and certainly will not be completely replaced by data systems anytime soon. Nor is it clear that they should. Rather, a significant amount of change has taken place to understand and implement data systems to replace *certain* voice communications where it “makes sense.” And as discussed by users of EMS systems that we have worked with over the past several years, including the Minnesota Mayday system, it only “makes sense” to replace voice communications if the quality of emergency health care service given to a patient is not compromised by doing so. As one adamant paramedic explained, “If I have a choice between entering data into the laptop and stopping profuse bleeding, the choice is obvious. I’ll communicate using my hands-free radio.” But before getting into more depth with examples, it would be helpful to provide context about multiorganizational EMS systems. Using our TCIS model illustrated in Figure 9.1 (Horan and Schooley, 2007), we look across the multiorganizational, end-to-end EMS process from a patient perspective.

The importance of looking at system operation from a patient perspective is this: a patient looks at an emergency incident as one single event that begins from the time of onset of a medical condition (e.g., heart attack) and continues through (1) incident notification (e.g., 911 phone call), to (2) the answering and reporting of the incident, to (3) the dispatch and arrival of service providers (e.g., police, fire, ambulance), to (4) response and coordination of medical services on-scene, through (5) definitive care at a health care facility (e.g., hospital emergency department), and ends when s/he is released from the hospital. In contrast, there are a multitude of public, private, and not-for-profit organizations that experience only a slice of the same incident. For example, a hospital typically views the incident only from the time that the patient arrives at the emergency department. We suggest that analysis of EMS systems should be conducted based on the aforementioned end-to-end (i.e., start-to-finish) view (Schooley and Horan, 2007). As such, the primary information technologies used for EMS vary across the process as illustrated in the simplified description in Table 9.1.

There are a number of other electronic systems used across the EMS process in various locations around the United States including electronic personal health records owned by individuals that can prepopulate the ambulance patient care record, geographical information systems (GIS) that geolocate emergency response resources, voice-activated systems for capturing data in the field, as well as performance management, business intelligence, and other data-mining tools for conducting systems analysis and reporting functions, and a range of others. While there are many opportunities to implement new technologies and integrate data systems across police, fire, ambulance, and hospitals and other organizations, the above list represents what

Table 9.1

Common Technologies Used in EMS

	TCIS process point	Typical information technologies used	Description
1.	Incident Report	Landline telephones Wireless telephones Internet Protocol (IP) telephones	 Becoming more prevalent
2.	Incident Information Acquisition, and	Landline telephones and PBX systems	For forwarding, cuing, and answering 911 calls
3.	Dispatch	Computer-aided dispatch (CAD)	For viewing and entering caller information, allowing for touch-screen dispatching of emergency responders, tracking dispatched resources, and following incident progress
		Two-way radio	For voice dispatching of emergency responders and providing ongoing support and coordination throughout the duration of an incident
4.	Response/ Coordination	Two-way radio	For receiving instructions from dispatch, coordinating patient delivery to a hospital, and coordinating services with other response organizations (sometimes)
		Patient care record systems	For collecting incident, patient, and medical care information at an incident scene until delivery to a hospital
		Hospital availability systems	For reporting the real-time capability for hospitals to accept new patients and to divert ambulances to other hospitals if hospital wait times are too great
5.	Definitive Care	Two-way radio	For coordinating the hand-off of patients from ambulance providers to hospitals
		Electronic patient registries	For recording the receipt of a patient into the emergency department, trauma center, critical care center, or other emergency care facility
		Electronic medical records	For tracking patient status and medical care information throughout the length of stay at a hospital/clinic

we have seen as “typical” in many EMS settings in the United States. We present this list to provide some meaningful context for the remainder of this chapter. Discussing the full range of advanced IT systems that have been implemented in the EMS setting would be far too exhaustive for this chapter.

MINNESOTA CASE STUDY

The purpose of the following section is to provide case-study context about the Mayday project including related statewide initiatives to reduce emergency response times, Mayday project organizational arrangements, business process changes that occurred, the information systems structure, and the operational performance of the Mayday system. The following information was collected and assembled through interviews with Mayday system designers, managers, and users; system documentation; and technical reports written by the Minnesota Department of Transportation (DOT) (2006) and Linnell and colleagues (2006). This section provides context for understanding the end-user perspectives extracted through interviews—which are reported later in this chapter.

Minnesota and the Goal to Reduce Traffic Fatalities

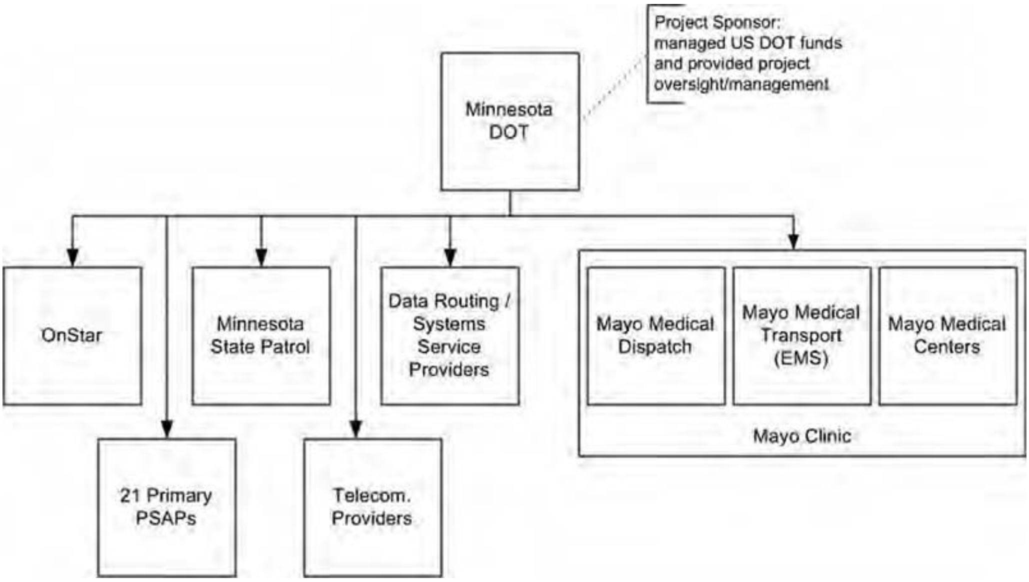
In 2005, the state of Minnesota had an estimated 5.1 million people living in 79,610 square miles. Approximately 2.6 million of those people lived in the Twin Cities metropolitan area, which covers less than 500 square miles (FedStats, 2006; Metropolitan Council, 2006). Approximately 50 percent of the residents and 95 percent of the land mass are located in rural and remote areas. In 2005, approximately 68 percent of all vehicle fatalities in Minnesota occurred on rural roadways. This is largely due to a number of geographical challenges associated with responding to rural and remote emergency incidents. There are often long delays before emergency responders are notified and long distances for emergency responders to travel to an emergency scene and then to an appropriate hospital. Though emergency response times vary a great deal across the United States, the National Emergency Medical Services Information System (NEMSIS) shows that many urban areas respond in less than twelve minutes. In contrast, some statistics show response times in rural areas to average over fifty minutes (USDOT, 2006).

While we are highlighting Minnesota, this is certainly not just a Minnesota problem. In the United States, over 50 percent of traffic fatalities occur on rural roadways. Furthermore, there were a total of approximately 43,000 traffic fatalities in 2005, placing traffic deaths as one of the leading causes of death in the United States (USDOT, 2007). This public health issue has become an important focus in the State of Minnesota as evidenced by the statewide Toward Zero Death (TZD) initiative. The TZD initiative includes the Department of Transportation, Department of Public Safety, Minnesota State Patrol, Federal Highway Administration, the Center for Transportation Studies at the University of Minnesota, and a wide range of other government and not-for-profit organizations dedicated to completely eliminating traffic fatalities in the state (Center for Transportation Studies, 2008).

The Minnesota Mayday 911 Project Overview

In 2004, the U.S. Department of Transportation funded the Mayday project, a statewide test project for the Minnesota DOT to establish a multiorganizational collaborative relationship with emergency response organizations to design and build an innovative interorganizational information system. The goal of the project was to use information technology to reduce emergency incident notification times for automobile crashes and the overall Emergency Medical Services response times for those crash incidents. The project included several counties in the state of Minnesota and proceeded from October 15, 2004, to September 30, 2005. The test project collaboration included the Minnesota Department of Transportation (Minn. DOT), the Minnesota State Patrol, GM On-Star, the Mayo Clinic including Mayo Medical Transport (air and ground ambulance provider), its dispatch centers, and trauma center, wireless and traditional wire line telecommunications carriers in the geographic region, data routing and information systems providers, and local and county 911 call centers commonly referred to as public safety answering points (PSAPs) (see Figure 9.2 for organizational arrangement).

Figure 9.2 **Mayday System Interorganizational Arrangement**



The geographic areas that participated in the project included 13 out of the 87 Minnesota counties (see Table 9.2), which included such populous counties as Hennepin, where parts of Minneapolis are located, and rural counties such as Renville and Meeker. The total estimated 2005 population in the test regions was approximately 2.5 million (FedStats, 2006; Metropolitan Council, 2006). Within these counties, there are 21 primary 911 call centers, or public safety answering points, and one medical 911 call center, or secondary PSAP, that participated in the project. These areas were representative of population density considerations; that is, 9 city, 13 county, 7 rural, and 15 urban/suburban call 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 (dispatch centers, State Patrol, ambulance providers, health care facilities, traffic management centers, and the traveling public). An important project goal was to utilize a standards-based, Web-services approach to achieve a national model for Mayday 911 event information delivery. Though the project was an operational test, the system was designed and developed for ongoing operations and remains in full operation as of this publication in 2007. The operational test included GM OnStar customers who were involved in real automobile crashes and whose crash data were automatically pushed to the GM OnStar call center, local Minnesota public safety 911 dispatch centers, and Mayo Clinic emergency medical dispatch centers.

Mayday Information System Overview

The Minnesota Mayday system was designed to bring OnStar crash information (data) into the Minnesota Department of Transportation statewide traveler information and information exchange system as well as the Condition Acquisition and Reporting System (CARS) that is available to authorized DOT, State Patrol, and other emergency response providers. The data generated by

Table 9.2

Minnesota Counties and County Populations Included in the Mayday Project

County	Population
Anoka	323,996
Carver	84,864
Dakota	383,592
Hennepin	1,119,364
Kandiyohi	41,119
McLeod	36,636
Meeker	23,371
Mower	38,799
Olmsted	135,189
Renville	16,764
Scott	119,825
Steele	35,755
Washington	220,426
Total in test areas	2,538,581

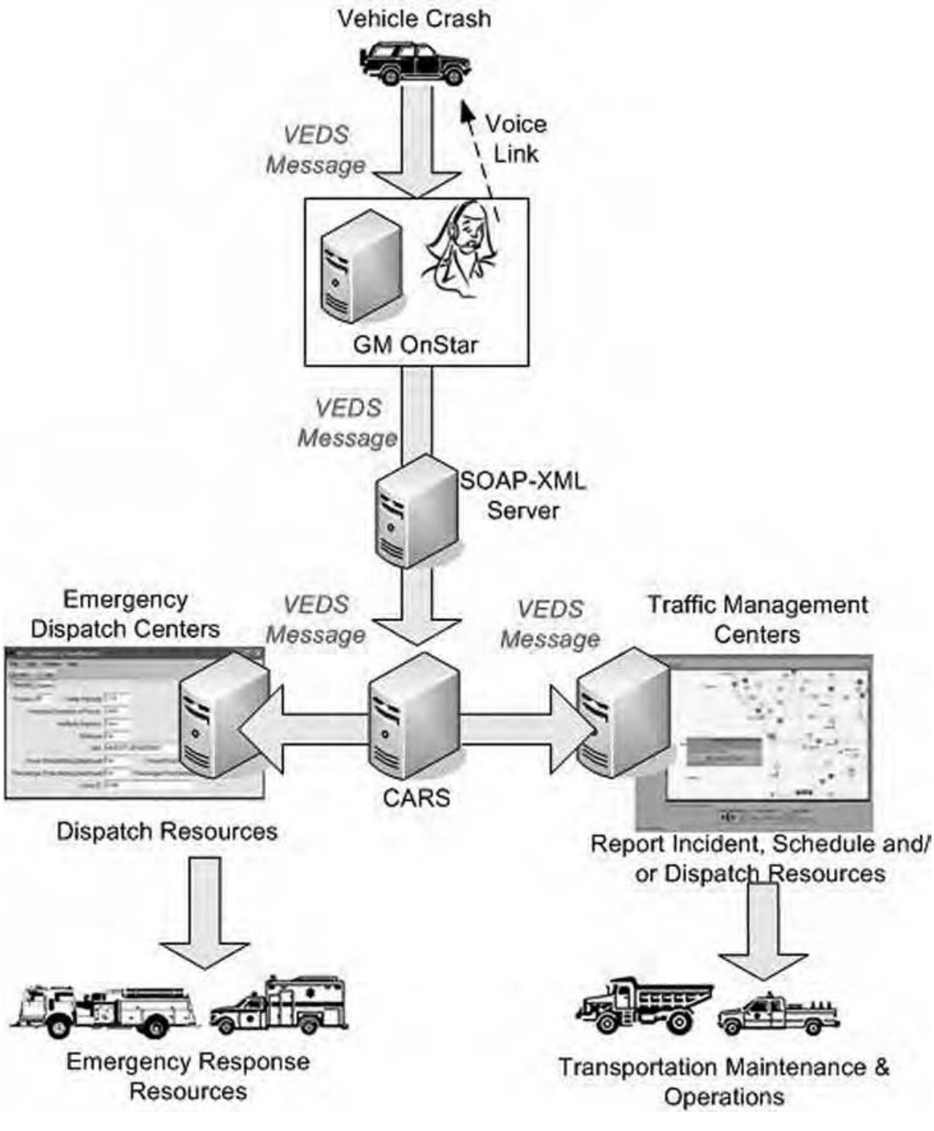
the emergency GM OnStar system is routed through the GM OnStar call center to a secure public Simple Object Access Protocol (SOAP) server, which then distributes the data by automatically pushing it to the CARS and to data routing systems to dispatch call centers and traffic management centers (see Figure 9.3). Crash incident data is delivered using the Vehicular Emergency Data Set (VEDS), a standard Extensible Markup Language (XML) data set developed by the Automatic Crash Notification Working Group that contains standardized variables for crash time, severity, and location that can be exchanged with pertinent stakeholders (COMCARE, 2006; Linnell et al., 2006; Minn. DOT, 2006).

The system created a significant interorganizational business process change with the purpose of reducing redundancies inherent in cross-organizational EMS communications and creating communication efficiencies that did not exist prior to the change. For each individual incident all applicable organizations are sent incident notifications simultaneously allowing both law enforcement and medical dispatch centers to receive emergency notifications at the same time. It also provides traveler information to the public through a public Web site that displays the locations of traffic incidents and resulting traffic congestion.

To give a better understanding of the significance of this business process change, Figure 9.4 displays the notification process in Minnesota *without* the Mayday system, and then the new process *with* the Mayday system. To help explain the significance of this change and the communications efficiencies that were created, we first describe the “without” scenario and then the “with” scenario.

The 911 process without the Mayday system starts with a vehicle or person notifying OnStar of an incident. In the case that a vehicle notifies OnStar, an OnStar emergency operator will try to contact the vehicle occupants to determine crash severity and their emergency needs. Whether they are contacted or not, the operator will then make or forward the call to the public safety 911 call center nearest to the incident. This can be very complicated since there exist an astounding 121 call centers distributed across the many small rural towns and counties in the State of Minnesota. Many of these call centers staff only one or two operators at a time and some are not functional 24/7. Though OnStar keeps a detailed database of these call centers and their geographic service areas, on occasion an incorrect public call center is contacted, which

Figure 9.3 **Mayday Emergency Data Routing System Overview**

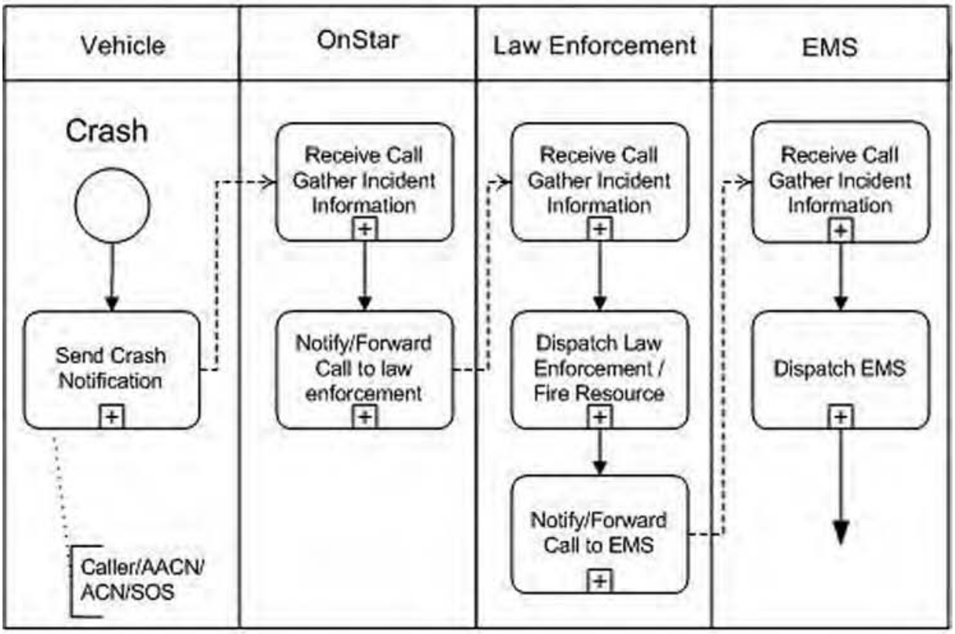


Source: Adapted from Linnell and colleagues, 2006.

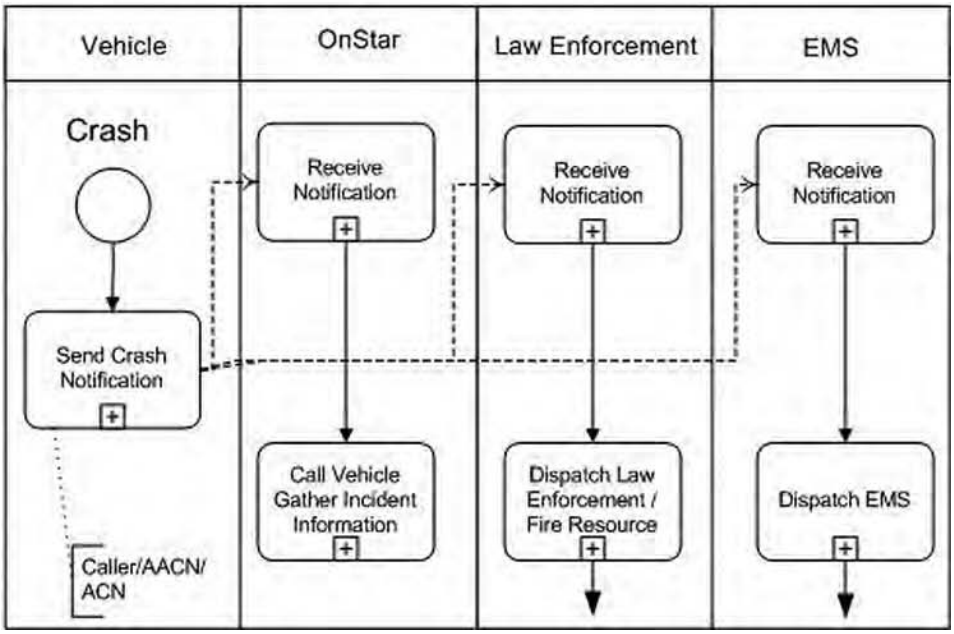
then requires the public call center operator to reroute the call to the correct call center. Despite rigorous efforts by the telecommunications industry to keep accurate 911 call center databases, 911 telephone calls are often misrouted, which requires rerouting by live operators, and can result in significant delays in emergency response efforts. In any case, when the call is answered by the public 911 call center, the OnStar operator will describe the incident to the public safety 911 operator providing the most important information first: incident location, phone number of caller, and some indication as to the severity of the crash. The occupants of the vehicle, if contacted, will then speak with the public safety 911 operator who is responsible for dispatching

Figure 9.4 **EMS Notification Business Process Change**

EMS Notification System without Mayday/9-1-1/CARS System



EMS Notification System WITH Mayday/9-1-1/CARS System



law enforcement resources (e.g., police, state patrol) and sometimes fire resources as well. The public safety 911 operator will then forward the call to an EMS medical dispatch center where the incident will again be described to the operator of that center. The caller will again describe the incident giving more details concerning the health condition of vehicle occupants. This third and final call center has the responsibility of dispatching medical emergency resources (e.g., air and ground ambulance, and sometimes fire). Verbal descriptions about an incident and the subsequent forwarding of a phone call to various call centers is the typical 911 call process for most locations in the United States. It can be a time-consuming and inefficient process, but there are of course many historical, political, organizational, and financial reasons for this—such as the historical need to separate law enforcement and medical emergency response crews due to the advanced skills set and knowledge base needed to handle each separate and distinct type of call (IOM, 2007). However, these reasons have been well documented in other sources and are outside the scope of this chapter.

In order to utilize a more data-driven approach to speed the notification and dispatch process, the Mayday system was born. The system notifies both public safety and medical dispatch centers simultaneously of an automobile incident, thus eliminating redundant reporting of an incident. Furthermore, the initial incident notification is distributed via data communications and then supplemented with voice communications, enabling resources to launch more rapidly.

The twenty-one 911 call centers that participated in the project are charged with dispatching local law enforcement, State Patrol, and fire resources while the Mayo Medical dispatch center dispatches ground and air ambulance resources. The Mayo Clinic, together with its dispatch center, ambulance transport service, and various medical and trauma centers participated in the response and delivery of patients to health care facilities.

Mayday System Performance Overview

Across the entire United States, GM OnStar reports a monthly average of approximately 380 advanced automatic crash notification (AACN) calls, 1,000 automatic crash notification calls (ACN), and 11,400 emergency push-button calls (SOS) (see Table 9.3 for definitions of AACN, ACN, and SOS as they apply to the Mayday Project). As reported by Linnell and colleagues (2006), during the Minnesota Mayday test period there were a total of 17 AACN calls, 137 ACN calls, and 1,093 SOS calls (see Table 9.4). Though not a large volume of calls, the test did provide an opportunity for end users to experience the operational changes that the system offered. Table 9.4 shows total call volumes, weekly average call volumes, the maximum and minimum number of calls received each week, and the amount of time it took for Mayday messages to be sent to emergency call centers for each of the call types recorded during the test (AACN, ACN, and SOS). In terms of weekly incident volumes, there were very few AACN calls due to the very few vehicles that are equipped with such systems across the United States. However, the number of vehicles equipped with such systems is growing dramatically each year, increasing the impact that the Mayday system will have on drivers and emergency responders.

Table 9.5 illustrates the types of data collected from each of the different types of OnStar calls. Different amounts and types of information are collected depending on whether the call is an AACN, ACN, or SOS call; with AACN providing the most in-depth description of an automobile crash incident. Further detail about the information provided in a Mayday message can be found below.

In terms of Mayday system performance, notification times across the duration of the project ranged from less than 1 second to approximately 23 seconds, far shorter than the average voice notification. Interviews with State Patrol and Mayo Clinic experts indicated that the Mayday

Table 9.3

Definitions of AACN, ACN, and SOS Calls

Term	Definition
Advanced automatic crash notification (AACN)	Those events where an advanced collision notification system is on board a vehicle. The system sends basic information to an OnStar adviser, such as the location of the vehicle, vehicle type, contact information, and whether an air bag was deployed or not; as well as additional crash information such as delta velocity (speed at impact), principal direction of forces, and whether a rollover occurred. A voice communication link is also established between OnStar and vehicle occupants.
Automatic crash notification (ACN)	ACN systems automatically send basic crash information such as the location of the vehicle, vehicle type, contact information, and whether an air bag was deployed or not. It creates a communication link between OnStar and the vehicle for voice communication to occur.
Emergency key press (also referred to as SOS)	Those events where OnStar users (vehicle occupants) press the emergency key button in their vehicle. This establishes a voice communications channel only between the vehicle occupants and OnStar. No crash information is sent automatically. In the case of a crash, OnStar advisers receive the call and establish a three-way call with the local 911 call center.

Table 9.4

Weekly Call Volumes (by type) **and Notification Time Intervals**

	AACN Calls	ACN Calls	SOS Calls	Failures	Time delivery (seconds)
Totals	17	137	1,093	50	
Weekly average	0.36	2.9	23.26	1.06	1.38
Range (maximum)	3	15	46	36	23.25
Range (minimum)	0	0	0	0	0
Weekly median	0	2	26	0	0.835

system reduced the emergency notification interval for ambulances by approximately 3 to 10 minutes and the overall ambulance response interval by approximately 2 to 9 minutes, depending on other crash factors such as the incident location, the capacity of the local 911 call center, and availability of an ambulance (Linnell et al., 2006). When comparing these time savings to the average time it takes to notify and respond to an emergency, it is clear that the Mayday system has the potential to significantly impact end-to-end efficiency. To put this in context, evidence indicates that average emergency response time intervals across the United States are as shown in Table 9.6 (USDOT, 2007).

MAYDAY USER PERSPECTIVES

Through interviews with system users, the overwhelming majority felt that the Mayday system proved a success. As is often the case with IT system assessments, there were plenty of complaints,

Table 9.5

Data Types Collected from Each System Type (ACN, AACN, and SOS)

Data types	AACN	ACN	SOS
Vehicle location	X	X	X
Incident type	X	X	X
Air bag deployed	X	X	
Time-stamp	X	X	X
Delta velocity	X		
Rollover	X		
Multiple severe impacts	X		

- *Vehicle location* (latitude, longitude). Description of the route or roadway that the event occurs on, as well as the intersection (or mile marker).
- *Incident type/description.* This key phrase contains the best description of the event. For example, automobile crash, heart attack, and so forth.
- *Air bag deployed*. This specifies whether an air bag was deployed during the incident. Advanced systems indicate which air bag/s.
- *Time-stamp data*. Incident start and stop times.
- *Crash information* (delta velocity, rollover, multiple severe impacts). Additional information concerning the crash facts may also be inserted. This is in accordance with what data OnStar is able to send. For the Mayday system, these data were limited to delta velocity (speed of vehicle at impact), whether the vehicle rolled over, and whether there were multiple severe impacts. Data forwarded to systems that provide data to the general public are limited to basic information about the location and general nature of the event.

Table 9.6

Average Time Intervals Across an End-to-End Emergency Response

Time interval	Rural crash	Urban crash	Mayday time benefits
Time of crash to notification of crash (911 call center receives call)	7 min.	3 min.	3–10 min.
Notification of crash to time of EMS arrival at scene (ambulance arrives)	12 min.	7 min.	2–9 min.
Arrival at scene to time of arrival at hospital	36 min.	25 min.	NA
Total	52 min.	34 min.	7–19 min.

suggestions for improvement, and newfound requirements for the next version of the system. But comments were generally positive about the end result largely because the project enabled and encouraged collaboration across traditionally disparate organizations. While there has been much written and spoken about collaboration, these groups were able to put such ideas into practice and gain benefits therein. One State Patrol Officer said:

> We've been able to see and get information in ways that, well we really couldn't imagine like 10 years ago. Just the traffic and road maintenance reports from Minn. DOT, crash reports from OnStar, and we can see where the ambulance is. This type of coordination, it's all very helpful for our officers in the field.

A more in-depth discussion about Mayday user perspectives follows. As mentioned in the methodology section previously, the following section discusses participant responses to a set of interviews and roundtable discussions with users from each participating organization. The case study examples illustrate the interrelated, parallel, and overlapping importance of the three dimensions: operational, organizational, and governance.

User Perspectives: Operational Level

The following findings focus on operational dimensions of interorganizational information sharing across the Mayday system. As mentioned previously, these dimensions include technical software and hardware systems, business processes, and communication flows that influence cross-organizational information sharing.

IT Quality Attributes: Usability vs. Security

The technical usability of the Mayday system came into question early on and throughout the duration of the project. The system went out of service several times as illustrated in the multiple message failures that occurred and were reported in Table 9.4. These outages were due to the expiration of the security key required to ensure a secured connection between all routers. From one system administrator's standpoint, the system was at least very secured, but sacrificed usability and ease of management as a result. As such, the need to renew security keys on a regular basis was forgotten about on several occasions. Administrators stressed the importance of implementing rigorous management checks and processes to ensure a balance between ongoing functionality and security—both cited as top system quality attributes for such a highly privacy oriented and potentially life-saving system.

Automation for Emergency Responders

Trauma care is highly variable in terms of the types of problems encountered and care interventions administered. It can be dynamic and fast-paced, and can involve a wide range of emotions on the parts of all concerned. In these cases, emergency responders want to focus their attention on the needs of a patient. An important benefit of the Mayday system is that the automated and simultaneous data pushes from OnStar to both law enforcement and medical dispatchers allow emergency responders to focus on providing care to a patient rather than on gathering phone number, location, or other information. The automated data pushes were so appreciated in fact that participants began looking for additional opportunities for automation. One of the technical designers and builders of the system stated:

> The next step in automation is to have all OnStar calls automatically routed to the correct PSAP [local 911 call center]. During the project, some calls were forwarded to the wrong PSAP because we designed the Mayday system so that OnStar operators had to manually dial the 10-digit number to each local Minnesota call center. So what we can do now is take out human error by making it automated.

Participants described the need to eliminate from the dispatch process even the rare cases of human error and stated that automated dialing was one way to help accomplish that.

Real-Time Decisions

The process of implementing and testing the Mayday system provided opportunities to reassess real-time decision-making processes across the service. In particular, it allowed for users to explore how crash data could provide advantages at various decision points. For example, one Mayo trauma physician believed that certain data, such as vehicle type, the speed of the vehicle at impact, what part of the vehicle suffered damage, whether air bags were deployed or not, and other related information could be used to calculate the number of individuals involved and the probability of injury to each vehicle occupant. The Mayo trauma director stated:

> That kind of data could be extremely useful for preparing a trauma team prior to patient arrival. That alone could save a lot of time and lives.

The Mayo dispatch manager thought that same data could be used by dispatchers to make better decisions on the number and type of ambulances (air or ground, advanced life support or basic life support) to deploy to accommodate one person or multiple individuals with various degrees of injury.

Incident Visualization

An additional valuable dimension of the Mayday system was how it enabled more effective communications within and between organizations. Participants discussed how emergency professionals were able to visualize other service providers from other organizations on the CARS user interface by looking at the GIS-enabled map. A dispatch supervisor explained:

> The CARS interface gave us a visual map to see what DOT and the State Patrol were doing about an emergency incident. We could actually see which ambulances were closest to the incident and then dispatch them. A few times, we sent the dispatch to a competing ambulance provider because they were closer to the incident.

The system also allowed emergency personnel in the field to know who they could contact at the incident and what type of service the patient might be receiving. A Mayo dispatcher described an experience:

> I could see that a CPR-trained State Patrol officer was the first responder at the accident and the report that we got was that either driver or passenger was having difficulty breathing. I told the paramedics who were en route that State Patrol was there and that he was CPR trained. I don't know if that information changed the overall patient outcome. That's hard to tell. But the paramedics like knowing what to expect when they arrive. They can at least know what equipment to bring with them, what procedures have been given, and what procedures they should prepare for.

In a like manner, State Patrol dispatchers could view the CARS interface to see the activity of Mayo EMS resources, for example, whether an ambulance had been alerted and was en route to an incident or not. The CARS interface also allowed dispatchers to view traffic congestion and road maintenance information from Minn. DOT. This enabled ambulances to make better driving route decisions to avoid traffic. Participants noted how this information allowed collaborating organizations to make more-informed decisions. For example, a State Patrol officer said:

> If I know that an ambulance is on the way, I don't have to spend time wondering "when is the ambulance going to get here?" or spending time telling EMS dispatch to send an ambulance that has already been sent. The new communication system was helpful in that sense.

In general, participants noted how their ability to visualize and see emergency and transportation resources enabled more effective communications, more-informed decision making, and a higher degree of perceived service performance.

Streamlining Interorganizational Processes

As stated previously, the Mayday system created a business process change. While it was agreed that change was good, participants discussed several operational challenges associated with the ongoing goal of establishing proven, tested, and standard business processes for delivering clinical care across service organizations. Standards of care often differ from one organization to another. For example, ambulance providers may adopt care practices based on their experience, or based on a different set of priorities (e.g., faster response times as a higher priority than care delivery), while the emergency department at a hospital may adopt a different practice based on other assumptions (e.g., new research). A trauma physician stated:

> Fortunately for us [Mayo Clinic], we purchased the ambulance provider just a few years ago, which has enabled us to have a more integrated approach to delivering care across the service. But it is still a very challenging task when you think of all the different types of cases we see. No case is exactly alike, which means we have to change our approach depending on the case.

Discussions alluded to the dynamic nature of emergency medicine and the need for information systems to support that environment. Some examples were provided. A trauma department administrator discussed how there are many complex interactions between human organs and biological systems, which makes diagnosis extremely difficult. Many injuries are discovered hours or even days after an automobile crash. In this regard, she explained that there exists a need to further develop quality of care standards and associated emergency health care processes that are adaptable based on scientific evidence. A Mayo trauma physician stated:

> Until there can be more agreement [on standards and processes], it will be difficult to create a comprehensive data set to share between emergency response and health care organizations.

In a related sense, participants discussed the need for a more comprehensive set of performance measures to adequately assess the end-to-end performance of EMS. The Mayo trauma department clinical director stated:

> One challenge is that there are numerous different descriptions of what good patient care means. Another is that there are so many variables involved in delivering health care that it makes performance measurement difficult. These challenges need to be addressed. A comprehensive look at quality care provision across the whole service has not been investigated in depth.

A data analyst felt that a discussion about medical care (business) processes, performance measurement, and quality of care needed to take into account the different types of data that are shared, or could be shared, across service organizations, which include “incident” data, “process” (timeliness) data, and then data that integrate the two. He explained:

> There is an important difference between “data about the incident” and “data about the process.” Data about the incident include information about the patient, his/her location, the incident type, care provided, resources dispatched and available and other related data. Data about the process include time-stamp data, which are used to determine process and work activity costs that essentially determine process efficiency. What is less understood is how to use both “incident” and “process” data to measure quality of care.

In terms of performance implications, an emergency physician stated:

> Time from crash to definitive care remains the most important indicator of survival or patient outcome. But the right type of care will also improve response time, care delivery, and outcome.

In sum, participant comments highlighted challenges to implementing process changes across organizations—each stakeholder wanting to make sure his/her priorities are not sacrificed. While participants discussed challenges to establishing new business processes, they also pointed at the Mayday system as a “good fit” with both operational and clinical care needs. Participants felt that future process changes, in order to be successful, also need to have both operational and clinical care benefits in order to achieve long-term acceptance by users.

New Service Complexities

While the Mayday system provided new efficiencies, several users discussed some added complexities. Several State Patrol officers provided an example when only partial incident information was received from a call made by an OnStar customer. Soon after a customer pressed the OnStar emergency button while driving his/her black Escalade, the call was dropped. State Patrol officers did not know whether the individual hung up the phone or the call was lost for some other reason. An officer explained:

> OnStar transferred the call to us but it was dropped before we could figure out the problem. The only information we received was the make, model, and location of the vehicle and the general coordinates where the call was made. But the car was moving and we didn’t know [in] which direction. So we were obligated to respond and of course, there was no black Escalade when we arrived. So, we pulled over every black Escalade we could find in the vicinity to search for the reported emergency. We never found it.

The State Patrol officers discussed their frustration with these types of incidents. They were obligated to respond to the call and look for the vehicle. Their obligation was based on the definition of their jobs as instituted by the State Patrol and Minnesota law; they also had a moral obligation. No exceptions had yet been made based on the circumstances of a dropped or lost call. They pointed out what they felt to be an important aspect of cross-organizational information systems—that quality and completeness of information relates to service efficiency. Though information systems (people and technology) may help improve service, they also create complexities that can result in service degradation when they do not function as intended. In this case, having only partial information led to a long and extensive search. Concerning the above example, the State Patrol officer said:

> Our time was wasted and an individual's health problem was possibly left unaddressed. It shows how important it is to have a complete set of information. We need to have policies in place that deal with incomplete information. We can't just ignore a dropped call. We have legal, not to mention ethical obligations to respond to every call. That's why we can sometimes seem pretty skeptical about taking on new technology.

Participant responses pointed to the need for new technology to be thoroughly tested and proven in order to ensure that the technology functions as intended, that the full range of intended information arrives at its destination so as to reduce user confusion and inefficiencies.

User Perspectives: Organizational Level

The discussion below relates organizational issues to information sharing. As outlined earlier in the chapter, organizational and interorganizational dimensions of information sharing include trust, cultural and subcultural differences/similarities, effective communications, level of participation, power relations, and resistance to change.

Partnership Trust

Mayo Medical Dispatch valued their Mayday partnerships and discussed how trust developed during the project. A Mayo dispatch manager explained:

> OnStar does a good job at screening calls. It's nice that when we do get a call we know it has been screened well. And our dispatchers pretty much know that the call is an actual emergency that needs attention. And so that lets us dispatch an ambulance right off the bat before spending more time screening the call.

Dispatchers believed that the Mayday system and partnership allowed them to be more efficient. They acknowledged the difficulty in measuring the end-to-end benefits in quantitative terms because they did not know how long it took OnStar to carry out its job to screen and forward the call (except in the case of AACN and ACN calls). But the perception from Mayo dispatch personnel was that the partnership provided a positive benefit to them because the information they received from OnStar was "trustworthy."

Easier to Trust Hard Data

A significant challenge to sharing data, according to paramedics and emergency department staff, rests between the "pre-hospital" and "hospital" environments. Participants discussed a lack of trust that can often exist between the two. A trauma center representative explained:

> Paramedics have to make assumptions about a patient's condition. But physicians question and discount those assumptions. So what I mean is a common perception that physicians

> have is that paramedics don't give accurate medical care information. And paramedics think physicians are arrogant. We do a pretty good job at Mayo to overcome that problem particularly when a patient comes into the ED [emergency department] from a Mayo ambulance. But we also get patients from the "scoop and run" [non-Mayo] ambulances and there can be definite trust issues in those cases.

According to Mayo physicians, a primary benefit of advanced data systems such as Mayday is the ability to distinguish between, or at least separate, qualitative human-generated and machine-generated data. More reliance on the latter helps to increase trust between service organizations. A trauma representative explained:

> Physicians and paramedics alike need to better understand that there is irrefutable hard data, like EKG readings, and then there is expert opinion that is subject to scrutiny.

The Mayday system provides an opportunity to advance hard quantitative data. Patient information, including demographics and health history, coupled with crash details offer the ability to create an objective description and predictive algorithms, which can be used to help determine proper care provision. For example, a predictive algorithm would include taking variables such as which air bags were deployed, the speed of the vehicle at impact, and which part of the vehicle was impacted, and would then calculate the probability and scale of injury to vehicle occupants. Based on these data, emergency responders could better assess how many and which emergency resources to send (e.g., helicopter, ground ambulance). A physician stated:

> That is one of the benefits of the Mayday system. We have hard data that says there has been a rollover event and we have the delta velocity [speed of vehicle at impact] rather than a paramedic saying, "the vehicle was traveling fast and crashed really hard."

As noted by the above physician, the general notion from participants was that there are levels of distrust when humans relay health-related opinions and/or impressions. And the hard data from instruments allows for performance improvement in terms of time, but also because human opinions and impressions are replaced by data by trusted instruments.

Aligning System Purpose with Organizational Culture

OnStar, the State Patrol, and the Minnesota Department of Transportation representatives all noted that their participation in the project was largely influenced by a shared belief that the Mayday system would both quicken response and allow for better health care decision making. This common and shared belief helped to mitigate typical interorganizational challenges to sharing information—particularly among the more integrated Mayo organizational units—Trauma center, Dispatch, and Ambulance service. Mayo participants felt that this was largely due to their organizational culture, which is both accepting of new innovations and focused on quality health care delivery. A Mayo representative stated:

> The Mayday system "fits" well with our philosophy and mission statement about putting the health of the patient first. We pride ourselves on providing quality care to every patient. It was a natural fit and received plenty of support. But we have to remember that we are

> spoiled here. We don't have many of the constraints that can be found in overcrowded, underfunded urban hospitals.

While Mayo was able to participate and dedicate resources to the project, participants noted that most trauma centers in the United States do not have the resources to implement such a system. Hence the importance of developing standards-based, duplicable models that can be implemented elsewhere.

Communicating Performance

Some participants discussed how an overemphasis on timeliness can act as an obstacle to communicating other valuable and pertinent information. Mayo Clinic personnel agreed that the time from dispatch to arrival at a hospital is paramount, but that there is too often an overemphasis on "timeliness" as a performance metric. A Mayo Clinic representative explained:

> How much and what type of care is given during that time period is equally (if not more) important. This is especially evident in rural and remote areas where response and transport time [are] lengthy, even for the most efficient responses.

Participants believed that the focus on response time had significantly impacted the regular exchange of response time data. And that a similar emphasis was needed to motivate the regular exchange of data that could impact health care decisions. A Mayo dispatch representative stated:

> There are many unknown, untested, but potential benefits to sharing "health care" information across organizational units. But we just haven't focused on that data enough. There is a lot of emphasis on the time-stamp data for good reason. We just need to extend the emphasis to other types of data. Mayday provides a good example of the potential benefits.

Cross-organizational Communication

Users discussed how one of the benefits of the Mayday project was that it stimulated managers to think more in terms of the future possibilities of using information technology to enhance EMS. A Mayo dispatch manager described an example:

> An automobile accident occurred on the outskirts of Rochester, an air bag was deployed, and an ACN message sent to OnStar and through the Mayday system. When responders arrived to the coordinates they couldn't find the crashed vehicle and almost gave up the search. It was finally found after an extensive search. It had driven off the road and into thick foliage underneath a freeway overpass. In our Mayday group meeting, we talked about that incident and it stimulated discussion from everyone [Minn. DOT, State Patrol, Mayo Clinic] about how technology could have been used to aid responders. Suggestions included sending repeated data messages until the vehicle was found and automated flashing lights or repeated horn honking to supplement data messages.

For participants, it was not the above solution that was most interesting, but the open conversation that took place between organizational representatives. The Mayday system created an atmosphere that facilitated cross-organizational communication.

Resistance to Change

Participants discussed how “immediate” and “observable” performance benefits helped overcome resistance to change. Dispatchers, State Patrol officers, and EMS professionals were able to see and experience immediate benefits from sharing information. A Minn. DOT project manager explained:

> Mayo dispatchers received incident notifications sooner than normal, and State Patrol officers were able to observe ambulances arrive on scene sooner than would normally be expected. Since they could see the benefits right up front, we really didn’t experience much of the resistance to change that we sometimes experience when we deploy new technologies.

Mayo dispatch participants stated that dispatchers have been resistant to information technology changes in the past. Yet, they were enthusiastic about using the Mayday system soon after the first emergency incident messages arrived and observable improvements were discovered. Similar comments were received from State Patrol, trauma center, and Mayo transport participants. The ability to observe performance improvements significantly influenced perceptions about the value of interorganizational information sharing.

Aligning Technology with Human Needs

The Mayday system was designed for interface flexibility utilizing an XML data standard. The participating dispatch centers did not expend the resources to integrate the XML messages into their existing computer-aided dispatch (CAD) systems and instead viewed automobile crash incidents through a separate Web-based graphical user interface (GUI). Participants explained that the desirable solution would integrate, or allow for Mayday data messages to be viewed within existing interfaces (e.g., CAD, patient care record [PCR] systems, and hospital-based decision support systems). A dispatch operator explained:

> We are often overwhelmed by the amount of information we must deal with on a regular basis and most dispatchers don’t want yet another computer screen to look at.

Several State Patrol participants stated that most of the small public safety answering points would likely not participate in the Mayday project just for that one specific reason—that new information must be integrated in a useful and convenient manner or not at all. Mayo Dispatch and State Patrol operators are surrounded by 1–2 phones, 1–3 two-way radios, 2–4 active computer monitors as well as wall-mounted large screen monitors to display the status of emergency units in the field; view real-time status of multiple incidents simultaneously; view weather information, real-time video, and graphically displayed traffic information; view the availability of emergency department and trauma centers; and to communicate via voice to provide a centralized support function. In short, they feel overloaded with information.

One State Patrol representative said:

> With so few OnStar users, it is difficult for many locales to justify the cost to implement technological systems that integrate with Mayday. They simply will not add another monitor or screen to the many already existing interfaces. It’s a significant issue for dispatch centers.

A Minn. DOT participant disagreed with the challenges:

> The programming, coding, and technical infrastructure [are] already in place. It was accomplished through the Mayday test project. Data messages are pushed to all subscribers in a standard XML format, which means that local PSAPs just need a computer and an Internet connection to link in.

Even so, there are costs associated with getting the data into a form that end users are willing to utilize. Participants believed wide-scale implementation would take place as AACN, ACN, and SOS technologies become more common in vehicles. Until then, agencies would not see the benefit of investing in systems to connect with the Mayday system.

In contrast to how the above professionals felt, information technology designers who developed the Mayday system felt that EMS professionals were reluctant to change. As stated previously, the Mayday information interface was a single large monitor shared by all communications center dispatchers. When an automated Mayday message came into the center, the interface map displayed the incident and an alarm signaled throughout the center. One system developer stated:

> The dispatchers don't want another screen to look at and they don't want the alarm. They were not enthusiastic during training. Several were skeptical and negative.

But dispatchers stated that the resistance was not due to the data, but due to how they received the data. A center manager explained:

> We have 3–4 monitors on the desk in front of us, a large screen on the wall with weather information, another with traffic, another with traffic video; we have a radio and a phone. We need the data to automatically enter our CAD system rather than have another interface to look at. It was OK during the test project and the OnStar data is very useful. But we need it to go to the next level and have it integrated with the CAD so we're not looking all over the room for information.

According to the dispatchers, the resistance was not due to the information being shared but due to the communication interface. Dispatchers felt that an appropriate interface would significantly impact their ability to use the data more effectively. However, issues still exist in terms of using new information effectively, as emergency professionals are often overwhelmed with data and information. This tends to create a culture of resistance to new or additional information.

User Perspectives: Governance Level

The following discussion relates governance dimensions of information sharing across the interorganizational Mayday system including participant roles, legal definitions, policies, and rules and regulations.

Success Due to Well-Defined Participant Roles and Responsibilities

Interviewees discussed how the overall success of the Mayday project was largely influenced by well-defined participant roles and responsibilities. Many barriers to information sharing were overcome because the Minnesota Department of Transportation had clear oversight and direct management over the project. A Minn. DOT project manager confirmed:

> The project was well designed, funded, it worked just as a field operational test works. We had an RFP [request for proposals] process at the beginning and everyone reported to us.

Minn. DOT funded the project through grant funding, which overcame budget issues for participating organizations. Minn. DOT had clear responsibility and accountability over system governance. This facilitated Mayday implementation and information sharing and enabled the performance efficiencies previously discussed.

However, participants from other organizations discussed their concern over who would own and manage the system and how it would move forward in the future. Ten months after the project ended, a Mayo Clinic representative stated:

> Minn. DOT has maintained the system since the project ended, but there is no indication as to how long it will do so. We know that the system that sent automated messages to ambulance pagers was shut off a few months ago. We don't know how long the system will keep working.

A Minn. DOT representative said funding was in place to keep the system running for a long time. Participants understood that the Mayday system started as a research project and demonstration and wondered about the sustainability of it. They were not aware of future plans, how long funding would continue, what the partnership arrangement would look like, or who would have financial/legal ownership. While clear governance structure was key to initial project success, uncertainty about its sustainability had created an atmosphere where some information sharing had terminated, and there existed a standstill in terms of furthering information sharing initiatives. One State Patrol officer speculated:

> I think the system will continue to operate. Maybe they'll change the structure of it. OnStar could manage on a fee basis, or maybe DOT will continue to outsource management using public funds. But we haven't moved ahead with any new plans since the end of the project.

The Need for National Direction and Strategy

Participants discussed a much larger issue, associated with information sharing at state and national levels, which has become increasingly important due to a focus on large-scale catastrophic events. A Minn. DOT representative explained:

> The Mayday system could have far-reaching implications. It could be very valuable, for example, to find patients and deliver care during or after large-scale geographically concentrated events like terrorist attacks or earthquakes. Because messages are based on open XML standards, it could notify a wide range of state and national organizations when there is a sudden increase in service calls and if a local EMS system needs additional help to respond.

The Mayday system was built in a manner that enables OnStar to *send* data all over the United States. A large portion of the technical infrastructure is in place. But participants explained that there is a lack of national directive, or strategy on how to expand the system and include/integrate it with new systems such as the National Highway Transportation Safety Administration

"NextGeneration 911" initiative, an effort to create a more "data-centric" 911 system. A Mayo Clinic administrator stated:

> There is a lack of political leadership and collaborative efforts on what needs to be done to achieve such a National goal. We need "building blocks" and a plan that describes how to achieve next generation systems in an incremental fashion. Not just technically, but in terms of organizational and policy plans.

Participants discussed the need to define the parts and components of the national system, and what needs to be accomplished to build a foundation on which EMS systems can exchange data across local, state, and federal systems.

The Health Privacy Issue: Health Insurance Portability and Accountability Act (HIPAA)

Numerous discussions took place at the beginning of the Mayday project to determine what advanced automatic crash notification data should or should not be sent from OnStar to other organizations. A Mayo representative described a topic of one of the meetings:

> We met with project representatives from each of the Mayday partner organizations. We discussed our "wish list" of data items we would like to receive, and then those items were discussed in terms of privacy and HIPAA regulations. There were some concerns that "travel speed at impact" and "seat belt engaged" data made available to State Patrol officers and insurance companies could cause major privacy concerns. But then we talked about how they already get that information. State Patrol experts conduct very accurate evaluations on highway accidents that produce that same information—travel speed at impact and seat belt information. So why shouldn't we get that data from OnStar?

State Patrol and Mayo participants discussed two primary concerns with the "hard" data. First, OnStar would be providing quantitative computer-generated electronic evidence that would be very hard to dispute, while the highway patrol analysis constitutes a human-generated evaluation that could be more easily argued as inaccurate. Also, OnStar is a private company while the State Patrol is a public organization charged with conducting such analyses. They also noted that OnStar would want to take precautions to avoid litigation risks and a possible backlash from existing customers. Though sharing AACN data could provide valuable information to emergency and health providers and insurance companies, participants explained that the Mayday data were used with much more discretion to avoid liability and privacy concerns. An OnStar representative stated:

> OnStar's current policy is to default to data sharing. However, we maintain that customers have the ultimate right to decline data sharing with other organizations. Our legal counsel states that if a customer declines services, we are obligated to that decision. We understand there are many in the EMS community to disagree with that standpoint.

Legal concerns act as a deterrent to sharing information across organizations. There was speculation in regard to the performance implications. One trauma physician explained that data fields such as "seat belt engaged" or "number of passengers in a vehicle" would have significant implications for EMS in determining the extent of injuries and the number of resources to dispatch, respectively.

A Legal Infrastructure for 911 Data Communications

The provision of 911 telecommunications services is regulated and monitored closely by the Federal Communications Commission. In order to establish the Mayday system data network arrangements and the ability to route 911 calls to PSAPs, a number of required forms and processes had to be filed. A network engineer stated:

> This was a significant challenge since the forms and applications are intended for telecommunications "phone" carriers rather than "data" carriers, and no simple guidance existed to help fill out the required documentation. Phone carriers have been around for a long time and know what they're supposed to do. At the same time, there's not a lot of new 911 carriers out there so finding someone to help was very difficult.

Participants stated that the regulatory atmosphere needs to be adjusted and adapted to more efficiently facilitate the establishment of "data" and Internet protocol-based 911 services similar to the Mayday system. The experience caused significant delays and acted as a barrier to information sharing.

THEMES AND DIRECTIONS

Responses from end users of the Mayday system provided insight into several topics related to the design and development of interorganizational information sharing systems for EMS. These topics are summarized below.

Operational: New Interorganizational IT and Business Process Change

The operational Mayday system, including the underlying information technology, the business processes, and communication flows between organizations, advanced information about an emergency incident in a new and different way throughout the end-to-end EMS service process. Participants observed performance benefits including reduced response times and the ability to deliver better and more quality health care by having and utilizing the data. The ability to dispatch an ambulance at the same time as the State Patrol provided one such obvious and observable advantage in terms of time savings. Yet participants noted several operational issues to improving information sharing. Issues included the need to integrate Mayday data into existing user interfaces, the need for additional automation for collecting and transmitting data, the need for data to better represent situational context, and the general need for the technology to more fully function as intended. Though system users noted challenges to understanding data, the potential benefits of using the Mayday data, and challenges to using the technology, the end-to-end delivery of EMS was improved through an innovative use of information systems. An operational theme for this case study is how information systems were used to create an interorganizational business process change for a public sector service, which resulted in a clear improvement over the preexisting system.

Organizational: Information Systems that "Fit" Organizational and Interorganizational Goals

Performance analysts in Minnesota have highlighted the time-value of the Mayday system. Participants agreed that reducing response time was an important accomplishment. But equally important, from the perspective of emergency health care providers, is the value of the data for improving the quality and appropriateness of care provision. The unique interorganizational aspect of this case study is the focus on cooperation. The State Patrol has cooperated and shared resources with the Minn. DOT for the past several years. In addition, the EMS dispatch center, the ambulance provider, and the "end" health care facility are all owned and operated by one organization—the Mayo Clinic. This allows for some commonality across these three functional units in terms of vision, goals, objectives, and the general culture that spans the larger organization. A major common goal that permeates the culture is the focus on delivering quality care. As such, sharing Mayday system data across organizations was viewed as a good "fit" with organizational and interorganizational goals. The result being that the new and additional information was accepted with few barriers. Participants noted several additional information-sharing inhibitors related to interorganizational trust, effective communications, and overcoming resistance to change. They also noted some issues and challenges associated with sharing information—such as the resistance to change experienced by professionals who often feel overwhelmed with information overload. But the general theme across observations and interviews was the notion that information sharing was beneficial and fit well with organizational and interorganizational goals.

Governance: What Happens to Governance Oversight When the Test Project Ends?

For the Minnesota Mayday system, governance dimensions to information sharing include the looming legal and political concerns over data privacy and regulatory challenges associated with establishing a "data-centric" 911 information system. But the primary governance dimensions discussed center around the structure that facilitates information sharing. The Mayday system began as a test project that included clearly defined organizational roles, responsibilities, and funding sources. Now that the test has been completed the roles, responsibilities, and funding source are less clear, and the result is that continued system improvement has halted. Yet, participants noted that the lack of guidance and uncertainty about a clear governance structure extends beyond the local or even the statewide system, and includes an absence of well-defined directions and concentrated effort at the national level. And, on a related note, it is also the case that as a general matter the automobile companies have not traditionally been active partners in the emergency response arena. This is a notable omission, as experts agree that information about the crash (i.e., speed at impact) can be critical to understanding the nature and extent of crash injuries and consequent treatment course. In this sense, this case illustrates the opportunity to participate (for some organizations) and the opportunity to include others (for other organizations).

CHALLENGES FOR EMERGENCY RESPONSE SYSTEM DEVELOPMENT

Some unique challenges exist for those responsible for system development or the management of information systems associated with emergency response systems. Although the service aspect appears to be much like any other business-process-oriented system, there are distinctive operational, organizational, and governance structures that must be taken into account.

One challenge rests with deciding and deciphering which data sources will provide the most benefit to a wide range of users. In the Mayday case, there was a great deal of discussion across stakeholders about the operational and clinical benefits of automobile crash data. In the end, it was decided that the data would be useful and a system was designed to forward that data to multiple stakeholders. While automobile crashes are a significant public health issue, there are numerous other potential data sources that could be tapped to enhance emergency responses for other EMS-related incidents—such as nonauto-related trauma, cardiac events, stroke, and a wide range of chronic diseases. The use of cell phones to stream video, preexisting patient data that reside in hospital electronic medical records, electronic personal health records that are owned by citizens, and a range of other data sources could help to provide valuable information to quicken a response and allow for better clinical decision making. The initial challenge rests with understanding which data would be most valuable for performance improvement. In a related sense, defining "value" or "performance" from each stakeholder's point of view would be a parallel challenging activity. In this sense, a lack of standardization in the measures regarding system performance can lead to an inadequate ability to assess operational characteristics. Because performance measures are not comprehensive, justification for enhancements that may be thought to increase the impact of information technology associated with automation or process visualization may be difficult to quantify.

Beyond this initial challenge, decision makers must decide who should pay for the array of hardware, software, change management initiatives, and training programs needed to make use of the "valuable" data (once decided upon). To do so requires interorganizational agreement. Aligning organizational goals with systemwide goals is a challenge inherent in interorganizational systems. The organizational structures must balance security due to privacy-oriented concerns with the overarching goal of system users, which is to save lives. Additionally, the organizations and the systems that they employ are varied due to factors associated with the diverse rural and urban settings in which they exist. While the Mayday project enabled and encouraged collaboration across traditionally disparate organizations, the historical evolution of the roles within typical organizations charged with emergency service provision tends to maintain strict separation of functions.

Emergency response systems and their users are governed by a number of federal, state, and local laws. For instance, 911 telecommunications services are regulated by the Federal Communications Commission. Data sharing between public and private entities is controlled through HIPAA regulations. Information systems that support emergency response must be designed to operate within the strict limits of a multitude of laws. These laws must be clearly understood and embedded within the design of emergency medical response information systems.

The time-critical information services framework as applied to the Mayday system has shown how the key aspects of an emergency response system can be evaluated in terms of operational, organizational, and governance constructs.

IMPLICATIONS FOR CRISES

A distinctive aspect of the Mayday project is that it introduced the automobile company as a partner in the emergency response system. By adding this partner, the system had better data on the crash, and through this experience the test provided a taste of a new type of partnership that could be used to enhance emergency response systems. While the Mayday system, and this chapter, has primarily focused on the activities and perceptions of a "day-to-day" operational system, there are certainly implications for the disaster scenario.

The ongoing Mayday partnership provides a forum for emergency responders to address communications during large-scale emergencies. Automated data pushes allow dispatch centers a method for obtaining data on collisions involving multiple vehicles, such as in the case of the

August 2007 bridge collapse on a major highway in Minneapolis. An early notification provides emergency responders the ability to assess volume and magnitude, rather than discovering the volume and degree of an incident through an onslaught of 911 phone calls—essentially taking more time. The multiorganizational partnership also provides the opportunity to provide crisis information to citizens, or subscribers of wireless and in-vehicle systems. In this sense, it is important to note the recent partnership between GM OnStar and the Red Cross to provide information to those in crisis situations (OnStar, 2007). OnStar can provide real-time crisis information and centralized assistance for food, water, and shelter; share information from the American Red Cross database; connect subscribers to loved ones, family, and friends; list OnStar subscribers on the American Red Cross Safe and Well Web site; and inform public safety, EMS, and other emergency responders when a subscriber is in need of disaster assistance. Such examples illustrate the opportunities and benefits made available through multiorganizational information-sharing partnerships. Yet, despite the promise of new systems, the Mayday case study also reveals that all levels must be in play—operational, organizational, governance—if a promising system is to provide lasting value.

APPENDIX 9.1.

STUDY PARTICIPANTS AND TYPES OF SEMISTRUCTURED INTERVIEW QUESTIONS ASKED

Study Participants

Participant organization	Position title
Minnesota State Patrol	Communications Center supervisor
	Emergency communications dispatcher
	Trooper
	Colonel
Department of Transportation, Office of Traffic Safety	Project manager
Mayo Clinic Emergency Department	Emergency physician, director
	Emergency physician
	Clinical director
	Hospital administrator
Mayo Medical Transport	Manager
	Paramedic
	Communications specialist
Mayo Communications Dispatch Center	Supervisor
	Dispatch operator
Software Development Consultant	Consultant
GM OnStar	Communications Center manager
	Technician
Total expert participants:	17
Roundtable discussions	2

Example Semistructured Interview Questions

Operational Dynamics

In regard to the Mayday system:

- Describe the end-to-end EMS service process.
- Describe your communication processes with organization A.
    - * Whom do you communicate with?
    - * When, in what circumstances (or service leg) does it take place?
    - * What information do you communicate (via voice or data)?
- Describe the data/information collection process.
- What information technologies does your organization use? (relative to incident information exchange)
- What emergency-related information does your organization not send/receive that you think should be?
- What specific service performance information do you obtain and use relative to your role in EMS?
    - * What performance does your organization track?
    - * What performance reports does your organization produce?

Organizational and Governance Dynamics

In regard to the Mayday system:

- What conditions inhibit or prohibit information sharing?
    - * What challenges does your organization face in terms of information sharing (with organization A)?
    - * What are the benefits of information sharing (a type of information with organization A)?
- Who decides what information you will share? How it will be shared? Who has oversight? Why?
- What role has IT played in enhancing/degrading information sharing?
- Why does your organization not send/receive (a type of) information?

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PART IV

EMIS DESIGN AND TECHNOLOGY

CHAPTER 10

SIMULATION AND EMERGENCY MANAGEMENT

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Abstract: *Live simulation exercises and computer-based simulations have an important role to play in emergency management. The needs and requirements of the stakeholders vary according to the different phases of emergency management. In this chapter we discuss how simulation may be used to support the stakeholders in each phase of the emergency. Several technologies exist for developing computer-based simulations. We focus on two technologies that have recently become popular in emergency management: agent-based and virtual reality. Developing a simulator requires understanding how emergency personnel make decisions, how they diagnose a situation, how they communicate and cooperate with other emergency personnel, and how these things are affected by the constantly changing crisis environment. In short, we need to know the cognitive activities of emergency personnel. Based on a cognitive engineering approach, we describe a methodology for developing a computer-based simulator. We show how this methodology has been applied in developing a simulator for evaluating different rescue plans and testing new communication technologies. Developing computer-based simulators of real-life situations is notoriously difficult. Problems with developing computer-based simulators are discussed and some recommendations are proposed.*

Keywords: *Agent-Based Simulation, Virtual Reality, Complex Social System, Methodology, Rescue Plans*

Traditionally, science has had two methods of investigation: theory and experiment. The arrival of the computer brought an entirely new way of doing science by joining theory and science through simulation. A problem that was too complex to understand theoretically or through natural experiments could be simulated on a computer (Kupers, 2001).

Simulation has been used for many years in sciences such as chemistry, physics, and biology. Only relatively recently has it been used in social science for simulating social systems such as emergency management. One of its main uses in this area is prediction. In order to be adequately prepared for emergency situations it is necessary to be able to assess in some way the effectiveness of the intended plans and strategies. Since it is obviously infeasible to perform experiments during an emergency situation, simulations have become an important tool. Another major use of simulation in emergency management is training. Live simulation exercises have traditionally been used for training emergency personnel. Recently, computer-based simulators have started being used to complement the traditional training tools.

This chapter has two aims. The first is to present a comprehensive overview of the different kinds of simulation and their potential uses in all phases of emergency management. The second is to describe a methodology for developing computer-based simulators. The chapter is intended for researchers and practitioners who would like to learn about the potential of simulation and about the specific problems faced when developing simulators for emergency management.

We begin by defining simulation and discussing its uses. We address two types of simulation: live simulations and computer-based simulations. After discussing the role of live simulations, we focus on two particular computer technologies that have become increasingly popular: agent-based and virtual reality. We then discuss the needs and requirements of the various stakeholders in the different phases of emergency response. We discuss how the various types of simulation may be used in the different phases of emergency management. We describe a methodology for developing computer-based simulators, beginning with an explanation of the theoretical background of the methodology. Readers who are more interested in the practical aspects may proceed directly to the section describing a concrete application of the methodology. Finally, we consider some major issues in simulator development, offer some recommendations, and discuss the future of computer-based simulation.

BACKGROUND

Simulation

Definition of Simulation

First, we clarify the distinction between a model and a simulation. A model can be considered as "an *abstract representation* of a system or process" from the modeler's viewpoint (Carson, 2005). Simulation means "*driving a model* of a system with suitable inputs and observing the corresponding outputs" (Bratley et al., 1983, p. vii). Either existing or conceptual systems can be simulated. In order to draw any meaningful inferences from the simulation, an artificial history is generated by the simulator (Banks, 1999). The history is then analyzed in order to make some conclusions about the real system that has been represented.

General Uses of Simulation

Simulation is generally seen as a tool for anticipating and predicting future actions through playing "what-if" scenarios. However, there are many other uses of simulation. The main purposes of simulation are: to obtain a better understanding of some features of a world, to make predictions, to develop new tools to substitute for human capabilities, to conduct training, to entertain, and to assist in the discovery and formalization of theories (Gilbert and Troitzsch, 2005). Likewise, Axelrod lists seven main purposes of a simulation: prediction, performance, training, entertainment, education, proof, and discovery (Axelrod, 2005).

Main Kinds of Simulation

Simulation may or may not be computer based. Since the advent of computers, computer-based simulation has become an important tool in modeling biological, physical, or human systems. There are many approaches to computer simulation. Early attempts mainly adopted a discrete-event approach (Pidd, 1998). In discrete-event simulation, the system is represented as a sequence of events. This approach has been widely and successfully used in simulating workflow and business processes. Unfortunately, with this approach it is difficult to model the adaptive behavior of entities, such as humans. More recently, an agent-based approach has become popular (Epstein and Axtell, 1996). This approach has its roots in the area of Distributed Artificial Intelligence (Ferber, 1999). An agent-based approach has the advantage of being able to model both autonomous adaptive individuals and the interactions between them. In the following subsections we discuss the role of live, non–computer-based simulations, agent-based simulations, and virtual reality simulations.

Live Simulation. Live simulations, also called exercises, involve humans performing an activity in a quasi-real situation. For example, live simulations are often used for testing emergency rescue plans. In such an exercise, teams of firefighters and medical personnel react to planned emergency incidents in staged surroundings. The rescue personnel may also play the role of victims. After the simulation exercise, the actors are informed of their performance in a post-simulation debriefing session. Despite the rise in computer-based simulators, live simulations still have an important place in crisis management.

The main advantage of live simulations over computer-based simulations is that they are often more realistic. There are several disadvantages of using live simulations. They are difficult, time consuming, and expensive to prepare and perform. Live simulations are also of limited value, since they typically allow only one scenario to be reenacted. If the organizers want to perform a different scenario, then a considerable amount of work is involved in preparing another exercise. Large-scale live exercises are also hard to organize, since they require coordination across a large number of agencies across multiple levels of hierarchy (Jain and McLean, 2005). Nonetheless, live simulations are fundamental for understanding the characteristics, the interactions, and the cooperative activities of actors involved in a shared environment.

Agent-Based Computer Simulation. Crisis management is an example of a sociotechnical system encompassing a delicate interaction between people and technology. The computer simulation of sociotechnical systems falls into the domain of *computational sociology.* An important notion in this domain is social complexity. Social complexity views a system as being composed of individuals or institutions that interact in a nonlinear fashion. The results of these interactions may be emergent macro processes (Gilbert and Troitzsch, 2005). These emergent processes may represent different social phenomena, such as cooperation, combat, the transmission of disease, and culture. Because it is difficult to study large numbers of individuals with changing patterns of interaction using a mathematical approach, a primary research tool of complexity theory is agent-based computer simulation (Axelrod, 1997). Indeed, over other techniques, an agent-based approach enables capturing emergent phenomena, provides a natural description of a system, and is flexible (Bonabeau, 2002). As a result, agent-based simulation has become a valuable tool for investigating complex sociotechnical systems.

Agent-based modeling consists of describing the constituent units of a system and their interactions (Bonabeau, 2002). The system is modeled as a collection of autonomous decision-making entities called agents. For example, an agent in the computer system may represent a person or institution in the real world. As in the real world, agents may interact with each other and with their environment. Each agent individually assesses its situation and makes decisions based on a set of rules. Agent-based modeling is often known as individual-based modeling, bottom-up modeling, or agent-based social simulation.

Agent-based modeling can be considered as a third way of doing science and can be contrasted with the two standard methods of induction and deduction.[1] Like deduction, it starts with a set of explicit assumptions. But unlike deduction, it does not prove theorems. Instead, an agent-based model generates simulated data that can be analyzed inductively (Axelrod, 1997).

To date, numerous agent-based simulators have been developed for many purposes including managing traffic, explaining consumer behavior, simulating social segregation, modeling crime prevention, and analyzing the spread of epidemics. For example, see the work of Bonabeau (2000), Makowsky (2006), Kreft and colleagues (1998), Strader and colleagues (1998), Terano (2000), and Carley and colleagues (2006).[2] In the area of crisis management, several studies have shown that an agent-based approach can be used for the design of complex organizational systems (Bellamine-Ben Saoud et al., 2005; Dugdale et al., 2000). Jain and McLean (2003) provide a compilation of over sixty tools and projects for emergency response.

Virtual Reality Computer Simulation. Virtual reality (VR) refers to interactive, immersive computer simulation, within a real or imagined simulated environment. One of the main advantages of virtual reality over an agent-based approach is its *realism,* its ability to provide a sense of *immersion,* and the notion of *presence.*

The level of *realism* in many current VR applications is due to technical advances in graphics technology and virtually spatialized audio. This realism has reached such a point that our senses are almost fooled into believing that it is the real world. If the VR system does not need to operate in real time, then the quality is so high as to make it virtually indistinguishable from real video images. Despite the huge progress made on increasing the quality of VR systems, there are still problems. A virtual reality avatar that is too realistic will increase user expectations. The more realistic the avatar, the more any nonhuman aspects will be apparent. Thus, even the smallest incongruence will highlight its falseness and remind the user of the unreality of the situation (Benford et al., 1997). In addition, any increase in realism will not automatically increase the degree of *immersion.* The challenge in virtual reality research has now moved away from increasing realism and has focused on *immersion, presence,* and *social interaction.*

The concept of *immersion* refers to a subjective feeling that the user has of being completely involved in the virtual world to the point that he or she is disconnected from the real world. The feeling of immersion is partially dependent on what is called a willing suspension of disbelief (Coleridge, 1973). This is defined as a state in which the user willingly suspends his or her critical faculties to believe a series of facts even if they are partially unrealistic or inconsistent. One of the main problems with creating a feeling of immersion is the extreme fragility of suspending disbelief. Users are quickly and easily distracted by inconsistencies such as the unnatural and mechanical movements of an avatar, or the lack of social or reflex reaction exhibited by virtual characters. The use of more natural interfaces that are able to exploit a user's own body posture and movement in interaction can increase the feeling of presence in the virtual world (Hendrix and Barfield, 1996; Usoh et al., 1999). The problem with the interface mainly concerns the notion of proprioception. This is unconscious perception of movement and spatial orientation that a user has of him or herself in a virtual space. To partially overcome this lack of embodiment, a virtual representation of the user's own body is shown in the environment.

The concept of *presence* refers to the feeling of being in a place or of being with someone (co-presence) as mediated through a technology. Internal and external elements contribute to this feeling. For example, the range of multisensory data provided by the system, the ease of a user's motor actions, a user's spatial perception, cognition, attention, and imagination all affect the notion of presence. These elements are closely intertwined. This makes it almost impossible to identify the contribution of any single element. According to Sheridan (1992, pp. 121–122), three things are *crucial* to the feeling of presence:

1. The extent of sensory information presented to the user. This refers to the amount of salient sensory information which should be presented in a consistent manner to the appropriate senses of the user.
2. The level of control the participant has over the various sensor and interface mechanisms such as tracked Head Mounted Display, data-glove, etc. This refers to the mapping or correlation between the user's actions and the perceptible spatio-temporal effects of those actions.
3. The user's ability to modify the environment. This refers to the ability to interact with the environment and to affect a change within that environment.

The final, and probably the greatest challenge, is *social interaction.* While social interaction in the real world is quite natural, it becomes much more complicated in a virtual world. This is partially due to the lack of nonverbal communication expressed through gestures, body postures, and facial expressions. These are an integrant part of human communication and are difficult to express in a virtual agent. Nonverbal clues are a crucial aspect in understanding human communication. For example, gestures may enhance or elaborate the content of speech (McNeill, 1992). They may be used as a support for interpreting ambiguous speech in noisy situations (Rogers, 1978; Thompson and Massaro 1986). Gestures can also indicate to the listener the speakers underlying reasoning processes (Church and Goldin-Meadow, 1986). Indeed, when there is a mismatch between the spoken dialogue and the gesture, listeners will give equal importance to both. They will not simply take the meaning of the communication from speech (Cassell et al., 1999). Interestingly, whereas speech is often littered with errors, for example, saying "left" instead of "right," people rarely commit any gestural errors. Observers can also reliably infer a person's *emotions* and *attitudes* from nonverbal behaviors (Ekman and Friesen, 1969). Finally, gestures as well as eye or head movements are essential information for managing communications, for example, taking turns in the conversation.

Emergency Response

Terminology

It is important to note that there are no commonly accepted definitions of emergency-related terms. However, following the literature, we will try to list some of the key terms. An *emergency* has been formally defined as an event that makes it impossible for an organization to *conduct business as usual* (Alles et al., 2004). An *accident* is an unexpected or undesirable event causing injury or damage (*Oxford American Dictionary,* 1982). According to Perrow (1999, p. 65), it is an "unintended and untoward" event that "disrupts the ongoing or future output of the system." The causes of an accident may be natural or man-made. Natural causes include floods, earthquakes, hurricanes, and tsunamis. Man-made causes include terrorist acts or problems with high-risk systems, such as nuclear power plants, chemical plants, air traffic control, airplanes and ships, nuclear weapons, and space missions. When many victims are involved, an accident becomes a *catastrophe* or *disaster*. When the situation includes substantial material or environmental losses, involving hundreds or thousands of injured persons, it is often referred to as a *large-scale disaster*. A catastrophe becomes a *crisis* as soon as there is a shortage of resources to manage the situation. Despite these formal definitions, in reality the terms are often used interchangeably by both researchers and practitioners.

Emergency Rescue and Management Characteristics

When a disaster occurs, the main objective is to rescue lives as rapidly as possible. Unfortunately managing such a situation is highly problematic. “A response to crisis situations, even natural disasters, always has a high degree of unpredictability with respect to the specific actions that must be taken, where they will happen, what resources will or can be assigned, and who will be responding” (Turoff et al., 2004, p. 12). The rescue process itself can be characterized as a complex social system. The system is inherently *distributed, open, collaborative,* and *multicultural* (Bellamine-Ben Saoud et al., 2006; Dugdale et al., 2006). It is distributed in the sense that its resources are physically or virtually distributed on various sites. It is open in the sense that it continuously interacts with its environment. It is collaborative in the sense that it includes stakeholders with similar or complementary skills who must make a mutual and concerted effort to work together. Finally, it is multicultural in the sense that it involves several groups from different organizations each having different sets of priorities and concerns.

Effective emergency rescue requires managers and on-site rescuers to make joint decisions based on changing and uncertain information in evolving situations under stress and time pressure. The success of such operational real-time decisions is dependent on two points.

1. The experience and preparedness of actors.
2. Their ability to dynamically adapt themselves and their previous knowledge and strategies to emerging situations.

Main Phases

There are three main phases of emergency management: before, during, and after the event. Efficient and effective rescue requires managing the whole situation. Effort should not only be limited to real-time management and response *during* the event. A large amount of work has to be done *before* and *after* the event. Although the three phases address different time spans, they include complementary activities. Emergency response includes activities for *identifying, detecting, planning, training, analyzing vulnerability,* and *real-time responding* to unanticipated events (Jain and McLean, 2003). Except for the latter, all the other activities are outside of the “during phase.”

The “before phase” refers to continuous preparedness activities. Past experiences have demonstrated that a lack of preparedness can lead to problems during and after the disaster (Izadkhah and Hosseini, 2005). “Before phase” preparation is a long-term process involving different stakeholders, each with specific objectives and needs:

- *Decision makers, authorities, and rescue response agencies* such as police units, fire posts, hospitals, and medical crews are continuously concerned with disaster prevention or mitigation. This group needs to be able to specify requirements and recommendations for preventing man-made catastrophes and protecting populations against natural ones. The threats and possible impacts of disasters need to be identified (Jain and McLean, 2003). *Discovery and prediction tools are therefore needed.*
- *Response agents* must have a good understanding of the potential impacts of catastrophes in order to define rescue plans. Rescue plans describe the organization and the roles and responsibilities of the rescue actors. The type of plan will depend on the type of disaster, and each plan may vary in its level of detail. The plans may also specify any required technologies and resources. Once a plan has been defined, it needs to be assessed. When it has been adopted, the rescue crews need to be informed and trained to collaborate accordingly. Consequently, *supporting tools and methodologies are required for:*

- Assessing, for each type of disaster, its evolution and spread, and its human, material, and environmental impact,

- Understanding the planned actions and interactions that will take place on-site. The work may focus on the communication, coordination, command, control, and collaboration among geographically close or distant rescue personnel,
- Designing new tools and technologies for emergency response, such as collaborative devices to be used by rescuers,
- Planning by designing new rescue plans and evaluating their feasibility and efficiency,
- Analyzing vulnerability by evaluating and assessing emergency response preparedness plans and strategies (Jain and McLean, 2003),
- Training for management and rescue response by following procedures, using tools, and mainly adapting to sudden and emergent incidents,
- Testing software tools and hardware equipment dedicated to rescue operations. For example, testing communication devices when bandwidth is severely overloaded (Jain and McLean, 2003).

• *Civilians, communities, and populations* need to be prepared to prevent or face a disaster event. Evidence from numerous disasters indicates that where societies have been prepared and educated for damaging events, there have been significant reductions in casualties and physical losses. For example, early warnings of heavy rains through radios stations in Mali in 1998 resulted in the effective evacuation of over 300 persons in the flooded area (Izadkhah and Hosseini, 2005). Also, a national program in Cuba raised people's awareness of hurricane threats. As a result, about 700,000 people and their cattle were evacuated during Hurricane George in 1998 (Davis et al., 2003, cited in Izadkhah and Hosseini, 2005). *Information dissemination and communication tools as well as personalized programs are needed* to increase disaster preparedness and awareness at all levels of society. These should take into account personal and cultural factors such as age and sex, religion, the town or village, the level of the country's development, and so on.

The "during phase" begins when a disaster event occurs, and ends when all of the victims have been evacuated or transferred to a safe place. First responders obviously have a crucial role to play in this phase. For large-scale catastrophes, such as Hurricane Katrina, civilian volunteers may also be involved in the rescue process. In this phase, real-time response is the primary activity. The main rescue activities include: searching for victims, evacuating victims to a local emergency post, stabilizing and treating the on-site victims if possible, and transferring seriously injured victims to hospitals. Rescue management mainly consists of optimizing the available rescue resources.

The "after disaster phase" involves conducting in-depth studies. These are undertaken in order to analyze past accident situations, to collect accurate data, and to capitalize on experience and knowledge of the real disaster. The studies are used to improve understanding and to feed the preparedness activities by updating the rescue plans. Unfortunately, in the daily life of the rescue services, accident situations and their management are rarely analyzed in a detailed way (Lonka and Wybo, 2005). Official reports containing the major facts, causes, and consequences are routinely prepared, but due to time pressure and tradition these reports are limited in terms of analysis and lessons learned (Wybo and Lonka, 2002).

Conclusion: Simulation in Emergency Management

Mapping Kinds of Simulation to Emergency Phases

As summarized in Table 10.1, simulation may be used during all phases of emergency management.

During the real-time response phase, managers as well as first responders need to collaborate. Together with efficient communication tools *real-time computer simulation* is a useful tool to

Table 10.1

Simulation and the Phases in Emergency Management

Phase	Aim	Simulation uses	Simulation types
Before	Preparedness and prevention	• Prediction • Discovery • Organizational and technological design • Planning • Training • Education	Live simulation Computer/agent-based simulation VR simulation Computer simulation as an educational support
During	Rescue victims and reduce losses	• Real-time decision making • Real-time resource management	Agent-based simulation
After	Learn lessons	• Investigation and analysis tools	Computer-based simulation

support decision making. Based on real disaster data, such tools may provide "best" rescue strategies and resource allocations by suggesting better scenarios. These may be expressed in terms of who, what resource, where to send them, and with which artifacts and tools. Thus, prediction, performance, and support for human capabilities are the main uses of simulation for this phase.

The "before" and "after" emergency phases are long-term, continuous preparedness activities that require a deep understanding of the complex emergency situations. This is necessary in order to *design* sociotechnical solutions that will be used during the incident. Consequently, simulation is useful for two purposes: (1) prediction, discovery, and support for design; and (2) training and planning. Live simulations are a traditional training tool. Live simulations are in part undertaken to rehearse and embed the appropriate response behaviors in the rescuers. Such behaviors are termed recognition primed behaviors. The goal is for rescuers to recognize patterns in a situation and respond with well-rehearsed actions (French and Niculae, 2004). Ideally, exercises should involve many stakeholders and should serve as real learning experience for all participants (Lonka and Wybo, 2005). More generally, simulation may be used in the before phase for supporting emergency education and for community preparedness.

Examples of Uses

From our own experience we have used simulation for many purposes in the domain of emergency management, for example, the training of firefighters, the testing of rescue plans, the physical design of control centers, and the design of technological tools. We have found that in real projects it is usually necessary to work simultaneously with several types of simulation, such as live exercises and computer-based simulation. The reason for this is that all simulations have their own limits in terms of realism. The more complex the situation, in terms of the number of different stakeholders, degree of uncertainty, and so on, the more difficult it is to model.

Computer-based simulators are commonly used to train emergency rescue personnel. It has been found that such simulators can reduce the training costs to one-tenth compared with live exercises (Robinson, 2004, quoted in Jain and McLean, 2005). During training, the trainees' decisions are strongly influenced by what they see and hear in the environment and the feelings that they evoke. Therefore, two important aspects in training rescue personnel with computer-based simulation are realism and immersion. The users' immersion in a situation, which is close to reality, greatly contributes to the efficiency of the learning process (Gee, 2003). The main benefits of using virtual reality technology for training are:

- the concept of "safe danger" where normally hazardous situations are reproduced in a completely safe and controlled environment,
- the deep post-analysis of the training session to identify the actions taken and the causes of mistakes made by the trainee, and
- the relatively reduced cost of development and use of such technology.

The advantage of using virtual reality over traditional classroom-based training methods became apparent in our work with the firefighters of the Departmental School of Fire and Rescue (EDIS) in Paris. We found that even if trainees have a good theoretical knowledge of the correct procedures to apply, as learned in the classroom, they were actually unable to concretely apply them in a stressful real intervention. In this case the advantages of virtual reality are twofold. First, the user is not passively memorizing procedures but is directly experiencing and experimenting with the effects of his actions on the environment. The second advantage follows situated action theory. The user is in a situation that is so close to the real one that he can train his skill as a *contextual* and *opportunistic problem solver,* through improvisation, instead of having to learn predefined plans. In addition, the similarity of the virtual context to the real one can also invoke emotions. The ability to cope with emotions and stress is one of the key elements of training emergency rescue teams, and it is probably one of the hardest aspects to train for in practice.

Virtual reality has proved to be an effective training tool in many fields, for example, military training (Gratch and Mao, 2003; Gratch and Marsella, 2001; Rickel et al., 2002), medical training (Kaufman and Bell, 1997; Stansfield et al., 2000), emergency and crisis management training (Tate et al., 1997), terrorist response training (Losh, 2007), and firefighter training.

Several simulators have been developed for emergency management. Mission Rehearsal Exercise (MRE) (Gratch and Marsella, 2001) is probably one of the most well-known examples. MRE was developed at the Institute for Creative Technology at the University of Southern California and was funded by the Defense Advanced Research Projects Agency (DARPA) with the collaboration of some Hollywood film studios. The MRE simulator was developed to train U.S. army officers to make the correct decision in a conflict social situation. MRE is a single-user system incorporating artificial intelligence techniques to drive the emotional and communicational behavior of the virtual agents. While MRE is mostly an experimental tool to test the possibility of virtual reality, other systems for training rescue personnel have been commercially available for some years now. Two examples of commercially available software are VectorCommand and DiaboloVR.[3] These VR training systems usually operate by having a single user interact with an intelligent virtual software agent or avatar. Unfortunately, such systems have several drawbacks: they typically require huge computational resources, use simplistic models of cognitive behavior and emotion to simulate intelligence in the agent, and usually allow only one user to participate in the training scenario.

In our work on training firefighters, field studies revealed that the way in which firefighters communicate with their colleagues during an intervention is greatly affected by environmental factors, such as the level of noise, or by physical factors, such as restrictions caused by the fire-

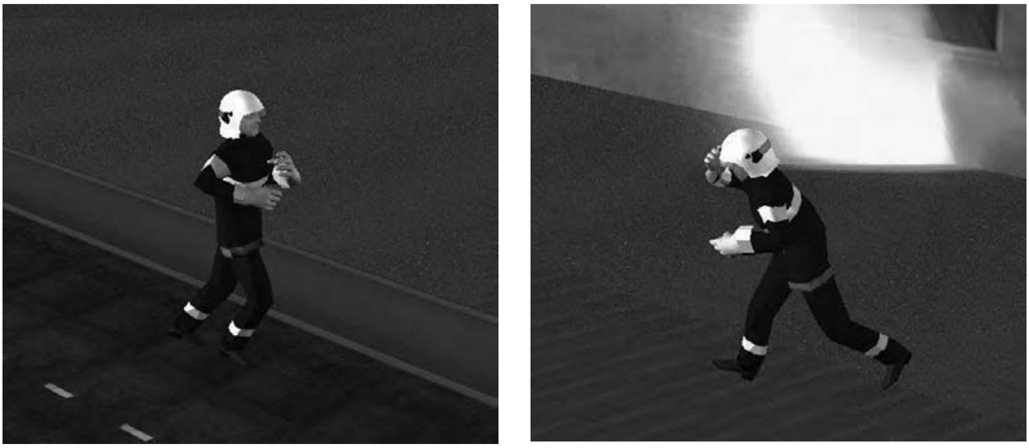
Figure 10.1 **A video-recorded interview with a firefighter (leftmost character) helps to extract behavioral gestures that are then implemented in a virtual character (rightmost character). The work concerns the development of a virtual reality training simulator for firefighters.**

fighting apparatus worn by the firefighters. The effect is that many communicative activities are largely nonverbal (see Figures 10.1 and 10.2). Until recently, virtual applications, including training applications, rarely incorporated any deep social, cultural, or emotional capabilities exhibited in normal human interaction. Following our field studies, we have developed an *interactive virtual reality training simulator for firefighters.* The virtual actors have nonverbal communications skills that can provide a sufficient feeling of immersion to reproduce an efficient simulation of human social interactions.

METHODOLOGY

The goal of this section is to describe a methodology for developing computer-based simulators in crisis management. We have adapted a methodology that is used in the domain of cognitive ergonomics. Cognitive ergonomics is concerned with the study of human cognition in real work settings in order to improve human–system performance. The cognitive processes that are of interest include diagnosing a situation, communicating, decision making, and planning. In order to improve our response to crisis situations it is necessary to understand the cognitive activities performed by crisis managers and how they are affected by the constantly changing crisis environment. A methodology grounded in cognitive ergonomics is therefore particularly suitable for analyzing the activities of crisis managers.

Figure 10.2 **An example of how a virtual character's walking action changes as a function of its contextual environment. The leftmost picture shows an animation of a virtual character walking toward a victim. Here the user animates the character using a joystick. On the right-hand side, the virtual character takes into account the environmental context of a nearby explosion and adjusts its way of walking. This change in behavior can then be visually interpreted by the other trainee users (nonverbal communication).**



Issues Supporting the Methodology

The following five key points support the methodology.

1. The methodology relies on a *thorough field analysis* that aims to provide a very detailed account of the situation. The idea is to observe the activity as it normally occurs, if possible. In crisis situations it is usually impossible to observe the situation, so observations of simulated events may be conducted. The description tries to be *global* in that small events are considered to be as important as larger ones and the observed event is put into context with the rest of the situation. Early approaches to field studies separated the role of the observer from that of the person analyzing the data. In 1914, Bronislaw Malinowski revolutionalized the whole ethnographic tradition by insisting that the analyst and the observer should be one person. He argued that a true analysis and accurate assessment of the context of the situation could be conducted only if the analyst was physically present (Malinowski, 1922).[4]

It is also important to recognize that each actor for example, the firefighter, the crisis manager, the medical doctor, and so on, has his/her own point of view on the same situation. Each of these viewpoints, including the context and perceived history of the situation should be thoroughly documented by the analyst. The aim of the analyst is to interpret the subject's actions by encouraging the subject to reflect and explain their activities (known as a process of *dialogism* or *reflexivity*). Unlike classical anthropology, which is mainly based on *what is observed and said,* cognitive ergonomics also considers what is *not said* (or hidden behind the discourse). Therefore, ergonomics and modern ethnomethodology are different from a traditional social sciences or human factors approach (which mainly refers to what is observed and sometimes to what is said).[5]

2. Cognitive ergonomics makes *a clear distinction between task and activity*. Task analysis refers to how work is officially supposed to be performed. For example, the official procedures

and written rules describe the tasks to be performed. Activity analysis describes the unofficial or implicit actions that are undertaken. Activity analysis can be conducted only via field studies. If we are to uncover how people really work then field studies are essential.

3. A *structural analysis of the work situation* should be performed. The aim of a structural analysis is to construct an "external" view of the work situation. We are interested in documenting the *social and technical context* of the work, since these are factors that strongly influence the present situation. This information "unconsciously governs" the social or individual behavior of the actors (following from Marx, Durkeim, Levi-Strauss). The type of information included in a structural analysis may be the history of the group, statistics dealing with age, environmental factors, and the like.

4. *Artifacts in the environment play an important role in cognitive activity*. Human cognition is often considered to be confined to, or contained within, the mind of the individual. *Distributed cognition* argues that human cognition and knowledge representations, rather than being solely confined to the boundaries of an individual, are distributed across individuals, tools, and artifacts in the environment. The concept of distributed cognition was developed by Ed Hutchins (1995), who argued that artifacts in the environment play an important part in cognitive activity. Such artifacts are common in emergency management. For example, firefighters use maps of a building or an area to develop a rescue strategy. Furthermore, such artifacts are actively used as communication tools for cooperation. Continuing with the map example, we may see different groups of rescuers coordinating their activities and communicating their intentions to other groups, based around a single map.

The theory of distributed cognition is a useful approach for designing emergency response practices. It may identify problems with existing work practices and the use of technology. It can also highlight what artifacts are important in the existing system (Rogers and Scaife, 1997).

5. *Cognitive processes should be formalized*. Individual scenarios are identified from the mass of data collected from the field studies. Scenarios are brief sequences of activity. Depending on the focus of interest, different cognitive processes are formalized. For example, we may be interested in how artifacts in the environment support communication between the actors (Zorola-Villarreal et al., 1995), or tracing oral communications between a group of actors (Benchekroun, 1994; Pavard et al., 1990), or the different types of communication media used (Bressolle et al., 1995), or the nondeterministic nature of communication (Pavard and Dugdale, 2000).

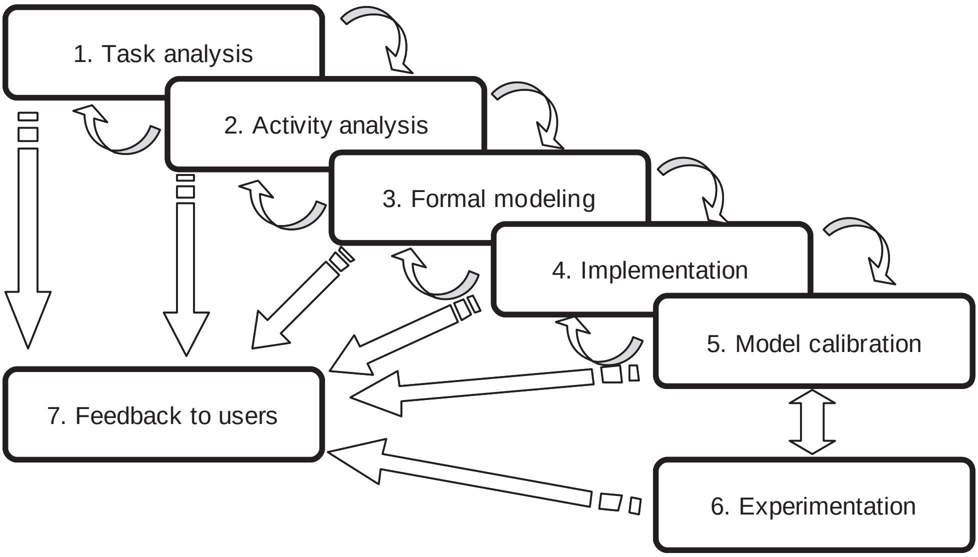
One of the main difficulties in analyzing a scenario is the link between what has been observed and how it is to be interpreted. Traditional cognitive psychology tries to develop a coherent *unity of meaning* between all the observed and interpreted events. Contrary to this approach, hermeneutic schools try to handle the *plurality of meanings* (i.e., one speech act may have several interpretations, and there is no pure description). For example, in the domain of language interpretation, Sperber and Wilson (2001), using the concept of "cognitive universe"[6] try to handle all the potential interpretations of any speech act. However, practically, it is very difficult or impossible to derive a finite list of all the possible interpretations given different contexts (Salembier, 1996).

Steps of the Methodology

The following methodology has been used in our work for developing several computer-based simulators (Bellamine-Ben Saoud et al., 2005; Dugdale et al., 2000, 2004). The methodology is composed of six steps, which are shown in Figure 10.3 and explained below.

Figure 10.3 **Stages in Simulator Development**

The approach is iterative, participative, and collaborative. Furthermore, calibration plays an important role.



Step 1. Task Analysis

Task analysis documents the prescribed work, that is, how the work is officially supposed to be conducted. Activity analysis documents how the work was actually performed. This distinction is extremely important since it is useful to know under what conditions people diverge from the prescribed way of working. From our own experience and from the literature, in real crisis management situations, the prescribed way of working is rarely followed. The reason frequently given is that every situation is different and therefore it is infeasible to create rules and procedures that can cover every eventuality.

Step 2. Activity Analysis

Activity analysis determines how work is really performed in the real work setting. Activity analysis can be achieved only through studying the data from field studies. This allows observers to identify not only those actions related to the prescribed work but also explicit (additional and known) or implicit (unconsciously performed) “side” activities. For example, although an actor may have a predefined role to play, he or she could also undertake someone else’s role. This may be because it is more convenient or practical at the time to undertake that role. It may also be due to emotional reasons. For example, in stressful situations, it is difficult to ignore helping a victim and concentrate solely on the role of coordinating a rescue incident.

Step 3. Formal Modeling

This step aims to model the key behaviors and characteristics of the situation. For example, this might be the communication and cooperation mechanisms between the rescuers, or the role played by technology.

It is also sometimes interesting to model the *regulation* mechanisms that actors use to keep the overall rescue "system" in a stable and constant condition. This is necessary if a new way of working is to be proposed that could affect these mechanisms. Some regulation mechanisms are explicit and known to all actors. However, many regulation mechanisms are performed unconsciously by the actors. Developing a formal model is important since it will help to assess how any new changes will affect the current way of working. For example, if we change a rescue procedure, we are interested in how it may affect the communication, cooperation, or decision-making processes. A formal model is developed using the concepts of scenarios and cognitive modeling. Scenarios are chosen in order to show the regulation mechanisms in place. Scenarios help us to understand what happens in normal and overloaded situations. The model also shows how agents react cognitively in both of these situations.

Step 4. Implementation

This stage involves converting the formal model developed in step 3 into a computer implementation. This includes choosing a suitable software platform or framework. Various conceptual and practical factors affect this choice, such as: ease of coding, flexibility of the platform (for example, ability to incorporate other modules or systems, ability to function over a distributed network, ease of maintenance in modifying or extending the system, ease of implementing complex cognitive processes), cost, efficiency, and ease of demonstrating the results to end users, and so on. Numerous agent-based and virtual reality platforms are available.[7]

Step 5. Model Calibration

In order to be able to trust and infer any meaning from the results of the simulator, the model must be calibrated. By calibration, we mean the tuning and adjustment of values so that they represent realistic states, evolutions, and behaviors. Within the domain of emergency management, this can be difficult since real-life data that would allow model calibration are often sparse or unavailable. Calibration is a crucial activity, and the specific problems associated with it are discussed below.

Step 6. Experimentation

This step covers performing experiments with the simulator. The exact nature of the experiments will depend on the object of the investigation. Due to the complex interactions within the system it is often difficult to interpret the results correctly. Any simplifying assumptions that were made during steps 3 and 4 should be taken into account when interpreting results. The results can be understood only with regard to what has and what has not been included in the model.

Step 7. Feedback to Users

While the task of giving feedback to the users is described as being the seventh step, in reality this occurs throughout the development process. Users can provide valuable information and confirmation on the design of the model and should be actively involved throughout the development cycle.

Practical Application of the Methodology

This section describes how the methodology has been applied to develop a simulator in the domain of emergency management. The goal of the simulator is to evaluate different rescue plans and to test new communication technologies. The simulator is essentially a test bed for evaluating several "what-if" scenarios concerning different possible rescue processes. Specifically, the aim of the simulator was to assess two main points:

1. What is the effect on rescue performance of replacing traditional paper medical forms with electronic forms? Currently, medical doctors record the status of victims on paper medical forms. These forms are attached to the victim and may be updated by other medical doctors as the victim's condition evolves. The information on these forms is relayed back to a control center in order to provide information on the number and gravity of victims. This information is used to allocate resources. There are two problems with the paper-based approach. First, there is often a long delay in relaying the information concerning the victims back to the control center. Second, the paper forms are sometimes lost.
2. What is the effect on rescue performance of dividing the incident site into several zones? Currently, the rescue site is considered as one zone and the rescue and treatment strategy is centralized. Would a decentralized rescue strategy result in a more efficient rescue, and, if so, under what conditions?

The simulator was intended to be used as a support tool during the "before phase" of emergency management. The intended users fell into two groups. The first group consisted of response agents interested in designing new rescue plans and assessing the effects of new technology on a rescue. The second group was made up of researchers. Since realism and immersion were not necessary in this support tool, an agent-based as opposed to a virtual reality–based approach was adopted. Furthermore, the notion of agents fitted well to the real situation. From the real situation it was clear that the various agents, for example, firefighters and medics, had *heterogeneous*, *complementary*, and *interwoven* competences. Rescue personnel have predefined roles but they may also organize themselves dynamically in groups and teams. As in real life, there are predefined rules and procedures, but rescue personnel often react to their environment in an unpredictable way. By modeling rescue personnel as agents, the above characteristics made an agent-based approach a suitable technique to use.

The methodology described above was applied as follows:

Step 1. Task Analysis

To see how the rescue is officially supposed to be conducted, we analyzed the French Rescue Organization plans.[8] There are two types of plan. The White Plan concerns the intervention of the *medical* resources at the site of the accident. The Red Plan concerns *firefighters'* interventions. According to the type and seriousness of the accident, there are different plans. The plans describe the main steps of the rescue, the hierarchical organization of the rescue teams, the responsibilities of each team's members, and the rescuers' behaviors. The overall aims of the plans are to ensure the efficient rescue of victims, perform a quicker evacuation, reduce human and material losses, extinguish fires, unblock routes, reduce delays, and minimize the number of dead victims. By studying these documents we were able to identify the relevant features of the rescue process and the main actors involved:

- According to the White Plan (Ecollan, 1989), there are five core phases of emergency medical care: (1) Assess the medical needs of victims. (2) Identify victims, moving them if necessary and providing essential medical care. (3) Categorize the victims according to the seriousness of their injuries and the situation. (4) Evacuate and transport the victims. (5) Retrospectively elaborate the victims' medical summary reports.

• The White Plan also gives information on how to categorize the health status of the victims. There are five possible categories. Living victims maybe classified as a *Relative Emergency* (RE) or *Absolute Emergency* (AE). The AE class includes *Extremely Serious* cases and *Very Serious* cases. *Extremely Serious* cases are severely injured victims who need immediate transfer to a hospital. *Very Serious* cases require intensive care or surgical treatment within the following six hours. The RE class includes *Serious* cases requiring hospital care and *Minor injuries.* Nonliving victims are classified as *Dead.*

• The Red Plan contains information on the organization of the incident site. It is composed of a *Critical Zone,* where the accident occurs, an *Advanced Medical Post* (AMP), an *Evacuation Park,* and a *Resource Park,* where, for example, the ambulances are kept. The Red Plan also identifies key personnel or supervisors who are responsible for managing the rescue. Among others, there is usually a Critical Zone Officer, Evacuation Officer, Resource Park Officer, Evacuation Park Officer, AMP Officer and Head AMP Doctor, Sorting Officer and Sorting Doctor in charge of reclassifying victims at the AMP, and a Help Operations Commander. In the critical zone, three rescue teams (Doctors, Nurses, Firefighters) are responsible for moving the victims.

Step 2. Activity Analysis

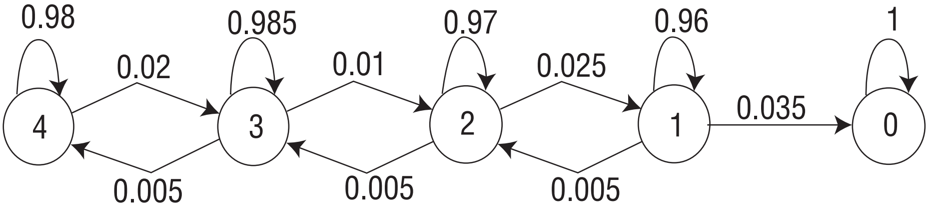
In order to understand how the actual rescue process occurs, live simulations are organized. For example, a four-hour simulation of an airplane crash at an airport was conducted. It involved 207 persons, including 73 victims (these roles were played by young firefighters), and four rescue teams: medics, paramedics, firefighters, and the airport's own rescue unit. Working together with the medical and emergency rescue services, we observed the simulation. Interviews were conducted, and rescue plan exercises were videotaped, analyzed, and discussed with the rescue personnel. These field studies allowed us to see the rescue operations in action. By observing several simulations we also identified some recurrent problems experienced by the rescuers. The main problems were (Dugdale et al., 2006):

- A lack of global visibility concerning the ground level situation at all levels in the rescue hierarchy. This meant that no one had a clear picture of the evolving situation. The main reason for this was that the victims' paper forms (on which is written the information related to the victim on-site) never arrived at the AMP or arrived too late to be of use.
- A lack of knowledge of the actual structure of command since the roles and responsibilities of rescuers change dynamically during the first hours of a large-scale incident. The adoption of additional roles is an example a "side" activity discussed above.
- A lack of tractability of the rescuers' position and their roles once they arrive at the accident site.
- A high cognitive load for the person at the evacuation center who is responsible for collecting information about the victims' medical history,
- Cultural conflicts among rescue teams.

Step 3. Formal Modeling

Based on task analysis and activity analysis findings, we designed an agent-based model. The model represented the dynamics of large-scale crisis situations and included the collaborative and social nature of the rescue activity. The model includes the actors, their behaviors and interdependencies, as well as the environment in which they are collaborating. We also represent the environment of

Figure 10.4 **An example of a Markov Chain, which shows the probability of a victim's changing his or her health category. The above example shows the probabilities for a victim in a non-dangerous location and without any intervention from rescuers.**



the emergency incident. The environment shows the whole city, including routes and hospitals, or the different areas where accidents may occur.

The main agents in our model are victims and rescuers. Victims are modeled as reactive agents with a continuously evolving degree of health gravity. We used the standard classification from the White Plan to specify the health status of the victims. The five categories have been translated into numbers in our model. The evolution from one category to another is dependent on several factors: the victim's location, specifically whether the victim is in a dangerous location or not; whether the victim received any treatment; and the time elapsed. These factors have been modeled using a Markov chain (see Figure 10.4).

Rescuer agents (supervisors, doctors, nurses, firefighters, ambulance team) have perceptive and cognitive intelligence, which enables them to understand their environment. More precisely, each rescuer has a field of perception in which it is possible to distinguish between a victim, a nurse, a doctor, and a firefighter. Supervisors at various levels in the rescue hierarchy are able to capture information about the situation from the rescuers on the incident site. Information may be captured directly or via communication devices. We have modeled communication by paper medical forms and radio transmission (as these are used in real life). We have also modeled communication by electronic medical devices and wireless local area networks. This is the new situation that we wish to assess with our computer simulator. By introducing this new communication technology, we define new interactions among rescuers who are exploring the site, evacuating, and communicating.

In order to model the rescuers' behaviors, heuristic algorithms have been implemented for each step of the rescue process. For example, we have modeled three different heuristics for how doctors may locate victims for treatment. Three other heuristics define how doctors examine and assess the status of victims. Some of these heuristics are used in real life. The other heuristics represent strategies that we would like to test with the "what-if" experiments.

A rescuer agent thus follows one of these heuristics and decides on the necessary treatment according to the victim's health evolution and the available resources. An evacuation priority is then assigned to the victim. The assignment of an evacuation priority follows the recommendations of consulted medical experts. The experts stated that: (1) victims with a status of "Absolute Emergency" need stabilizing first and/or on-site treatment and receive a higher priority for evacuation than other victims; (2) victims with a status of "Relative Emergency" do not usually need to be stabilized and receive a lower evacuation priority. These recommendations have been implemented as a global heuristic.[9]

The multi-agent model also includes the notion of the centralized rescue strategy used in real life. One of the aims of the simulator is to test the effects of a distributed strategy. This is where independent subteams in various subzones cooperate and exchange resources. We have therefore modeled the possibility of specifying subteams and subzones. There are two types of parameters associated with the simulator.

- Parameters that model *concrete* components of the rescue situation. For example, this could be the probabilities associated with how a victim changes from one health category to another. Another example is the time delays involved in treating a victim. These parameters must be calibrated to reflect the real rescue process (see step 5). This is necessary if the simulator is to be used and trusted by decision makers.
- Parameters that allow testing of *different rescue scenarios.* This allows the user to specify different kinds of accidents in different environments. For example, the user can change the number of victims, rescuers, or resources; change how severely the victims are injured; change the location of the AMP; change the number, location, and capacity of the hospitals; specify the exact number of doctors, firefighters, or nurses; change the speed of rescuers' movements; change the radius of perception of rescuers; specify that the incident site is treated as one zone using a centralized rescue strategy or split it into several zones using a distributed rescue strategy; specify that electronic medical forms are used instead of paper ones, and so on. These are essentially input values to the simulator and allow us to experiment with "what-if" scenarios.

Step 4. Implementation

The simulator has been built using the multi-agent platform JADE (Java Agent DEvelopment Framework) version 2.5 (available at http://jade.tilab.com). JADE complies with the FIPA specifications and is written in the java language (running under Sun JDK 1.4 Java Virtual Machine). Jfreechart 0.9.4 (available at www.objectrefinery.com/jfreechart/index.html) library is also used. It is also connected to a database. JADE was chosen mainly for its compliance with FIPA specifications, its documented open source availability, its ability to be deployed over a distributed network, its relative ease of coding, and its ability to model cognitive processes and agent behaviors.

The simulator interface provides input, output, and control widgets and displays. The user can passively monitor the rescue process or interactively change the parameters during a simulation run.

Step 5. Model Calibration

Exhaustive tests of extreme values of the parameters have been conducted to study the simulator behavior. These values were taken from the field studies, which in turn reflect real scenarios. To calibrate the transition probabilities of the Markov chain, hundreds of simulations were conducted. For each probability, a range of values was chosen with experts.

Step 6. Experimentation

Before experiments could be conducted and the data analyzed, a large amount of preparatory work took place. Sets of virtual experiments were designed, efficiency criteria were defined, and configurations parameters were set. The simulator is generic and highly interactive. It allows us to conduct tests of various combinations of heuristics—both real ones, which represent existing rescue strategies, and new, hypothetical situations, which enable us to test alternatives and to assess new solutions.

Virtual experiments were designed combining the following aspects: (1) limiting the environment to just the incident field or extending it to cover a whole city including one or many incidents, routes, and hospitals; (2) centralizing or decentralizing the rescue organization strategy; (3) considering the incident field as one area or as being divided into subzones; (4) changing some rescuers' actions from exploration to prioritizing evacuation; and (5) changing the doctors' actions according to the distance to, or the severity of, the victims.

Preliminary results have raised interesting points considering the difference between centralized and distributed control and regarding the use of electronic or paper medical forms. Experiments improving evacuation time efficiency have been identified. A description of the experiments and results is unfortunately outside the scope of this chapter. Further details can be found in Bellamine-Ben Saoud and colleagues (2006).

Step 7. Feedback to Users

The simulator was developed using an iterative and participative approach involving input from rescuers. Three different groups worked on the development of the simulator: rescuers, cognitive ergonomists, and computer scientists. The rescuer group had four roles in the development of the simulator. The first task of the rescuers was to define the requirements of the simulator. Essentially, this was a description of the kind of rescue scenarios they would like to test. Their second role was to supply information and data concerning the rescue process. Their third role was to validate the conceptual model of the system. The final role was to take part in the testing and simulation experiments. In practice, it was the cognitive ergonomists that worked with the rescuer group.

DISCUSSION AND CONCLUSION

First, we discuss some of the major issues in simulator development. The chapter concludes with some guidelines and recommendations and a discussion on the future of computer-based simulation.

Simulators can be productively used in the various phases of emergency management. However, their development can be problematic and several issues must be considered and various pitfalls avoided. Some important points are the following.

The Complexity/Emergence Problem

The micro-level interactions between agents in computer simulations give rise to macro-level emergent phenomena. For example, the emergence of mutual knowledge within a group of people is caused by the micro-level interactions between the individuals. The identification of macro-level phenomena is not always obvious, and they are still mostly detected or recognized "by eye." This approach falls into the category of the *pattern formation* type of emergence identified by Crutchfield (1994). This refers to an external observer who is somehow able to recognize how certain unexpected features or patterns "emerge" during a process. These patterns do not appear to have specific meaning *within the system*, but obtain a special meaning *to the observer* once, and if, he or she is able to detect them. The often surprising nature of emergent phenomena makes their identification difficult. The situation is often made harder when the emergent phenomenon has a negative, rather than positive, impact (Pavard and Dugdale, 2000). In addition to the recognition problem, there is also a problem of identifying the factors contributing to the emergent phenomena. Given that there is some notion of causality between the agents' interactions and what is observed on a larger scale, the problem then is to identify exactly what factors were involved in producing the emergent phenomena. However, crisis management systems involving interacting humans and technology are complex. The nondeterministic nature of complex systems and the nonlinear interactions between the agents mean that it is impossible to accurately determine causal factors.

The Inclusion/Exclusion Problem and Making Assumptions Explicit

When developing a model of the situation for simulation it is tempting to include every observable feature of the real-world problem. Indeed, we could say that a truly complex system would be completely irreducible. This means that it would be impossible to derive a simplified model from this system (i.e., a representation simpler than reality) without losing all of its relevant properties. However, in reality, different levels of complexity obviously exist. Thus, the essential question is to gauge which of the real-world properties should be included in the model. The reduction of complexity is necessary, and the most relevant variables must be chosen. Bearing in mind that a complex system may be constructed using only a few variables, a good approach is to start by defining a minimal set of relevant factors. The problem with this approach is that we are in danger of developing a model that is so far removed from reality that it is useless. At this point, we should be very clear about the purpose of the simulator and what assumptions we are making when including or excluding real-world factors (Law, 2005). Extreme care needs to be taken on interpreting the results of the simulator since they are so closely linked to the underlying assumptions of what was and what was not included.

The Model Development Problem

The central issue here concerns answering the question “from what is the model built?” In emergency management, many simulators attempt to model some aspect of the real world. This requires coupling an understanding of the real-world situation with an underlying theory. An understanding of the real-world situation may be obtained via field studies, documentation, interviews, and so on. This should be linked to a theory. For example, the *learning theory* behind a training simulator should provide a feasible explanation of how the trainees learn. Several learning theories and approaches exist. For example, the theory might follow a constructivist approach. Here, the learner actively constructs or builds news ideas or concepts based upon current and past knowledge. Alternatively, the simulator might adopt a cognitive theory based on multimedia learning.

The Validation Problem

Computer simulators, being representations of real-world complex systems, are notoriously hard to validate. The problem is in ensuring that their output is representative of the real-world situation. Given the notion of sensitivity to initial conditions of complex systems we cannot expect that the output of the simulator perfectly matches that observed in the real world. However, we should expect that it adheres to trends observable in the real world. Therefore, a common way of validating the output of a simulator is to compare it with real-world data. For example, data from live simulations or from information written about real emergency incidents may be used. This may be used in conjunction with testing the simulator with emergency management professionals. This approach to validation is what may be called “evidence-driven.” Another approach is to use “theory-driven” validation (Moss, 2008). Ideally each aspect of the model should be validated in isolation. In practice, this often requires gradual construction of a “layered” simulator and thorough testing of each layer before progressing.

Recommendations on Simulator Development

Concerning recommendations on simulator development, the crucial point is to be very clear about the aim of the simulator, for example, whether it is for training, prediction, or help in designing new technologies. The aim of the simulator will determine its functionality and influence the development methodology. If the simulator is intended to be multipurpose, it will often have different types of end users. Each user group will require access to different functionalities and different interfaces may need to be designed. For example, training simulators require a radically different functionality and have different end users compared to predictive simulators that may be used by crisis managers.

The second recommendation concerns the simplicity of the simulator. According to the purpose of the simulator, the detail included in the model may vary. If the purpose is to deepen our understanding of some fundamental process, then simplicity of the assumptions is important and realistic representation of all the details of a particular setting is not (Axelrod, 1997). This requires adhering to the KISS principle, which stands for the army slogan “Keep it simple, stupid.” Although the topic being investigated may be complicated, the assumptions underlying the agent-based model should be simple (Axelrod, 1997). In this way the simulation outputs remain completely under control and can be explained by the model and its assumptions. Adopting the KISS principle in turn eases simulator validation and the interpretation of results. Conte rephrased Axelrod’s principle to “Keep it as simple as suitable” (Conte, 2000). She explained that models should be abstract enough to achieve an adequate level of generality. This will highlight the fundamental points of the phenomena under study and will facilitate interpretation. However, she added that models do not need to be more complex than what is required by the purpose of the simulation.

On a practical level, recommending one specific simulator platform or language is impossible since the choice depends on many factors. The choice should take into account the existing expertise of the developer and the cost of the platform. Another important aspect is the flexibility of the platform and its adherence to standards. A system that complies with standards may be more easily linked to other software, such as a global positioning system. The choice also depends on the capability of the platform to model complex agents, for example, cognitive agents. If we have a crisis situation that we would like to simulate, the question is: “Is the platform that we use going to be able to implement the mechanism that we are interested in?” Unfortunately, there is a trade-off between ease of implementation and powerfulness. Finally, this depends on how easy it is for the software to display data generated by the simulator. The ability to display results in a meaningful and clear manner is important if, for example, one of the purposes of the simulator is to convince stakeholders. Unfortunately, it can take a long time to code even the very simplest data capture and display tools. It is therefore useful if a platform already provides a library of such facilities.

In this chapter we have tried to give an overview of the uses and development of simulators for the emergency rescue domain. The use of simulators within this field continues to increase, aided by cheap computing power and easier development tools. With the advances in virtual reality we have entered a new era for serious, nongaming applications. Instead of having separate simulators for different purposes, it will be possible to easily combine simulators. For example, virtual reality simulators may be coupled with agent-based simulators, with each part addressing a different user need. In future, the range of users who make use of simulations may also be broadened. Such tools will no longer purely be the domain of the research scientist or simulator skilled manager, but will be able to be easily used by a wide variety of users forming a virtual community. The challenge now lies in facilitating our interaction with the simulator and replicating everyday social interaction in a virtual world.

NOTES

1. Induction is the discovery of patterns in empirical data. Deduction involves specifying a set of axioms and proving consequences that can be derived from those assumptions.

2. See also articles in the *Journal of Artificial Societies and Social Simulation,* http://jasss.soc.surrey.ac.uk/JASSS.html.

3. For Vector Command, see www.vectorcommand.com/; for DiaboloVR, see www.neetisolutions.com/DiaboloVR.htm.

4. This represented a fundamental shift in how field studies were to be conducted. Malinowski defined what would become known as participative observation (1914–1918), a distinctive feature of modern ethnology. See also the work of Franz Boas (1920).

5. In this discussion we could also mention the American anthropological school referred to as "proxemic anthropology" (Hall, 1966), which is interested in the social and cultural construction of the space between speakers.

6. This concept refers to all possible meanings that an agent may produce when listening to an utterance.

7. For agent-based platforms, see the list of agent software on AgentLink at http://eprints.agentlink.org/view/type/software.html. For VR platforms, see for example, the VIRTOOLS Platform at www.virtools.com/solutions/index.asp, or Quest3D at www.quest3d.com. The DevMaster's Game and Graphics Engines Database provides a good list of current engines. Note that given the fine line between gaming simulations and simulations of real-life situations many products are advertised as game engines. However, game engines may also be used for nongaming situations such as simulation of crisis activities. Unfortunately, it is out of the scope of this article to compare the various software products available.

8. The simulator was developed in France.

9. Further details on the model and heuristics can be found in Bellamine-Ben Saoud and colleagues (2006).

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CHAPTER 11

CONCEPTUALIZING A USER-SUPPORT TASK STRUCTURE FOR GEOCOLLABORATIVE DISASTER MANAGEMENT ENVIRONMENTS

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Abstract: *Disaster management is capturing increasing attention from researchers across many disciplines (geography, sociology, operations research, and a range of other social, environmental, and information sciences). In geographic information science, important research efforts are targeting better collection and analysis of geospatial data on disasters, representation of risks and vulnerability, integration of physical processes and social models to enhance the prediction of hazard impact, and a range of information access, analysis, and problem-solving tools that support individual and joint work across the disaster management process.*

This chapter provides a framework for the design of geocollaborative environments. These environments are intended to support disaster management activities, through group interaction and collaboration that is enabled by access to relevant geographic information through geographic information technologies designed to support group as well as individual work. We propose that the design of geocollaborative environments requires a focus on cognitive models for task representation, dialogue design, and workflow (action, actor, object, and tool). The framework outlined is based on the conceptualization and characterization of disaster management tasks and operations, and is the basis for the structuring of people/roles, data/information, resources, tasks, and specific tools needed to support each task. The framework is then used as the basis for modeling user tasks; specifically, this modeling is used to structure the design of geocollaborative environments in a way that can facilitate group collaboration through access and sharing of heterogeneous data and information derived from it, shared geographic and concept maps and annotations of both, and the overall coordination of operations. A resulting prototype system and interface is described; the system was developed specifically to support collaborative activities and dialogue, enhance awareness among collaborators, and provide support for group memory by linking information resources and enabling shared knowledge and collaboration.

Keywords: *Disaster Management, Geocollaboration, GIS*

We live in a world of ever-increasing risk, with recent disasters resulting in substantial and often extended economic, social, and environmental impact. Climatologists are warning of increasing meteorological disasters as a result of global warming. September 11, 2001, also focused increased attention on the threat of terrorism, and we live in a society where industrial accidents can occur with increasingly catastrophic results (e.g., Chernobyl, the Bhopal Chemical disaster, etc.). Not surprisingly, disaster management is capturing increasing attention from researchers across many disciplines (geography, sociology, operations research, and a range of other social, environmental, and information sciences). Research efforts are targeting better understanding of the causes, the monitoring of disasters, disaster prevention, preparedness, and response (Cutter, 2003).

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. Examples of recent disasters with wide-ranging geographic information needs in the United States include hurricanes (Katrina, Rita, and Wilma) and wildfires (in Oregon and California). Internationally, recent natural disasters include earthquakes in Indonesia, Pakistan, and Iran; flooding and landslides in Central America; a volcano in El Salvador; tsunamis in Sri Lanka, Indonesia, and Thailand; and a typhoon in the Philippines. All of these events generated requirements for geographic information and technology-enabled planning, response, and recovery.

The increased attention to disaster management has translated into research in vulnerability and disaster response, and has resulted in steps toward better preparedness. At the same time, there have been dramatic advances in information technology that can be leveraged to address some of the challenges. 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.

As noted above, most crisis management activities require geospatial information—to determine where events have occurred, who is at risk and how the risk varies geographically, 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.), and many other factors. As a result, geographic information systems (GIS) have the potential to make a substantial positive impact on our ability to plan for and cope with crises of many kinds. GIS and remote sensing tools have already enhanced the ability of emergency managers and responders to meet the challenges of disaster mitigation and response.

GIS is quickly becoming an integral part of disaster assessment, however, it is not yet well integrated into the disaster management process, and GIS for disaster management remains a relatively new GIS application domain. This is paralleled by a relatively modest body of related research.

While advances in GIS practice have come from post-event analysis of GIS use in major disasters (Kevany, 2003), a more comprehensive research approach is needed. In geographic information science, important research efforts are targeting better collection and analysis of geospatial data on disasters and representation of risks and vulnerability as well as integrating physical processes and social models to enhance the prediction of hazard impact (Cutter, 2003). Relatively less attention has been directed to research focused on supporting collaboration with geographical information and GIS technologies, making GIS accessible to a wider range of disaster management practitioners working in distributed response center and field locations, or the more general problem of developing interfaces to GIS that require less technical expertise to use. The research outlined here is part of a broader project that addresses these challenges.

Specifically, in the GeoVISTA Center at Penn State, we developed a series of prototype, Web-based, geocollaborative applications, as one activity within the GeoCollaborative Crisis Management (GCCM) project. The objective of these applications is to support disaster (crisis) management operations such as humanitarian relief and recovery operations, positioning and monitoring of field teams and distribution sites, or supply routing. In this chapter, we analyze disaster management operations in order to model tasks; the modeling is undertaken in order to structure the geocollaborative applications in a way that can facilitate group collaboration through the access and sharing of heterogeneous data and information derived from it, shared geographic and concept maps and annotations of both, and the overall coordination of operations.

Below we provide a general overview of disaster management tasks and the potential roles of geographic information systems in five phases of disaster management. We analyze disaster management phases, leading to a proposed structure for disaster management activities and related operational tasks. We provide a conceptual structure for designing geocollaborative support for these disaster management tasks and review some of the benefits and problems that may occur in the use of such systems. We describe a prototype Geocollaborative Web Portal we have developed and the results of initial field trials of its use. Finally, we discuss lessons learned and plans for future development and research on this system.

CONCEPTUALIZING DISASTER MANAGEMENT TASKS

Disaster Management Phases

In the literature, disaster, crisis, and emergency management are sometimes used synonymously and sometimes with slight differences depending on the operational procedures in place at different organizations. In this chapter, we use the term disaster management to refer to a wide context in which a disaster is a serious disruption of the functioning of a society, or a catastrophic situation causing widespread human, material, or environmental losses that exceed the ability of the affected society to cope using only its own resources; this is a definition adopted by the United Nations International Strategy for Disaster Reduction (ISDR). In a disaster event, emergency interventions are required to save and preserve human lives, infrastructure, and the environment.

Different phases of disaster management are also described in the literature. Descriptions typically identify either four or five phases, and different definitions of these phases of disaster management exist. Some descriptions organize disaster management activities into a hierarchy, while others portray all phases as part of a continuous cycle at one level.

In order to develop a task structure and scenarios that reflect actual disaster situations for use in the design of information systems that can better support user tasks, it is important to understand activities surrounding each of the different phases of disaster management. The most common parsing of these activities is one recognizing four distinct disaster management phases: mitigation, preparedness, response, and recovery (Alexander, 2002; FEMA, 1997; George and Bullock, 2004). Others have added a fifth phase to this process (e.g., reconstruction—Cutter, 2003; or content identification and planning—Greene, 2002). We have adopted the latter (a five-phase process) and used it as the starting point for a model of the task structure and to derive a framework for geoinformation technology–supported disaster management. Below, we describe the five phases. For each, we cite one of the many typical roles for geographic information and technology:

1. Planning

Disaster planning is the process of developing plans and procedures that will enable individuals and organizations to respond to a disaster so that critical activities can be resumed within a defined time frame, minimizing loss and restoring affected areas. Typically, disaster planning involves an analysis of the processes and continuity needs and may also include a significant focus on disaster prevention. Developing and implementing an effective geographic information and technological infrastructure before a disaster event occurs is one key aspect of planning. For example, establishing cross-jurisdictional or organizational geographic data-sharing agreements or licensing issues (Goodchild, 2006).

2. Mitigation

Mitigation refers to pre-disaster efforts directed at reducing the effect of the disaster event on human life and personal property. An example might be the limitation of development in low-lying coastal areas, or more stringent building codes that account for potential earthquakes in seismically active zones. Increasingly, mitigation can take the form of modeling disaster events, assessing the results of the model, and then taking steps to correct potential problems. This activity can include the use of technological solutions such as flood levees, legislation and insurance, or land-use planning. Geographical aspects of mitigation include mapping, visualization, and identification of vulnerable populations such as elderly people or those in a high-risk zone having limited financial resources to cope with damage to property or disruption of employment opportunities.

3. Preparedness

Preparedness refers to the actions taken prior to a disaster event that enable disaster management units to appropriately respond to the threat. Examples of actions include operational and procedural training of disaster responders through activities such as mock-event exercises developed as a result of mitigation activities, or technological training such as showing a first responder how to use mobile geographical technologies such as GPS-based PDAs (global positioning system-based personal digital assistants). Furthermore, preparedness can be directed to citizens more generally with public information materials and announcements about what to do in different disaster circumstances (these materials often have a geographic/map component focused on alerting the public to evacuation routes, shelter locations, etc.) and activities such as testing of emergency warning and communication systems. In order to maximize response in a crisis, emergency managers need to prepare by having the ability to incorporate real- or near real-time information concerning the areas at risk and resources available for these areas in their decision-making process. One example of the potential of GIS is that GIS can incorporate maps of gas lines with areas of potential earthquake seismic risk and show emergency managers potential fire hazards, which could be mitigated by additional firefighter service or a relocation of the unnecessary gas lines.

4. Response

Response is defined as actions taken immediately prior to, during, and after the disaster event that help to reduce human and property losses as well as actions taken to aid in the post-disaster recovery effort (the next step described below). Response includes several geographically based operations: search and rescue, the evacuation of threatened populations, location of medical assistance facilities, managing distribution of critical supplies (such as water and food) to victims, maintenance and dissemination of geospatial intelligence information such as satellite imagery (Nourbakhsh et al., 2006). Maps and images play a key role in response during events.

5. Recovery

Recovery is considered to be the phase during which measures are enacted that facilitate the return of social and economic activities to an acceptable standard (Gunes and Kovel, 2000). Recovery

Figure 11.1 **Disaster Management Phases**

includes rebuilding destroyed property and repairing other essential infrastructure. Recovery also includes supplying the affected area with a reasonable opportunity for long-range return to viability and potential for growth. Geographical aspects of recovery include the use of maps as the objects of collaboration in community planning dialogues and rebuilding efforts (MacEachren, 2005).

The different phases of disaster management activities are shown in Figure 11.1.

From an information system design perspective, it is important to categorize operational tasks for each disaster management phase and then focus on an analysis of information needs. Generally, information needed in a disaster management situation includes that related to: climate and weather, population, community capacity, industry, public buildings, spaces and events, critical infrastructure, essential services, hazard source, vulnerable sector, potential risk, level of risk action priority.

Structure of Disaster Management Tasks

The disaster management phases described above lead us to a description of activities and tasks (see Table 11.1). The main activities and operational tasks listed in the table were compiled based on operational procedures and guidelines (FEMA, 1997; USAID, 2005).

In the United States, the National Response Plan (NRP) outlines structures and protocols for collaboration and coordination across various levels of government and private sector entities. The incident annexes of the NRP give an example of how the U.S. federal government conceptualizes response tasks and collaborative actors/agencies involved in those tasks for particular types of incidents. The NRP incident annexes define operational scopes, policies, concepts of operations, and definitions of coordinating and cooperating agencies for the following incident types:

- Biological Incident
- Catastrophic Incident
- Cyber Incident
- Food and Agriculture Incident
- Nuclear/Radiological Incident
- Oil and Hazardous Materials Incident
- Terrorism Incident Law Enforcement and Investigation

Different actors are involved in the different disaster phases, activities, and tasks described above. Examples of immediate responders compiled based on (USAID, 2005) in a disaster event include:

- Firefighters
- Law enforcement officers
- Paramedics and ambulance personnel
- Emergency room personnel
- Unexpected responders (for example, when disaster victims are also responders)
- Mental health professionals
- Workers with voluntary organizations such as the Red Cross, the Salvation Army . . .
- Remote responders
- Emergency managers
- Emergency support personnel
- Shelter and care givers
- Body recovery, identification, and burial personnel

Although this is not an exhaustive list of actors that fits all disaster events, it includes the main elements of a disaster response team. Each member of this group has roles and tasks as described in the disaster activities and tasks in Table 11.1. Information needed to accomplish these tasks ranges from maps of affected areas to enable planning and decision making, through logistics support (Kapucu et al., 2007) and resources, to communication among workers (Cutter, 2003). Table 11.1 describes the overall task structure and tools needed.

As described above, GIS can play a major role in the activities described for the different phases of disaster management. In the next section we further explore the potential role of GIS, the distributed use of GIS, the limitations in its use, and how geocollaboration can be added to GIS use for disaster management activities.

GIS AND GEOCOLLABORATIVE SUPPORT FOR DISASTER MANAGEMENT TASKS

GIS is a valuable tool to support the activities and tasks described above. This section describes the potential and current use of GIS in disaster management, and suggests ways in which geocollaborative support can provide additional disaster management benefits.

GIS in Disaster Management

Disaster events vary in both spatial and temporal extent. Impacts from a disaster event can be as temporally and spatially broad as a month-long flooding of a major river, such as the Midwest floods of 1993, or as temporally and spatially local as a chemical tank explosion. The spatial aspect of disasters requires crisis management agencies to maintain awareness of the geographic characteristics of the natural and built environment in order to manage disaster events in ways appropriate to the places in which they happen. GIS can be used at all the disaster phases described above. Planning a response or responding to a disaster requires access to and management of accurate georeferenced information. For example, GIS has the capacity to help identify emergency shelters or immediate locations that have suffered heavy damage, and to inventory and track resources to these locations in a more efficient and timely manner. Access to data about critical

Table 11.1

Structure of Disaster Management Tasks and GIS and Geocollaborative Support Needed

	Main activities	Operational tasks	Users	Tools needed
Planning	• Develop plans and procedures that will enable response to a disaster • Analyze the processes and continuity needs • Conduct activities related to disaster prevention • Organize public awareness and education to promote prevention	• Conduct functional planning tasks • Conduct needs analysis • Organize communication with the public	• Emergency managers • Emergency support personnel • Firefighters • Law enforcement officers • Paramedics and ambulance personnel • Emergency room personnel • Mental health professionals	• Concept mapping • Geographic maps: vulnerability maps, planning maps • Communication tools
Mitigation	• Model disaster events • Construct flood levees • Enact legislation • Provide public information and education • Ensure proper insurance is in place • Conduct environmental management, land-use planning, and management activities • Perform urban planning activities, protection of critical facilities	• Identify threats and risks • Identify and evaluate alternate protection techniques as they become available • Use modeling and simulations • Analyze trends	• Emergency managers • Emergency support personnel • Firefighters • Law enforcement officers • Paramedics and ambulance personnel • Emergency room personnel • Mental health professionals	• Concept mapping • Geographic maps • Modeling and simulation tools • Hazard analysis tool • Data analysis and visualization tools
Preparedness	• Train disaster responders • Ensure proper equipment is in place • Develop and test emergency population warning methods • Set up emergency shelters • Conduct emergency evacuation • Stockpile various materials or commodities • Develop warning system and public information/education, including forecasting, dissemination of warnings	• Prepare maps, food, and material stockpiling; emergency drills; prepare emergency kits • Construct stands and other types of housing • Conduct real-time monitoring • Activate detection, alarm, warning systems, and public information • Mobilize resources (personnel, medicines, logistics, organizations) • Update, train, and assign personnel to emergency tasks, based on standard operating procedures	• Emergency managers • Emergency support personnel • Firefighters • Law enforcement officers • Paramedics and ambulance personnel • Emergency room personnel • Mental health professionals	• Concept mapping • Geographic maps • Training tools • Inventory tools • Communication tools • Deployment monitoring system • Personnel alert system • Experts contact list • Risk-mapping tool

Response	• Conduct search and rescue operations • Evacuate threatened populations • Provide victims access to air and water • Provide first aid treatment • Monitor secondary disaster • Construct temporary housing • Provide social and moral assistance • Distribute clothing and blankets • Provide housing/temporary shelter • Provide medical care, manage medical assets • Provide food supply	• Coordinate the event (identify, localize event; assess, monitor event; manage actors, logistics) • Provide first aid to the injured • Conduct need assessment • Contact isolated groups or localities • Evacuate dangerous areas • Mobilize resources (personnel, medicines, organizations) • Provide public information and issue warnings • Locate the victims • Recover bodies, conduct identification and burial • Organize reporting/debriefing sessions • Collect, collate, analyze data and information • Communicate with actors • Manage, maintain, and track supplies, equipment, and people • Conduct real-time monitoring	• Emergency managers • Emergency support personnel • Firefighters • Law enforcement officers • Paramedics and ambulance personnel • Emergency room personnel • Unexpected responders • Mental health professionals • Workers with voluntary organizations such as the Red Cross, the Salvation Army, and so on • Remote responders • Shelter and care givers • Body recovery, identification, and burial personnel	• Annotations, collaborative annotations • Collaboration tools: chat, group discussions, document sharing, whiteboard • Concept mapping • Mapping: * Map of damage areas * Maps of evacuation zones, evacuation routes * Map populations, areas at risk * Map of critical facilities * Maps of shelters, nursing homes * Map area of operations * Map of resources (locations, type, quantity) • Communication tools • Risk-mapping tool • Real-time monitoring tool • Event coordination tool • Reporting tool
Recovery	• Rebuild destroyed property and repair other essential infrastructure • Provide disaster-resistant construction, appropriate land-use planning, livelihood support, industrial rehabilitation	• Conduct service and site restoration • Conduct reconstruction activities	• Emergency managers • Emergency support personnel	• Geographic maps

factors such as the number and location of assisted-living facilities or hospitals in an area that might require special evacuation assistance, distribution of supplies, identification of sites to evacuate, and evacuation routes are some of the support provided by GIS. As such, GIS is often an integral part of designing crisis response plans. GIS also supports development of *what-if* scenarios and creation of associated training exercises in the disaster-preparedness phase. It has the ability to support a disaster forecast of an area by enabling analysis of available data and then providing the necessary information for determining the potential affected areas as well as the extent of populations at risk (Gunes and Kovel, 2000). Floodplain maps can, for instance, be overlaid with overland runoff flow maps or distributed hydrological models (Zerger and Smith, 2003) and with housing and population data to determine whether flooding is likely to occur during a rain event and, if so, how many and which properties need to be evacuated. Crisis managers could also use information provided by GIS to take mitigation actions prior to an event such as an oncoming flood, for example, ensuring stormwater drains are clear, sandbags are available, or early evacuation is initiated for flood-prone areas.

Distributed Use of GIS in Disaster Management

Crisis management requires multiple individuals and organizations sharing information, expertise, and resources in support of rapid situation assessment and decision making (Cai et al., 2005). A team may work together at the same or different time and at the same or different places (Armstrong, 1993; Ellis et al., 1991). Furthermore, effective crisis management requires acquisition and dissemination of historical and real-time information from many sources.

Distributed GIS in disaster management has been recognized to provide access to spatial information during a crisis event to a larger group of people, in a fast, easy, and cost-effective manner (Cai, 2005). Distributed GIS has the potential to increase the usage and accessibility of geospatial data. It provides a platform for exchanging ideas, knowledge, and the latest information during the event.

Distributed GIS 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 owning a GIS and having access to data (Peng and Tsou, 2003). There are different types of distributed GIS based on different computer networks that are available. The most common include Network GIS (Yang et al., 2006), Internet GIS (Peng and Tsou, 2003), Intranet GIS, Wireless GIS, and distributed GIServices (Yang and Tao, 2005), Web GIS (Plewe, 1997), and location-based services (Jiang and Zipf, 2005). These various types of network GIS refer to different communication infrastructures such as Internet, Intranet, and the Web.

There have been reports of many successful applications of distributed GIS. Mobile GIS (Montoya, 2003; Wang et al., 2004) or field-based GIS (Pundt and Brinkkotter-Runde, 2000; Zingler et al., 1999) have been used in field data collection. These systems use wireless communication systems, mobile computers, and positioning systems to achieve the ability to access, process, and display geospatial information in the field (Casademont et al., 2004; Nusser et al., 2003). Particular focus in the field of distributed GIS has been given to enabling geocollaboration among users. Cai and colleagues (2004) proposed the use of maps to mediate emergency operation center mobile team collaboration for crisis management. Cai, MacEachren, and colleagues (2005) developed a group interface for geographical information systems, featuring multimodal human input, conversational dialogues, and same-time, different-place communications among teams, in a Map-Mediated GeoCollaborative Crisis Management system. MacEachren and colleagues

(2006) put an emphasis on designing technologies to meet real-world needs in GeoCollaborative Crisis Management.

The potential role of GIS in disaster management has been well documented. The recent report of the U.S. National Research Council (2007) concluded that geospatial data and tools should be an essential part of all aspects of emergency management from planning for future events, through response and recovery, to the mitigation of future events. The potential of geospatial data and tools was recognized in the report for contributing to saving lives, the limitation of damage, and the reduction in the costs to society of dealing with emergencies, by providing useful information products that allow response to proceed without the confusion that often occurs in the absence of critically important information (National Research Council, 2007). However, some field studies (Zerger, 2002; Zerger and Smith, 2003) showed that GIS is rarely utilized in real-time crisis response. Zerger and Smith (2003) reported results from scenario observations and post-scenario interviews with risk managers that highlight the limitations of GIS for real-time disaster planning. Limitations include the scale of spatial data and its suitability for large-scale decision making, implementation problems that can cause GIS to fail, user access and knowledge impediments, in addition to the availability of spatial data and models. The next subsection further explores the impediments to GIS use.

Impediments to GIS Use

As described above, 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, GIS is currently not used to its 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 is a 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.

The U.S. National Research Council (2007) concluded that issues of training, coordination among agencies, sharing of data and tools, planning, and preparedness, and the attention and resources invested in technology are the critical factors to be addressed if future responses are to be effective. The report also indicated that numerous impediments exist to data sharing, including lack of interoperability at many levels, lack of knowledge about what data exist and where, restrictions on use, lack of training on the part of users, concerns about data security, and lack of operational infrastructure in the immediate aftermath of disaster. While enormous amounts of data relevant and essential to emergency management exist, they are frequently scattered among multiple jurisdictions, in disparate and often incompatible formats. Most relevant to the work presented in this volume is the fact that GIS currently lacks support for distributed collaboration and teamwork such as field/command post coordination. In the next subsections, we analyze the way in which our approach can support user tasks in disaster management. We then explore options to improve distributed collaboration among users.

User-task Support in Disaster Management

To analyze the way in which our approach for geocollaborative support can accommodate disaster management tasks as described above, and to provide additional support for disaster management tasks beyond current GIS use, we relate disaster management phases to actors, their roles and tasks,

Figure 11.2 **Disaster Management Phases and Context of Support**

and tools needed to accomplish the tasks (see Figure 11.2), as described in Table 11.1. We also outline some of the strategies/tools for supporting user tasks described in the previous section.

Based on the activities and operational tasks described in Table 11.1, we have derived a list of the functionality that needs to be provided by the tools to support each set of tasks. An asterisk placed in front of a functionality listed indicates that the functionality is implemented in the current version of our prototype system described in the next section.

* Identify applicable threats and risks
* Operational assessments (damage assessment, needs assessment)
* Real-time monitoring: location, extent, time
* Information collection (collect, collate, analyze)
* Allocations of resources/logistics
* Collaborative use of maps to assess damage and make inventories
* Deployment monitoring: searches for closest, available, or lowest cost equipment, personnel, and supplies
Analysis of trends
Simulation (e.g., plume/puff models to estimate how an evolving atmospheric contamination situation will change)
* An event log that tracks the location of users
* Catalogue important actions already performed for future review
* Hazard analysis: to identify natural and technological problems. Find all map locations where one hazard exists or all the hazards in a given area
Personnel alert: displays a prioritized call-up list of selected staff for any function, hazard, or emergency response capability
Expert contact list: lists the experts with the technical knowledge or skills needed in emergencies
* Risk mapping, generate routing maps for search, rescue, and evacuation

* Warning and public information
* Event coordination (manage personnel, logistics)
* Communication between actors
* Reporting/debriefing
* Electronic meetings
* Documentation of participants, their roles, responsibilities, skills/functions, and affiliation

Most of these tasks involve mapping. The mapping needs include maps of disaster extent, population and areas at risk, aid supply routes, emergency evacuation routes, planned locations of camps and aid facilities, and many others. There is also clearly a need for coordination in terms of data/information collection, access, and sharing.

Supporting Group Work and Group Collaboration in Disaster Management

Disaster management is a time-critical and collaborative activity that involves multiple individuals and organizations sharing information, expertise, and resources in support of rapid situation assessment and decision-making activities (MacEachren et al., 2006). Timely compilation and analysis of information from a large number of spatial data sources are crucial for situation assessment in order to support the decision-making process. Such tasks are commonly carried out by groups of people (e.g., crisis managers and first responders) who need to access geospatial information as they monitor the changing situation, communicate about the situation, and make decisions. The integration of communication and coordination tools is needed to support group interaction and collaboration.

Several specific basic elements are necessary to support collaboration. One of the most important is to have an ongoing collaborative dialogue, both human–human (Khoshafian and Buckiewicz, 1995) and human–system (Cai, Wang et al., 2005; Cai, 2007). This collaborative dialogue can be structured at different levels according to the task structure (hierarchical, logical, temporal, and so on). For human–system dialogue, features such as the GeoDialogue system (Cai, Wang et al., 2005) can facilitate conversational dialogue between the user and the geographical information system.

To support collaborative dialogue between users, tools such as chat, video or audio conference, map and image annotations, and threaded discussions can be used. The design or integration of these collaboration tools needs to take into account four main factors (Carroll et al., 2003):

- Situation (the event or activity the group is addressing in a particular context)
- Group dynamics (roles of each actor, subgroup differences)
- Tasks (their structure, sequences in which the tasks will be performed, kind of outputs to store or share)
- Tools needed for each task

Given the cooperative work nature of the disaster management activities, there are several group interface issues that need to be addressed. Some of these include the following items.

1. Awareness

Awareness relates four main components: users (who, where), tasks, and interaction tools needed to manipulate data, and information or objects in order to achieve specific goals in the problem domain. This conceptualization of the representation of awareness is depicted in

Figure 11.3 **Model for Representing Awareness**

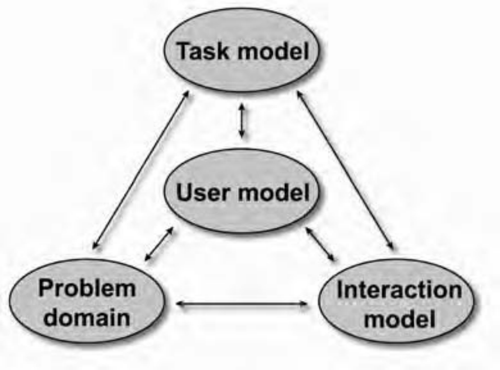


Figure 11.3 in which the user model relates to the task model, the problem domain, and the interaction model.

Designing a geocollaborative group interface to enhance awareness in general requires a focus on cognitive models for task representation, dialogue design, workflow (action, actor, object, and tool). For example, an information pane can be added to the interface to show who is carrying out activities, what they are doing and the activities that are under way (MacEachren, 2005). A session manager can allow users to know what is happening or what has happened at time *t*. This can be organized in a way similar to a Harris matrix (Harris, 1975), to show the sequences or sessions chronologically or spatially. There are multiple kinds of awareness that must be maintained, and that interface and display methods can be developed to support, including: activity awareness, social awareness, and workspace awareness. Each is outlined below briefly.

Activity Awareness. It is important that users are clearly "aware" of each other while working as a group. This can be achieved by integrating a notification system to support awareness of presence, tasks, and actions of collaborators. As Carroll and Rosson (2003) point out, many collaboration environments provide "notification systems" that allow individuals to be aware of the presence, tasks, and actions of their collaborators, but they also need (although do not often include) methods through which the collaborators can maintain awareness of complex and persistent activities, a capability that they call *activity awareness*. Dourish and Bellotti (1992, p. 1) define this as "an understanding of the activities of others, which provides a context for your own activity." Carroll and colleagues (2003, p. 611) described activity awareness with the question "how are things going?" and action awareness with the question "what's happening?" to represent the team's presence and activity level.

Social Awareness. Carroll and colleagues (2003) describe social awareness with the questions "who is here" and "who can I work with?" Users should be able to "socialize" through casual conversational dialogue enabled through chat tools, group discussion tools, and any other tools that can act to simulate in-person social interaction when collocated collaboration is not possible.

Workspace Awareness. Social awareness is related to workspace awareness. This is because workspace awareness involves understanding (or awareness) of another person's interactions (or social interactions) with a shared work environment. Shared workspaces such as whiteboards or collaborative annotations can be integrated to allow group work and support workspace awareness (Gutwin and Greenberg, 2004). Workspace awareness is used in collaboration to coordinate activity, to simplify verbal communication, to provide appropriate assistance, and to manage movement between individual and shared work (ibid.). Gutwin and Greenberg (1998) suggest that workspace awareness support can include:

- the location of others’ viewports in the workspace,
- the location and motion of people’s cursors,
- the motion of workspace objects as they are moved.

2. Annotation

Annotations here are considered to be any user-supplied information (e.g., text, drawings, pictures) that can be attached by users to objects in the display. To support geocollaboration, map and image displays must support annotations anchored to places. To support multiple users, organizations, and ad hoc subteams during a disaster event, it is important to provide mechanisms for annotations to be stored separately from the map (or other display). This makes it possible for several users (or subteams) to annotate the same area of the map using, perhaps, different concepts, and to decide when it is useful to share perspectives.

Annotations can serve multiple roles in enabling collaboration. Hopfer and MacEachren (2007) discuss the potential of annotations to act as boundary objects, thus as objects that serve as mediators from one perspective to another. When anchored to a map or image, in addition to the explicit information they contain, annotations carry implicit geographic meaning (e.g., an indication of geographic scale and that the place is considered important). In addition, as Hopfer and MacEachren outline, annotations have the potential to help a group overcome collective information-sharing bias (the tendency for groups to discuss information that all members know at the expense of discussing unshared or unique information).

Annotations should have a simplified, coherent symbology and classification. A user can add annotations to the map by placing a marker or a symbol, and enter text, which will be displayed with the marker. To minimize the attention users give to the interface versus to the collaboration, predesigned symbols (e.g., flooding, fire, drought, etc.) can be provided with tools that allow them to be dragged directly onto the map and allow associated annotations to be attached. In addition, pictures can be added to the map. The picture can be represented as a thumbnail beside the marker or with a different color of marker. If clicked, a new window opens that shows the picture in its original size.

To further enhance use and usability, annotations can be categorized to allow better access to them. The structure of the annotations can include:

- Date and time (to allow new annotations to be on top of a list of annotations in a window)
- Category or theme and subcategory or subthemes of the annotations
- Source (ground operations, individuals, and so forth)
- Public or group access only (accessible to the public or annotations only used by a group)

Annotations should be noticed as they arrive in the system. For example, a message alert can help users become aware of incoming annotations or comments for discussion. Organized discussion about annotations can help analyze situations and make collective assessment of the disaster (McGee et al., 2002).

3. Concept Mapping

A concept mapping tool can be used to support collaborative activities and group memory by linking information resources, issues, and options to support a crisis action planning methodology and by enabling shared knowledge. The use of concept maps and other representations such as cognitive maps or causal maps (Eden, 1988), Fisher's (1990) semantic networks, knowledge or node-link maps (Dansereau, 2005; Holley and Dansereau, 1984), and mind maps (Buzan and Buzan, 1996), has proved useful in expert knowledge elicitation (Coffey et al., 2006). For example the user can load an ontology of disaster recovery into the system to identify the different concepts, resources, and operations involved in recovery (Berardi et al., 2006).

DESIGN OF A PROTOTYPE GEOCOLLABORATIVE CRISIS MANAGEMENT WEB PORTAL (GWP)

At GeoVISTA we are addressing the issue of distributed collaboration and teamwork to enhance coordination, data sharing, and interaction among users of GIS for disaster management. We emphasize the use of a collaborative Web portal that allows individual and group work enabled by geographically aware information access and analysis tools (Tomaszewski et al., 2006).

The GeoCollaborative Crisis Management Environment

The development of the GeoCollaborative Crisis Management Web Portal (GWP) is intended to provide specific functionality and tools within a Web-based environment that supports situation assessment, positioning and monitoring of field teams and distribution sites, and supply routing. The tool is designed to enable group interaction through collaborative annotation and visualization procedures. The GWP supports both synchronous and asynchronous group interaction through collaborative annotation and visualization procedures, and awareness of group interactions. The GWP also allows the integration of external geospatial resources such as documents, GPS data, and images. One of our goals is for the tool to offer an opportunity to collect information from the public and integrate that information with official sources. These external resources are retrieved in the portal as imagery and documents, and real-time feeds of information such as news and weather reports.

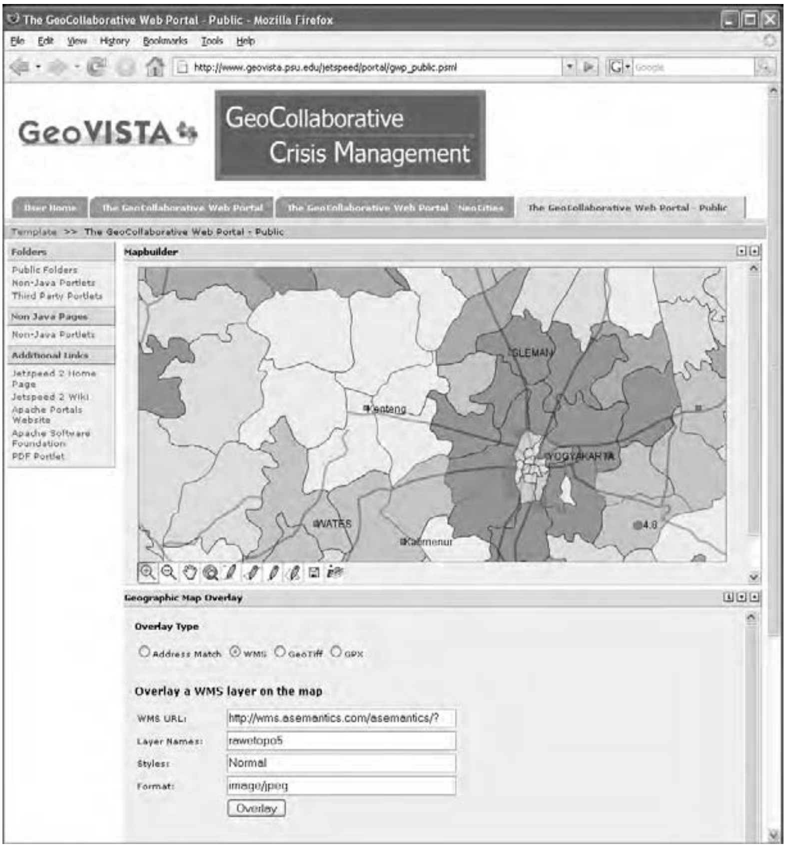
The Web portal also provides access to concept maps that represent operational procedures and command structures. The link between the concept map and the geographic map is designed to support an understanding of task procedures at different places, and to retrieve information about concepts that can be found at different locations on the map (Berardi et al., 2006).

Figure 11.4 shows the GWP interface.

Architecture of the System

As outlined above, the GWP (Figure 11.4), focuses on both the integration of data resources (accessed from distributed sources or uploaded directly by collaborators in the field) and support for information and idea sharing (through activity awareness, action history, and shared annotation tools). To facilitate collaboration, the GWP tracks and records user map interactions (e.g., panning and zooming the map extent) and annotation, and allows users to see what map actions other users have carried out and where they have gone in both map space and real-world space (the latter through display of GPS tracks). Users of the GWP have the option to be online simultaneously

Figure 11.4 **The Geocollaborative Environment (Geocollaborative Web portal)**



Overlay Type: ○ Address Match ● WMS ○ GeoTiff ○ GPX

WMS URL: http://wms.asemantics.com/asemantics/?
Layer Names: rewetopo5
Styles: Normal
Format: image/jpeg

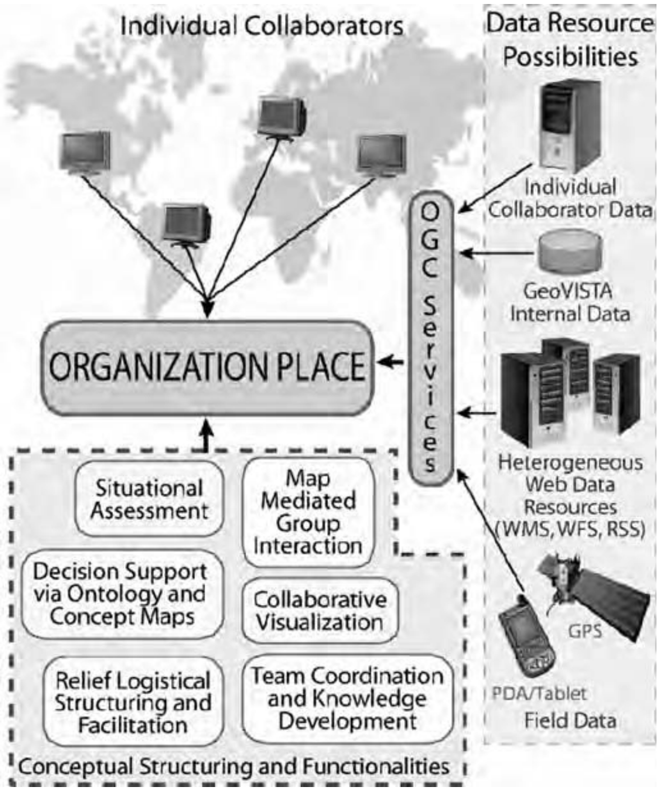
Note: This view shows demographic information for Indonesia loaded into the portal as part of a case study application during the 2006 earthquake recovery period.

and interacting in near real time, or they can leave and return to sessions as needed, interacting asynchronously. Figure 11.5 describes the architecture of the system.

The portal runs as a client server application using a Web browser as the client and is accessed using simple HTTP (hypertext transfer protocol) requests, allowing the tools to work on most computing platforms and to pass through firewalls that may be in place at organizations involved. The GWP is based on the Java Portlet Specification (JSR-168), which allows small fragments of software to be combined into a portal. The use of portlets allows functionality to be added and removed from the site quickly, and different application areas and user groups to be accommodated relatively easily.

Three main open-source geospatial information projects are integrated and extended in this research. Starting with the client software, Community MapBuilder (http://communitymapbuilder.org/) is a mapping client that allows developers to create Web-based mapping solutions in conjunction with server-side mapping software. MapServer (http://mapserver.gis.umn.edu/) and GeoServer (www.geoserver.org/) are Open Source development environments for building spatially enabled Internet applications and for rendering spatial data (maps, images, and vector data) for the Web.

Figure 11.5 **Architecture of the System**



MapBuilder draws maps based upon server-side feeds from Web Map Services (WMS), Web Feature Services (WFS), GeoRSS (Geographically Encoded Objects for Really Simple Syndication) feeds, and Google Maps. The main MapBuilder interface within the GWP displays maps derived from two different WMS sources (GeoServer and Mapserver, which will be discussed below). MapBuilder issues a request to the WMS, which returns an image of the map or multiple images that are overlaid on each other. MapBuilder can be used with any WMS that implements the standard. This allows the use of different WMS in the same client. GWP users may also add a georeferenced layer to the map from any other WMS.

In the GWP, Mapserver is used to overlay GeoTIFF imagery on the map because of its strong support of raster data. GeoTIFF is a metadata format for TIFF (Tagged Image File Format) files that have geographic data embedded as tags within the TIFF file; the tags make it possible to position the image in the correct location and geometry on the screen of a geographic information display. GeoServer is used for the majority of mapping; it is an OpenGIS “Web Feature Server-Transaction” (WFS-T) that provides read/write access to numerous spatial data sources via standard Internet protocols.

MapBuilder also supports the OGC standard of Web Feature Service-Transaction (WFS-T). We customized this functionality to allow users to add and delete back-end GIS data that are stored on the server. For example, WFS-T was used within the GWP for storing annotations added to the map by distributed portal users. MapBuilder uses vector graphics to allow users to draw points, lines, and polygons on the map and stores the geographic coordinates of the drawings in HTML (HyperText Markup Language) input fields. These coordinates, along with information about what the user is annotating, are then sent to GeoServer using a WFS-T request to be stored in the back-end database. Storing the annotations in the server-side database allows users to both save their own and view other users' annotations. It also supports query on the annotation history, makes temporal ordering of the annotations possible, and allows the exploration of sequences of discussion topics derived from the annotations.

MapBuilder was also extended to allow users to dynamically add data to the geographic map. Users of the GWP can enter any address in the United States and the address is geocoded (using www.geocoder.us) and plotted on the map. Or users can simply enter a latitude and longitude to add a point (e.g., if they have a GPS). In both cases, users may add attributes describing that point and associate an image or Web page with the point. In the case of images, the image is saved to the server, and a reference URL (Uniform Resource Locator) to the image is stored along with the point in the database. This functionality can be used to allow field-based users to upload pictures of damage in a particular area and to allow remote users to assess conditions on the ground. When an external WMS is accessed, a MapBuilder context layer is dynamically created and then added to the MapBuilder context (Mapbuilder stores its map data inside a context document called context layer, which describes the list of WMS layers). This also allows the user to add a GeoTIFF image to the MapBuilder map. A GeoTIFF image on the user's machine is uploaded to the server, and a dynamic layer is created in Mapserver. This layer becomes a WMS layer, which is added to the map as described above.

Lastly, users have the option of overlaying GPS points or tracks on the map (Figure 11.6). The GPX file format is an XML-based format for GPS data. Most modern GPS receiver software can export data into GPX format. This file can then be uploaded to the GWP where the file is parsed and the points and tracks are added to the back-end database. Users can use a GPS in the field and take pictures at the same time, then use our GeoZipUp tool to upload to the GWP. GeoZipUp allows users to put a GPS track and set of related pictures into a zip file that can be uploaded in one action to the GWP. When the GWP recognizes a zip file and the contexts are automatically extracted, the pictures are georeferenced by using their time stamps to match appropriate GPS waypoints, and the results are displayed in the portal with clickable icons for each picture at the appropriate location.

Geocollaborative Work in the Geocollaborative Environment

In order for users to maintain individual perspectives and a social awareness, the geocollaborative interface provides standard floor control and attention modes for both real-time and asynchronous group interaction. These are important design considerations for geocollaborative systems in order to manage how users may or may not control each others' display views, display features, and layers (Schafer et al., 2005).

Our current implementation uses what can be considered a "passive leader/follower" approach to floor control. In this approach, users can select to "follow" another person in the system by synchronizing their own display to that of the collaborator, and the person being followed may not be aware of this. This differs from a traditional leader/follower approach where one person is selected explicitly as a leader, and others are designated as followers to this leader.

The GWP makes initial steps toward supporting both *activity notification* and *activity awareness*. Carroll and colleagues (2003, p. 606) characterize "activities" as "long-term endeavors directed at major goals like planning the layout of a town park." Activity awareness, as described

Figure 11.6 **Example of Uploaded GPS Track and Time-linked Photos of Hurricane Katrina Damage**

http://www.geovista.psu.edu/jetspeed/portal/_ns:YXNpbXBsZXN0LTh8ZDI_/gwp.psml

○ Address Match ○ WMS ○ GeoTiff ○ GPX ● ZIP

Upload a Zip File containing Images, Audio clips, and video

C:\Data\day2_final.zip

User Show History Follow this user

☐ Reset

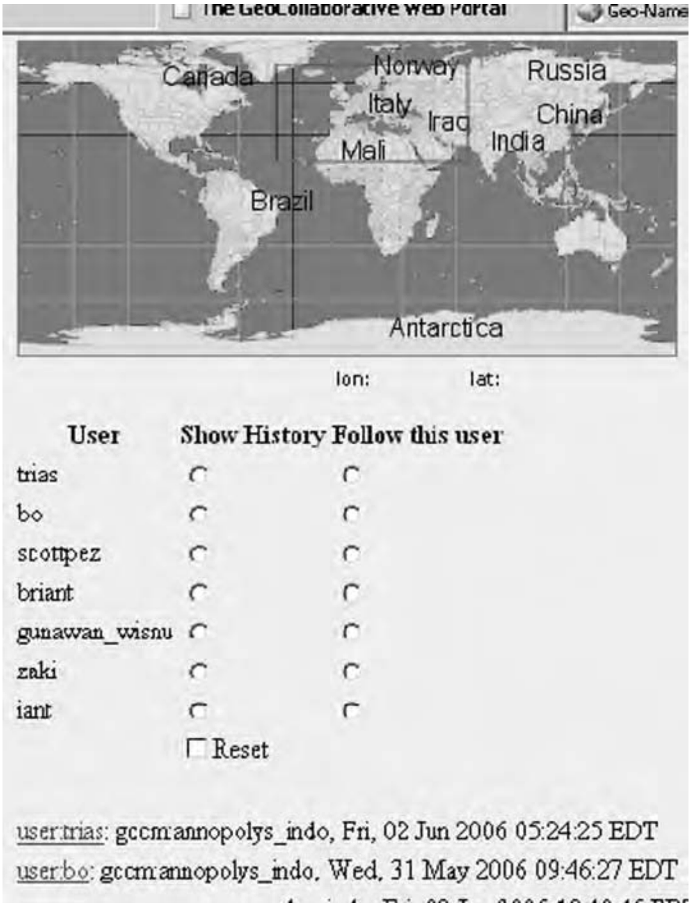
GeoServer GeoRss: Collaboration

user:scottpez: gccm:annopolys, Mon, 30 Jul 2007 10:14:06 EDT
user:briant: gccm:annopolys, Sun, 29 Jul 2007 21:19:49 EDT
user:admin: gccm:annopolys, Sun, 29 Jul 2007 21:21:58 EDT

above, is the ability to allow users to be clearly "aware" of each other while working as a group. Activity notification is the action by the system that alerts users that a change in status related to some activity of interest has occurred. Activity notification is provided through a visual snapshot display of current collaborator positions rendered as rectangles signifying the map extents of individual collaborators (see Figure 11.7).

A simplistic form of activity awareness is provided through the passive leader/follower mecha-

Figure 11.7 **Map History and Notification System**



User	Show History	Follow this user
trias	○	○
bo	○	○
scottpez	○	○
briant	○	○
gunawan_wisnu	○	○
zaki	○	○
iant	○	○

☐ Reset

user:trias: gccm:annopolys_indo, Fri, 02 Jun 2006 05:24:25 EDT
user:bo: gccm:annopolys_indo, Wed, 31 May 2006 09:46:27 EDT

nism detailed above; with synchronization on, the follower is continually aware of changes in the location and geographic scale of focus for their leader as the “the radar view” updates. More comprehensive activity awareness is also provided through textual, temporally organized summaries that represent past geographic viewpoints within the portal map view. Conceptually, these position histories may be considered cognitive artifacts that have recorded the frame of reference for work and its change over time. Users can retrieve this information (or cognitive artifact) from the past in order to inform the present situation (Hollan et al., 2000), direct attention modes, and gain insight into overall group activity.

The temporal histories described above support establishment (at least partially) of a transactive memory system (Wegner, 1995; Wegner et al., 1991). Transactive memory is the notion that individual memory systems, over time, become integrated into larger, organized group memory systems untraceable back to the individual. In addition to temporal histories of map movements, the GWP supports development of transactive memory through its facilities for allowing individuals to add time-stamped artifacts to the map display, including photographs, geospatial images, and annotations, with each addition being identified with an individual and its time of addition. This feature can blur the lines between the actions of individuals and present a holistic view of the group situation.

Case Studies, Design Issues, and Evaluation Plan for the Geocollaborative Crisis Management Environment

As part of the design process for a suite of prototype tools to support geocollaborative crisis management, a limited implementation of the GWP was tested in both a real case study with the Indonesia earthquake in 2006 as well as in a hypothetical Penn State Campus emergency response scenario.

Earthquake Experiment

Following the earthquake in Indonesia in 2006, there were serious concerns about aid supplies and distribution to the most remote villages. Individual initiatives focused initially on building independent shelters, since aid from government and other agencies was not yet arriving in the villages and the lives of many children were endangered because of two days of rain combined with lack of proper food and shelter. Shortly after this major event, working with a collaborator from Indonesia, the GWP was applied in limited ways to try to assist those in the field. The objective was to provide relief teams on the ground with the possibility to upload data, reports, stories, and photos with GPS tracks into the portal, so others could use these artifacts for coordination purposes.

The challenges of distributed, real-time coordination with remote locations experiencing a major disaster were, not surprisingly, beyond the capabilities of a relatively fragile, experimental research prototype. Thus, we are not able to report a success story of geocollaboration meeting real world disaster needs. However, many lessons were learned from this exercise with interaction between developers of the software and those assisting on-site.

As in most developing countries, data availability of the area was a major problem. Some local institutions do have data but they are not publicly available. The primary available data that existed for the area impacted were basic administrative boundaries and population totals. IKONOS images of the area could also be found through the Web.

Due to time pressure during the disaster event, system response time proved to be a critical factor. While the system supported distributed users through a Web interface, when asked to try the system from remote locations (in Indonesia and elsewhere), some relief team members reported a major concern about system response, which was found to be slow. For example, the capacity to draw annotations on the map was judged to be too slow to be useful.

Campus Experiment

As part of an iterative design, implementation, and assessment process, a second case study was undertaken. Working with a cross-campus team focused on integrated tools to support emergency event simulation and response, a hypothetical University Campus emergency scenario was developed. The scenario involved a major disaster event that could happen on the campus. In the scenario, emergency personnel would conduct evacuations, damage assessment, and other operational procedures. As part of this experiment, a student toured the campus and took digital photographs of the campus while collecting GPS data of his position to share with others and contribute to the situation assessment. The data were then uploaded to the GWP using our GeoZipUp tool as described above. Users could then assess the evolving situation by reviewing relevant geographic raster and vector data of the scenario area together with the georeferenced photographs of potential disaster areas.

The time-stamp method of georeferencing the photographs was quite successful. The user in the field was able to use a digital camera to take photographs, collect the GPS data with a GPS receiver, transfer the data to a laptop, and easily upload the data through the portal interface connected by a wireless Internet connection. The GPS tracks and matched photographs were properly georeferenced and displayed within the GWP for other users to access without assistance by the software developer or GIS expert.

Summary of Lessons Learned from the Case Studies

In summary, two case studies have been performed with the GWP thus far. The first required a user in the field to interact with a GIS expert and software developer in the office to load geographic data into the GWP and allow that data to be accessed by others. The second case study allowed a user in the field to load digital photographs and GPS data through the GWP interface independently. The data were then displayed for others.

There were benefits of using GeoServer that include: support for many file formats, support for many projections, output to an image format accepted by a large percentage of users, and adhering to Open Standards. These strengths allowed the data to be fed into the system by the GIS expert in the field.

The earthquake experiment provided the basis for improvement of multiple aspects of the system: a number of measures were taken to improve system response by simplifying the annotation system; fixes were made for bugs found when using Internet Explorer rather than Mozilla Firefox; deleting and adding features were made more stable; and panning and zooming were improved. Some specific additional needs also were reported. For example, users wanted to include maps of districts in Indonesia with their population. Data on casualties by deaths, displaced/homeless, buildings destroyed, villages, and so on could then be shown by district with simple charts to which users are accustomed. Users also reported the need for a map legend where necessary (e.g., for symbols used) and how-to instructions on the screen.

One of the many objectives of the GeoCollaborative Web Portal was to provide a place where users could come to find and contribute heterogeneous information about the disaster. Ideally, the users in the field would load data into the system and have these challenges overcome by the software. However, during the Indonesian case study, those in the field fed data to a developer and GIS expert. That expert was able to fairly easily handle the difficulties of ingesting the data. In the campus experiment, the system worked well with the Image Upload portion of the GWP. However extending the approach from the small case study to real-world use requires meeting several challenges. In the campus experiment, the brand of the GPS receiver and the digital camera were known. This will not be the case in real-world applications. Most digital cameras provide a time stamp in Exchangeable Image File (EXIF) format associated with the digital picture file. However, not all cameras use the same XML tag information within the EXIF data to denote time stamps. The different time-stamp tags of different cameras could potentially be problematic for the system to know what the time stamp is. In addition, not all time stamps are in the same format. Furthermore, time and time zone of the camera and GPS receivers needs to be properly set by the user or recognized by the system (the latter requires additional information in the tags).

For the GPS data, GPS Exchange Format (GPX), a standard data format that allows GPS data to be easily exchanged, was used. This Image Upload feature of the GWP was also used to collect damage photos from Katrina in New Orleans and match with GPS tracks in the GWP map.

Besides the images and GPS tracks upload, we were also able to successfully integrate high resolution imagery and vector data about campus buildings, parking lots, and other physical details into the system and make that information usable.

Planning for Evaluation

A series of further, more comprehensive tests of the Geocollaborative Web Portal are planned in order to evaluate whether and how the system meets the needs of disaster management operational tasks. One aspect of the tests involves a series of small-world simulations that are designed to address a range of theory-based questions about the role of information technology (particularly map-based, interactive visual display) in support of group work. The experiments are based on a campus disaster situation in which the GWP is used by teams of emergency management personnel.

CONCLUSION

In this chapter we have presented disaster management activities and how they can be supported using a geocollaborative web portal. The chapter described disaster management tasks as they relate to the different disaster phases, the kind of users (groups), and the kind of support that GIS and geocollaboration can provide. An emphasis was put on supporting group work in disaster management activities. We reviewed group interface theory in addressing geocollaborative support in the design of the geocollabortaive web portal (GWP).

The GWP was developed to address a portion of the disaster management tasks described in the overall task structure, mainly situation assessment, positioning, and monitoring of field teams and distribution sites, supply routing, and field reconnaissance to do situation and damage assessments. The GWP user interface design was guided by the structuring of people/roles, information/data or objects, resources, tasks, specific tools needed to perform each task, and the way output or results must be organized. A suite of additional capabilities is being developed, and laboratory studies of group work with a variant of the GWP are under way.

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CHAPTER 12

OPERATIONAL APPLICATIONS OF SPACE TECHNOLOGIES IN INTERNATIONAL HUMANITARIAN EMERGENCY RESPONSE

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Abstract: *This chapter focuses on how the international humanitarian community, including the United Nations (UN) and nongovernmental organizations (NGOs) benefit from space-based technologies to support humanitarian emergency response interventions. The tools discussed include satellite imagery, satellite communication, and global navigation satellite systems. Space technologies are currently used in a wide range of intervention types, including natural, technological, and chemical disasters as well as conflict situations. What is important to realize is that this community is very pragmatic. There is no room for experimenting with unproven applications and cost is always a major issue. Hence, when including space-based applications in the disaster management decision-making process, the UN and NGOs must be assured that services are indeed available when needed. The international humanitarian community is a complex set of actors. Some are more technologically advanced than others. It is therefore important to tailor applications to the varying requirements and uptake conditions. In general, UN and NGOs primarily use space technologies for telecommunication in disaster areas. However, with geographic information system (GIS) software becoming more user friendly and affordable, global positioning system (GPS) receivers becoming part of standard field equipment, and information derived from satellite imagery distributed in short turnaround times at the relevant level of details, the use of these tools in disaster management has also increased. This chapter provides a background on state-of-the-art operational use of space technologies and examples on how various actors choose to integrate solutions for their operations.*

Keywords: *Emergency Response, Satellites, Humanitarian Aid, United Nations, NGO, GIS, GPS*

International humanitarian assistance to support response to natural disasters and complex emergencies has evolved significantly over recent years. With a steep increase in the number of actors on the ground, the coordination of humanitarian emergency response is a challenge. The United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA) is mandated to coordinate the UN agencies' involvement in such emergencies, while other organizations can choose to follow OCHA's coordination as they deem appropriate. This clearly poses a significant challenge to effective emergency response, as coordination is an important element for successful delivery of assistance and efficient use of funds. Key to successful coordination is common baseline information about the area of operations, such as demographics, road networks, populated places, and results from damage assessments. This information must be managed in order to ensure the international humanitarian community makes well-informed decisions based on the best information available in the relatively short time span during which crucial decisions must be made.

With recent technological developments and institutional uptake of such tools as global positioning system (GPS) receivers, satellite imagery, geographic information system (GIS) analysis, and Internet-based collaborative platforms for emergency responders, the role of information management has risen from a purely technical undertaking to an integral part of the decision-making processes. Properly conducted information management is now a cornerstone for decision makers and donor agencies at headquarters as well as for field practitioners. However, the technical tools must be operated in an agreed framework and not seen as easy solutions for successful emergency operations. Solid fieldwork, pragmatic approaches to information sharing, and collaborative attitudes will still be the most important elements for information management during humanitarian emergencies.

This chapter focuses on the practical use of space technologies, most notably satellite imagery, as well as on satellite communication and satellite navigation and how these contribute to twenty-first-century international humanitarian emergency response.

EMERGENCY TYPES

The international humanitarian community responds to a range of disaster types: floods, earthquakes, landslides, storms, volcanic eruptions, fires, and environmental disasters, such as toxic waste and oil spills. In addition, so-called complex emergencies, often with a political dimension and linked to dynamic violent situations, may cause refugee flows to neighboring countries with the subsequent need for international protection. Most emergencies are such that the affected country itself is able to manage the situation. The in-country Red Cross or Red Crescent society typically has a lot of expertise and together with governmental disaster managers provides assistance to the affected population. United Nations and nongovernmental organizations (NGOs) already present in the country also contribute to the internal handling of the situation. However, when major disasters strike, governments do—when needed—welcome international assistance, and also sometimes specifically request it. In these cases, the United Nations is normally asked to facilitate disaster management expertise, food, medicine, tents, logistical solutions, and other assistance as required in the specific situation. OCHA, and in particular the UN Disaster Assessment and Coordination (UNDAC) system, is often the first to depart to a country that has been struck by natural disaster, in order to help the government tackle the crisis and undertake quick damage assessments, so that when other early response actors within and outside the UN system arrive, an operations center (OSOCC—On Site Operations Coordination Centre) is already in place with much needed information on the situation already available.

COORDINATION TOOLS AND MECHANISMS

UN Office for the Coordination of Humanitarian Affairs

The coordination mandate for humanitarian affairs given to OCHA is wide and includes overall information management during relief operations. This is why the organization currently invests in a structured system able to serve not only internal decision makers but also the organizations that OCHA is set to coordinate. Properly defined information management systems, developed in consultation with sister UN agencies and other actors, such as the International Federation of the Red Cross and Red Crescent Societies (IFRC), have the potential to make humanitarian operations more effective and will in itself promote collaboration and coordination. However, the challenges are considerable in view of the sheer number and variety of actors—some professionals, and others, although strongly motivated, unable to function as part of a large operation in a coordinated manner. Geospatial products and services are an integral part of the collaborative approach that defines a well-functioning information system.

International Federation of Red Cross and Red Crescent Societies and the International Committee of the Red Cross

The IFRC and its members in a network of national Red Cross or Red Crescent organizations are the most important actors in immediate disaster response. Since the national members are already in the affected country, with long experience and detailed local knowledge, these, together with the local population, are often the first to assist victims and start the planning of assistance. In cases where international assistance is requested, the IFRC links closely to the UN. Although less directly involved in natural disasters, the International Committee of the Red Cross (ICRC) links to the IFRC, and they tend to collaborate relatively closely in many cases. ICRC is in general more involved in prolonged political situations that have caused suffering among the population and in making sure the international convention of the Red Cross is respected.

Inter-Agency Standing Committee

The Inter-Agency Standing Committee (IASC) is headed by OCHA, more specifically the Emergency Relief Coordinator, but includes several large international humanitarian actors—UN and non-UN. The members and standing invitees of the IASC include all of the principal international humanitarian organizations.[1] However, in practical terms, there is no distinction between members and standing invitees. This broad participation is a significant strength of the IASC, as all key humanitarian actors are involved in the decision processes.

This is a unique forum for coordination, policy development, and decision making among operational humanitarian organizations. In addition, the IASC also provides a clear division of responsibility for a wide range of issues related to humanitarian assistance. Furthermore, it addresses response gaps and promotes effective application of humanitarian principles.

UN Institute for Training and Research (UNITAR) Operational Satellite Applications Programme (UNOSAT)

UNITAR/UNOSAT is the only UN program dedicated to providing the UN family, its partners, and member states with operational satellite-derived solutions during emergencies.[2] Established in 2001, it is now a full-fledged UN program that provides satellite image analysis to all major natural disasters and increasingly also to complex emergencies. This is also why OCHA and UNOSAT have signed a collaboration agreement where UNOSAT is the provider of satellite imagery and related services to OCHA. UNOSAT typically covers all UNDAC missions and is frequently requested to assist the IASC and bi- or multilaterally several UN organizations with image-based services, for example, the UN High Commissioner for Refugees (UNHCR), the World Health Organization (WHO), the World Food Programme (WFP), and the International Labor Organization, to name a few thematically different agencies. Although the topic of this chapter is humanitarian emergency response, it should be noted that UNOSAT covers the whole “disaster cycle,” including early recovery, reconstruction, development, risk reduction, and preparedness, as described by Pisano and Bjorgo (2006).

The Global Disaster Alert and Coordination System, Virtual OSOCC, and Humanitarian Information Centers

In the framework of the institutional setups mentioned above, the Global Disaster Alert and Coordination System (GDACS), facilitated by OCHA, ensures, in collaboration with the European Commission Joint Research Centre (JRC) and UNOSAT, the issuing of immediate alerts for natural disasters and the directly predefined tasks following these alerts. For example, after a major earthquake has struck, the JRC issues a GDACS alert on e-mail and SMS. The next step is for OCHA to quickly gather more information on the disaster in the event an UNDAC team will be deployed. At this stage, the Virtual OSOCC—a Web-based collaborative platform for practitioners and in fact a virtual version of the above-described OSOCC (not yet set up at that time of the emergency response process)—will be active on that specific disaster. Information on the situation, availability of early responder teams, maps, specific logistical and operational issues are all to be found within hours at the Virtual OSOCC. This remains the main coordination tool for humanitarian action during the first phase of the disaster—typically two to three weeks.

In some cases, when the information management need is particularly strong due to the magnitude or complexity of the disaster, a humanitarian information center (HIC) is set up. The center typically follows the OSOCC and ensures that all actors can benefit from sharing of information in a neutral environment. Although normally facilitated by OCHA, the HICs are designed to be interagency, and they foster a coordinated approach to information management and decision making, in particular through their Who Does What and Where (3W) database and GIS functionalities designed to support effective relief operations through identifying gaps in the delivery of humanitarian assistance and thus target activities toward areas with a stronger need. The HICs also promote the use of standards in information management and encourage the operational entities not to focus only on narrative reporting, but rather to use geocoded databases—a method much more suitable for efficient information management.

Other Actors

Other actors in a typical humanitarian operational scenario include national NGOs and regional organizations such as the European Commission Monitoring and Information Centre (ECMIC). These often have their predefined networks and ways of working directly adapted to the specific culture of the disaster-stricken country. It is very important that members of the international humanitarian community interact and serve these actors as well as the government itself—which is always in charge of the operations. The international community is there to help the government cope with the situation, and so full cooperation with local authorities is fundamental to the successful contribution of international actors.

REQUIREMENTS AMONG OPERATIONAL ACTORS

Humanitarian emergency operations often take place in areas with poor availability of and/or out-of-date geospatial information. The geographical context of the disaster and status of, for example, transport infrastructure may be unknown to many of the actors, the exact location of severely hit villages or refugee camps may be unfamiliar to international first responders, and communication lines may be down (Bjorgo, 2000, 2001). This is why support tools, such as satellite imagery integrated with GIS, satellite navigation, and satellite communication, are now acknowledged within the UN as core elements of information management during international humanitarian emergencies. Below are a few examples of requirements for selected disaster types:

- Floods—extent of flood surface water and affected population
- Earthquakes—damage assessments of buildings and other infrastructure such as bridges
- Landslides—extent of landslides and their location compared to populated places and roads
- Storms—extent and location of flash floods and damage to infrastructure and agriculture/forest
- Volcanic eruptions—extent of lava flow and location of populated places and infrastructure, smoke plume damage to crops
- Fires—burned forest and agricultural areas, burned areas compared to populated places
- Environmental disasters—location of disaster and population distribution surrounding it, extent, for example, of toxic liquids and sea surface oil spills
- Complex emergencies—situation overview and damage assessments, change detection

It should further be noted that geospatial requirements are also dependent on the specific organization that is the end recipient of the products, as internal decision-making processes vary. Listed above are examples of general requirements. Further details on spatial resolutions needed to detect specific parameters such as roads and bridges are available in the literature, for example, as described by Gupta (1995).

SATELLITE IMAGERY

The use of satellite imagery for humanitarian emergency response has increased drastically in recent years. UNOSAT has played an important operational role in this regard, as has the International Charter “Space and Major Disasters” (Space Charter), facilitating free satellite image data to entities such as UNOSAT, which then processes and analyzes the data and sends out satellite-image-derived maps and related information to other operational actors in the field and at regional and headquarter offices.

Although limitations on the use of satellite imagery, such as clouds (NASA, 1999), revisit frequency (Umberger, 1990), and spatial resolution are still important, the increased number and diversity of satellite sensors mitigate these problems. With commercial and scientific satellites now being able to provide detailed imagery of less than 1 m spatial resolution and wide area cloud-penetrating radar imagery over large areas, the humanitarian community regularly receives up-to-date satellite-imagery-derived maps. The wide range of satellite sensors makes it easier to meet the various special requirements, as the satellite sensors are chosen based on the type of disaster and specific needs. The one-size-fits-all approach cannot be applied in this context, and the range of satellites now orbiting allows for much better information extraction than was the case ten to fifteen years ago.

One myth regarding the use of satellite imagery is the cost. In fact, compared to the budgets dedicated to other parts of humanitarian operations, close to nothing is required to take on a dedicated satellite imagery analysis and mapping. The benefits, however, are considerable, as the imagery-derived information benefits a wide range of actors, making the whole operation better planned, better coordinated, and better implemented. Properly conducted mapping and analyses reduce operational costs, for example, by providing up-to-date information on the location of ports and airports in relation to roads and their condition (flooded, washed away, destroyed bridges, etc.). The cost of sending a shipment of relief items to the wrong place is great compared to a relatively modest investment in imagery analysis and the following targeted distribution of results. Access to imagery is typically through commercial vendors, bilateral agreements with data owners, free public data, or no-cost imagery from the Space Charter, as described above. The additional cost of so-called value adding (image processing, analysis, mapping, reporting) is still very limited in the overall context of a humanitarian emergency relief operation.

In the following subsection we provide examples of how satellite imagery has been used to produce information for improved decision making, coordination, and implementation of the international humanitarian community's response to disasters. The specific events described here cover floods, earthquakes, tsunamis, fires, volcanic eruption, and complex emergencies.

Examples

Flood: Somalia

In November 2006, large regions of Somalia were flooded due to significant seasonal rainfall—far exceeding the normal precipitation. This caused a major humanitarian emergency as crops were destroyed, roads cut off, bridges destroyed, and livestock greatly affected—all against the backdrop of one of the deadliest civil conflicts in recent years, and occurring at the same time as Somali exile government forces joined Ethiopian forces to oust the Islamic Courts Union that was in control of a large part of the country, and in particular Mogadishu. Due to the security situation in the field, the international community, including the United Nations, had little field information on the extent of the flood and which areas were affected.

OCHA requested support for coordination of this humanitarian emergency through provision of satellite-imagery-derived maps and analyses (see Figure 12.1). Satellite data were provided by the Space Charter and quickly processed to ensure that timely maps, imagery-derived flood extent as GIS-ready layers for local use, as well as statistical information were distributed to field actors. The satellite-derived information was used by a wide range of actors including OCHA operational coordination, WFP logistical assessment and planning, Food and Agriculture Organization assessments of effects on agricultural production, and the UN Humanitarian Coordinator for Somalia, and including high-level discussions with local officials.

Earthquake: Yogyakarta

On May 27, 2006, a 6.3 magnitude earthquake hit Java, Indonesia. The province of Yogyakarta was the most severely affected, and it quickly became clear that a major disaster had occurred. In total, 5,700 people died in the earthquake, while 78,200 were reported injured. Over 150,000 homes were destroyed and more than 180,000 heavily damaged (see Figure 12.2). Thus, several hundred thousand survivors were left homeless.

The GDACS alert system quickly sent out a red alert SMS message, and triggered UNOSAT's rapid mapping service. Detailed pre-disaster imagery was quickly received and used to create dedicated baseline information atlases, each including several map sheets depicting the infrastructure prior to the earthquake. As soon as imagery was received, damage assessments from interpreting pre- and post-disaster imagery were carried out (see Figure 12.3), and results quickly distributed to the field. These products were found highly useful by UN agencies, their implementing partners, and local government for coordination and implementation of the early response activity and following relief work, in particular, rapidly available pre-disaster atlas sheets derived from high resolution imagery, and later damage assessment statistics and atlases (see Figure 12.4).

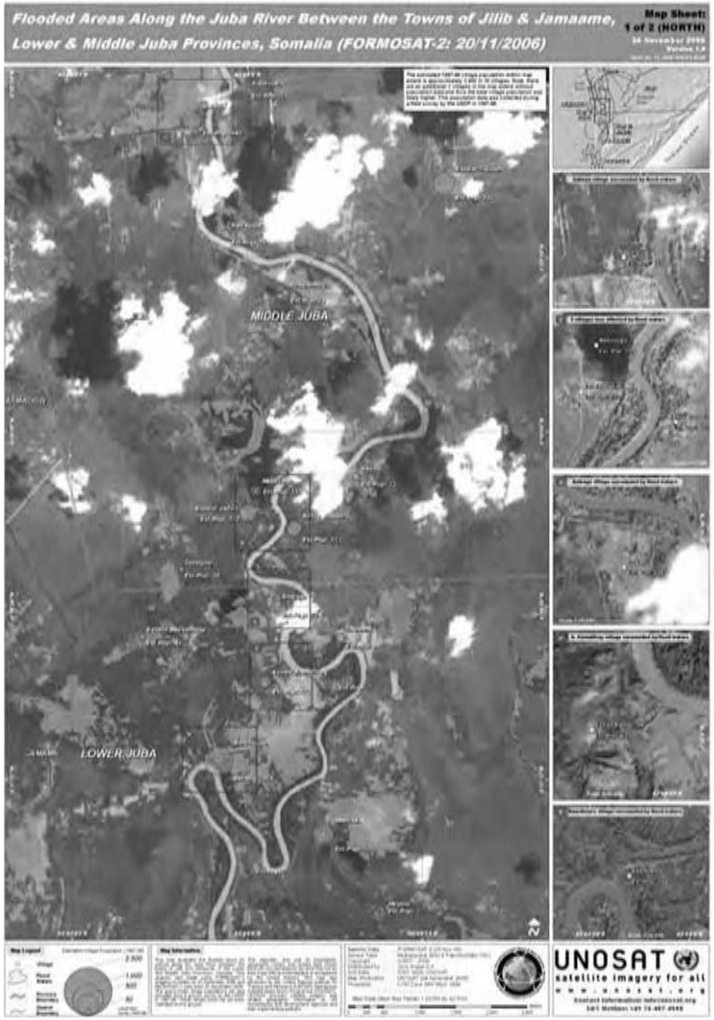


Figure 12.1 **Example flood map (left) and high level discussions with local leaders using satellite maps (right)**

Figure 12.2 **Destroyed building from Yogyakarta earthquake**

An International Telecommunication Union (ITU) field mission, in collaboration with UNOSAT, was conducted. This mission verified the extensive use of satellite atlases by the international community and local actors. However, it also documented that several local actors working on geographic information felt sidelined by the international community and demonstrated a significant duplication of mapping efforts in the field. There was good collaboration with OCHA GIS officers in the field and with representatives from the University of Gadjah Mada, from which more than sixty students had volunteered to undertake GPS recording and support government assessments. The produced satellite maps were used to support the new humanitarian reform cluster process both in the field and at headquarters through the provision of common baseline data and damage assessments to support field reports.

Tsunami: Solomon Islands

The humanitarian emergency relief operation following the Indian Ocean tsunami event of December 2005 received unprecedented attention and financial support. However, the number of lives lost and material damage caused by that tsunami was of such a magnitude that it is not representative for assistance required after more “normal” tsunami events. The example below is from the Solomon Islands. Here, a magnitude 8.1 earthquake struck on April 1, 2007, resulting in a serious tsunami affecting several of the Solomon Islands. Potentially affected zones were rapidly estimated using digital elevation models and predicted effect of the tsunami. In addition, satellite-image-derived damage assessments were carried out based on imagery provided by the

Figure 12.3 **Subset from analyzed imagery—pre-disaster (left, July 11, 2003), post-disaster (right, May 31, 2006). Note the total destruction evident in the post-disaster image.**

Figure 12.4 **Example atlas sheets: pre-disaster (left) and post-disaster (right).**

Note: Atlases not over same area

Space Charter (see Figure 12.5). The maps and analyses were used to support field assistance, coordination and planning of early recovery.

Fires: Macedonia

During the summer of 2007, southern Europe was hit by a series of forest fires. The extreme temperatures and lack of rainfall had created a situation highly vulnerable to fires. In Macedonia, the UN Resident Coordinator and the United Nations Environment Programme (UNEP) requested assistance to assess where fires had taken place and to monitor the situation. Based on satellite imagery, maps pinpointed which areas and places in Macedonia had been affected by the fires—a crucial task to manage the situation in-country and to plan for requests for donor support to the most severely affected areas. Maps, such as that shown in Figure 12.6, were produced very rapidly due to off-the-shelf satellite-derived data available from NASA and a streamlined in-house production chain at UNOSAT.

Volcanic Eruption: Mt. Merapi, Indonesia

During early summer 2006, the Mt. Merapi volcano in Indonesia showed signs of large-scale eruption. OCHA requested analyses of potential hazard zones should the volcano indeed erupt. Using geophysical models, digital elevation data, satellite imagery, and population distribution data, several hazard maps were created. These included deposition zones where ashes and volcanic debris were likely to accumulate. This information was also analyzed relevant to the distribution of population in the area surrounding Mt. Merapi. Imagery verifying the volcanic activity was also processed and mapped, showing ash clouds, ejection of pyroclastic material, and lava flowing from the main crater (see Figure 12.7). Since a relatively large international community was already in place in the region following the Yogyakarta earthquake, maps and analyses were widely distributed and used toward disaster preparedness and risk reduction, contingency planning, and, to a smaller extent, emergency assistance for those areas affected by the relatively modest outbreak that did occur.

Conflicts: Lebanon and Timor-Leste

During the Middle East crisis in July and August 2006, the international humanitarian community needed to understand the extent of damage and where to focus the relief efforts. Example damage types as observed in detailed satellite imagery are provided in Figure 12.8. Due to the security situation, field assessments were difficult to undertake and the area affected was almost all of southern Lebanon. A wide range of products, from situation maps during the conflict to damage overview maps for most affected areas, statistics, and detailed damage assessment atlases (see Figure 12.9) were used by the humanitarian community and Lebanese civil defense. The work done was also useful for early recovery planning and implementation.

Due to the complexity of the situation and the issues at stake, the UN had to undertake an independent and transparent analysis feed into the UN decision-making process. Focus was set on direct support to teams working to provide humanitarian relief on the ground as well as various environmental assessments (by UNEP). These results complemented the joint European Union Satellite Centre (EUSC) and European Commission Joint Research Centre study, which was designed to aggregate information for decision makers involved in funding relief activities. UNOSAT undertook a ground verification assessment on its imagery-based analyses, where ground

Figure 12.5 **Impact map from Solomon Islands tsunami**

Figure 12.6 **Example fire map**

Figure 12.7 **Population distribution (left) and modeled likely accumulation areas for volcanic ashes and debris (right)**

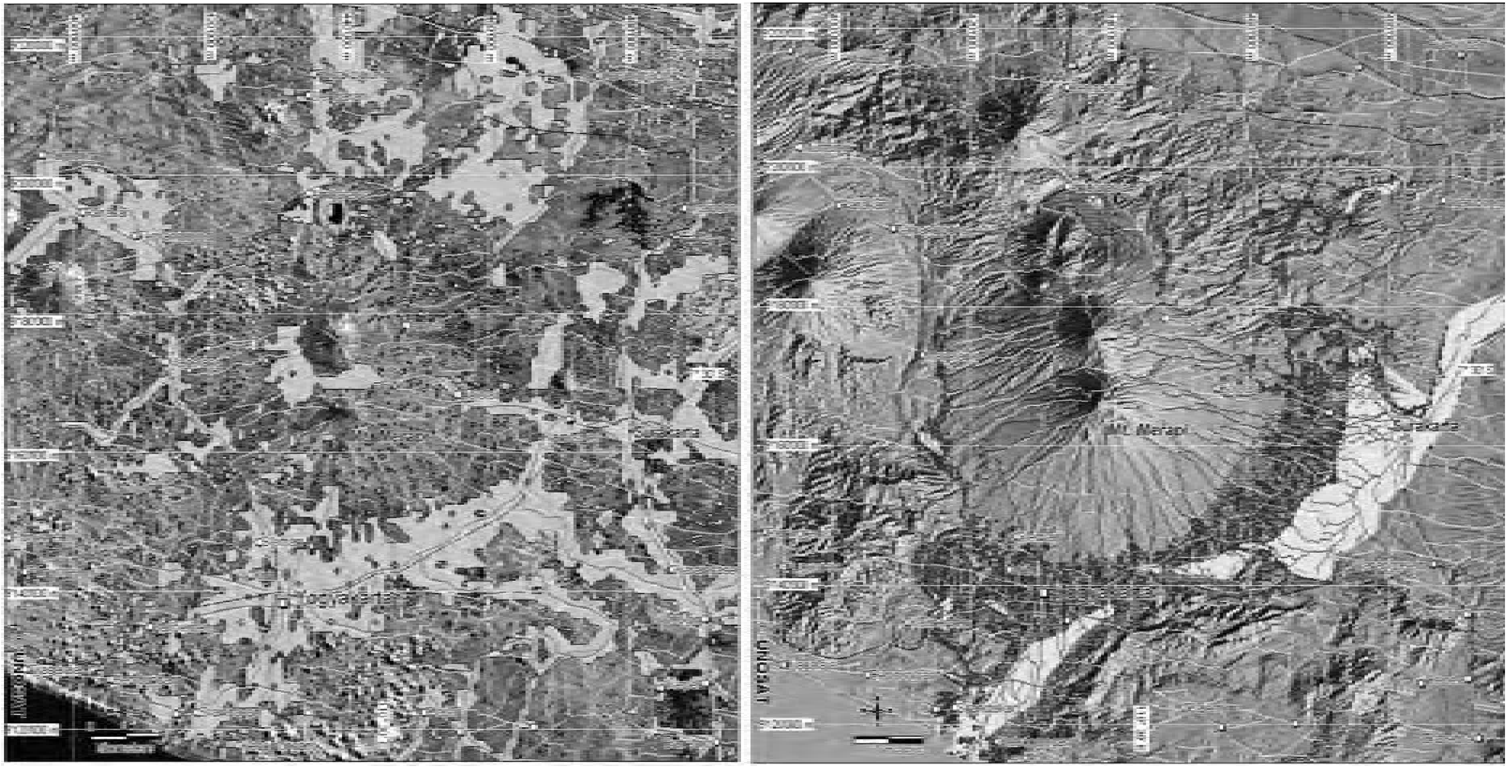


Figure 12.8 **Example damage types on infrastructure as evident in detailed satellite imagery**

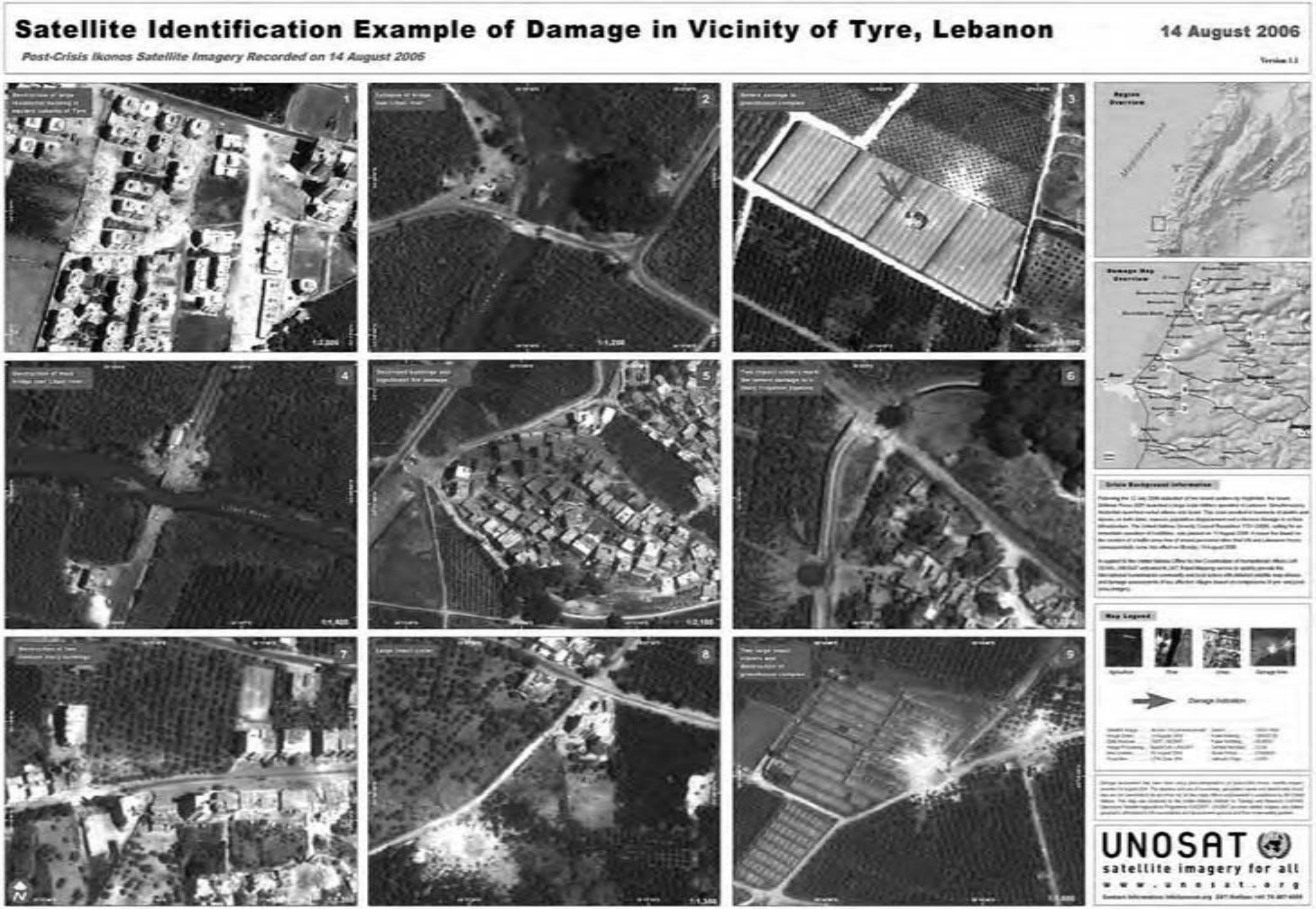
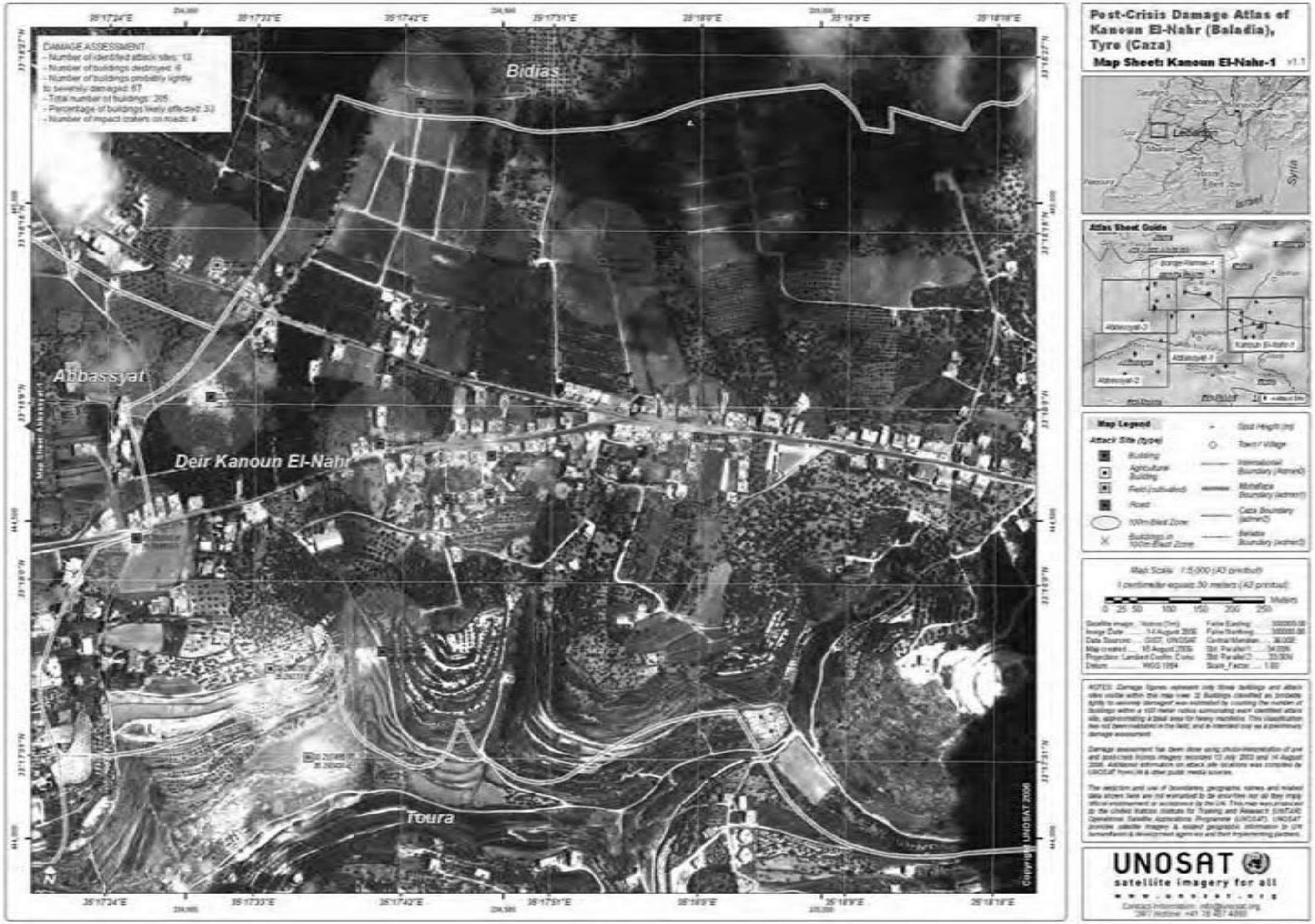


Figure 12.9 **Example map sheet with statistical information (top left) and damage assessment**



data were collected from various locations. This work was complemented by GPS coordinates and photos of the assessed sites. The results were included in a GIS, and the validation showed that the remote analysis was accurate.

Another example of how detailed satellite imagery can be used to support humanitarian assistance in conflict situations is seen in events in Dili, Timor-Leste, during 2005–2006. Following a series of violent protests, the United Nations Development Programme (UNDP) country office needed complementary findings of the locally conducted field assessment. Very high-resolution satellite imagery was used to compare in detail the situation before, during, and after the protests (see Figure 12.10). Significant damage to infrastructure, including burned houses and schools, was identified. The image analysis results were included in a GIS for further analyses and mapping. The results were used to plan reconstruction and longer-term development activities to support the government of Timor-Leste.

SATELLITE COMMUNICATION

Satellite telecommunication is perhaps the most widely accepted and used “space asset” in humanitarian emergencies. Most often, the regular telecommunication network is destroyed or disrupted during natural disasters. With hardware and services available to meet at least the most pressing demands for voice, data, and e-mail solutions, several emergency teams now arrive in the field with their own satellite-based telecommunication kits. These are used to communicate among actors distributed on the ground and to communicate with regional offices and headquarters. More and more solutions with e-mail and regular Internet access for down- and uploading information on the World Wide Web are routinely used during emergencies. An example of this is the VirtualOSOCC, which is also populated and used by field actors. Organizations such as OCHA, WHO, and UNHCR all equip their emergency teams with relatively lightweight satellite telecom solutions.

An NGO specializing in providing telecommunication assistance to the local community affected by natural disasters is Télécoms sans frontières (TSF). This organization arrives very quickly in-country from regional hubs and often sets up a working satellite-based telecommunication service before the other responders arrive. These can then benefit from TSF’s solutions before other systems are in place, and continue to use it in cases where they do not have such equipment themselves. Even more important is the service TSF provides to the local population, by allowing them to make free telephone calls to families, friends, and others immediately after a disaster such as an earthquake has struck (see Figure 12.11). TSF also acts as a technological hub, distributing satellite imagery maps from UNOSAT locally both in digital and hardcopy format, thus avoiding unnecessary download by several actors at more or less the same time.

The International Telecommunication Union (ITU) is the main UN agency for information and communication technologies. ITU is active in supporting emergency telecommunication systems. Another actor, the European Satellite Operators Association (ESOA), supports the international humanitarian community through its members and provides a coordinated approach toward the benefits of satellite communication. The Working Group on Emergency Telecommunication (WGET) is an open forum to facilitate the use of telecommunications in the service of humanitarian assistance. It includes United Nations organizations, NGOs, ICRC, ITU, and experts from the private sector and academia. This group increases the effectiveness of its participants in disaster relief telecommunication. With the rapid development in satellite communication solutions, organizations in the humanitarian relief community now have available a range of tools to support their mandates, and the future will bring even better solutions, such as significantly improved Internet access in remote areas.

Figure 12.10 **Pre-conflict image (left) and post-conflict image (right).**

Note: Destroyed buildings are clearly visible in the post-conflict image

Figure 12.11 **TSF field mission supporting local affected population (left) and providing telecom solutions to early responders (right)**

SATELLITE NAVIGATION

Global navigation satellite systems (GNSS) services are now mainstreamed in developed countries. Many have purchased GPS devices for their private vehicles and handheld devices for hiking trips. More and more of these tools are also used by humanitarian emergency response actors. The importance of recording the geographic location where something has happened is now evident—for example, the location of a destroyed bridge, villages of special concern, locations of toxic waste, locations of internally displaced persons (IDPs), and field verifications of satellite image assessments (see Figure 12.12). These data recordings become integral parts of information management in emergencies, as they constitute core baseline information, which can also be shared among the actors. GPS data entries are easily uploaded to databases and combined with specific information, such as photos or explanatory text, useful for cartographic products, but also to verify information and link it to a specific location. A recurring problem in humanitarian emergencies is ensuring that actors operate with the same spellings of populated places. Village names are often spelled differently by various actors and may also exist in several local languages. To overcome this problem, a system of place codes (P-codes) has been developed. In this system, each location is given a unique code with which several name spellings can be associated. Furthermore, these codes are also linked to geographical coordinates. Hence, GPS recordings are used to implement P-codes in areas where this is not already predefined once a disaster strikes. Accurate geolocalization is thus much more than putting a point on a map—it becomes the foundation for effective information management and humanitarian coordination.

FUTURE DEVELOPMENTS

In the coming years, one will see even wider dissemination and use of space technologies during humanitarian emergencies. The use of satellite imagery, satellite telecommunication, and satellite navigation is now becoming more and more integrated among humanitarian actors. The benefits of common baseline information, rapid information exchange, and accurate geolocalization are clear. Step by step, actors will integrate these support tools into their decision-making procedures and operational field kits. It is of course important to undertake this work in a coordinated and collaborative manner so as to ensure interoperability not only at the technical level but also at the institutional level and across thematic areas, which is what the IASC Working Group on Information Management, headed by OCHA, is looking at.

At the technical level, more detailed satellite imagery will be available to the humanitarian community, such as the recently launched TerraSAR X, a cloud-penetrating radar satellite capable of acquiring images at 1 m resolution—which previously was only possible using optical sensors. Satellites carrying a multitude of bands (hyperspectral) will also be able to classify a much wider range of parameters than is possible from space today. More and more satellites capable of furnishing very detailed imagery will be available, further improving the timeliness of imagery acquired to support humanitarian emergency response. Unmanned aerial vehicles (UAVs) are currently being developed and tested for use during humanitarian emergencies. UAVs with remote sensors and GPS devices show promising results for potential use during humanitarian emergencies, possibly complementing data acquired from satellites. However, UAVs may face restrictions on permissions to fly in certain countries and over specific areas.

More specialized online mapping services will be available, including satellite imagery and derived information, such as Emergency Online Mapping currently being developed for OCHA by UNOSAT to support GDACS and VirtualOSOCC. Interoperable geographic data sharing using

Figure 12.12 **Examples of use of GPS applications—recoding locations of toxic waste (left) and field verification of remote analysis (right)**

open source standards, such as Web Map Service (WMS) and Web Feature Service (WFS), allow for imagery and derived vectors to be directly integrated into numerous GIS at different locations facilitating customized assessments of the same baseline data. Such tools are likely to be increasingly integrated within and among humanitarian organizations. Data storage and processing using distributed computer networks, known as grid computing, will facilitate easier access to satellite data from developing countries and is already prototyped, with support from the EC-funded GMOSS project, in the UNOSAT Grid. A similar grid technology is also used, for example, by the European Space Agency (ESA) through its Fast Access to Imagery for Rapid Exploitation (FAIRE) system, running in its Earth Observation Grid Processing on Demand (GPOD) platform. Initiatives, such as the European Commission and ESA-initiated Global Monitoring for Environment and Security (GMES) program (Béquignon, 2006) are currently developing services through projects such as GMOSS, LIMES, and Respond. GMES will, when operational, also contribute to international emergency response, although the primary focus will be on Europe.

CONCLUSIONS

This chapter has demonstrated how satellite solutions are now an integral part of operational humanitarian emergency response. They will continue to be further integrated and increasingly used in the field at regional and headquarter offices. A wide range of satellite imagery types is needed to respond to the diverse information requirements for different disaster types. Satellite solutions are ideal for supporting a wide range of actors simultaneously and contributing to objective baseline information and damage assessments, for example. With the present increased focus on information management and efficient management and implementation of humanitarian operations, the tools described here will be mainstreamed into decision-making processes. With the establishment of UNOSAT in 2001, the UN now has a proven operational entity capable of supporting humanitarian emergency response with satellite solutions globally.

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NOTES

1. Food and Agriculture Organization (FAO), OCHA, UN Development Programme (UNDP), UN Population Fund (UNFPA), UN High Commissioner for Refugees (UNHCR), UN Children's Fund (UNICEF), World Food Programme (WFP), World Health Organization (WHO), International Committee of the Red Cross (ICRC), International Council of Voluntary Agencies (ICVA), International Federation of Red Cross and Red Crescent Societies (IFRC), American Council for Voluntary International Action (InterAction), International Organisation for Migration (IOM), Office of the High Commissioner for Human Rights (OHCHR), Office of the Special Representative of the Secretary General on the Human Rights of Internally Displaced Persons (RSG on Human Rights of IDPs), Steering Committee for Humanitarian Response (SCHR), and the World Bank.

2. UNOSAT is the United Nations Institute for Training and Research (UNITAR) Operational Satellite Applications Programme.

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CHAPTER 13

NEAR REAL-TIME GLOBAL DISASTER IMPACT ANALYSIS

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ZSOFIA KUGLER, AND LUCA VERNACCINI

Abstract: *The increasing amount of public domain and open content global geographic data along with the availability of near real-time physical data on natural hazards allows the development of numerical and geographic models that can calculate the likely humanitarian impact of disastrous events. Consequence analysis is typically performed with a risk formula combining the magnitude of a hazard with an element at risk (such as the amount of people in the affected area) and a vulnerability factor accounting for physical and socioeconomic resilience of the affected area. While consequence analysis models have been used for years on local scales, their application on the global scale required for humanitarian disasters has been restricted by a lack of data. This chapter describes how this has changed and uses the Global Disaster Alert and Coordination System (GDACS) as an example. GDACS, jointly developed by the European Commission and the United Nations, combines existing Web-based disaster information management systems with the aim to alert the international community in case of major sudden-onset disasters and to facilitate the coordination of international response during the relief phase of the disaster. This system shows that it is feasible to provide global disaster alerts based on consequence analysis models. In addition, such models can produce valuable information for decision making, such as reports on affected areas, expected damage, logistics, critical infrastructure nearby, potential secondary effects, and weather forecasts. This, in turn, can be combined with other public domain or open content information related to a particular disaster such as media reports, field observations, and satellite-based damage maps.*

Keywords: *Disaster Management, Humanitarian Aid, Impact Analysis*

The European Commission Humanitarian Office (ECHO) is the largest donor of humanitarian aid. In 2004, ECHO commissioned the development of a system that would integrate the many existing systems related to disaster monitoring and information sharing in the aftermath of sudden-onset disasters, thereby offering a service to all humanitarian actors, most of which are small nongovernmental organizations (NGOs) that lack the capacity to monitor disasters continuously. This resulted in collaboration between the European Commission, the United Nations, and several scientific organizations to participate in the Global Disaster Alert and Coordination System (GDACS).

With expertise in the field of natural hazards and geographical information systems, the European Commission Joint Research Centre (JRC) developed disaster impact and alert models for earthquakes, tropical cyclones, volcanoes, and floods. JRC also developed an automated media monitoring system. JRC's expertise in the field of Web technologies allowed the development of a system of systems to collect and present information from partners in a single GDACS portal. In parallel, but as an integral part of GDACS, the United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA) developed a Web portal for information exchange between early responders, called the Virtual On-Site Operations Coordination Centre, Virtual OSOCC for short. Finally, UNOSAT contributes with satellite-based disaster impact maps.

In this chapter, we discuss several aspects of disaster alert and information systems based on the experience of JRC with the Global Disaster Alert and Coordination System. First, event detection will be discussed with a focus on a flood detection system developed by JRC. In a second step, the hazard must be modeled in order to calculate the risk zoning. The JRC tsunami propagation system serves as the example. Next, the impact on population and critical infrastructure must be calculated based on the hazard zone. We illustrate this with the GDACS impact models. Finally, we discuss aspects not related to consequence analysis. These include automated media and information collection and the Virtual OSOCC.

BACKGROUND

Needs-Driven Information Systems for Humanitarian Relief

All major donors of humanitarian aid agreed in 1995 in the Madrid Declaration (ECHO, 1995) that international response to disasters should be independent and impartial or, in other words, needs-driven. In a recent report of the United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA, 2006a) on the effectiveness and efficiency of humanitarian aid, the emphasis is on the accurate assessment of humanitarian needs, partially to be achieved by improving the information exchange between humanitarian responders. The United Nations has organized response in nine "clusters" (ibid.). These clusters represent broad categories of needs during a relief operation and can be divided into *Information needs for responders* (Camp Coordination and Camp Management, Logistics, and Early Recovery and Emergency Telecommunications) and *Relief needs for affected population* (Emergency Shelter, Health, Nutrition, Protection, and Water, Sanitation, and Hygiene).

While it is essential to qualify and quantify these needs for each particular disaster in order to target an effective response, there are other information needs that are as important to set up an efficient response. For instance, the international humanitarian community must be made aware of the disaster through early warning (before the disaster strikes) or alert (immediately after it occurs). Understanding of the size and characteristics of the disaster is equally important for good response. Other information needs relate to particular problems such as tracking missing people and managing volunteers. In particular, in a complex and heterogeneous community such as the international humanitarian community, efficient response can be planned only if it is coordinated. Coordination of response requires a clear situational awareness by the whole community.

Table 13.1 shows the list of information needs for an efficient and effective response. This list stays at a general level, based on the UN clusters, with a focus on situational awareness. Typically, the main sources for such information are:

- The local government, with its local emergency management authority (LEMA): this is the main source for official information on the scale of the disaster.
- The Office for the Coordination of Humanitarian Affairs (OCHA): with the mandate to coordinate humanitarian response, OCHA is the central hub for relief and response information.

Table 13.1

Information Needs and Providers in Humanitarian Response

Task	Information needs	Hazard alert or early warning	Automated impact analysis	Media	Operations coordination center	Local emergency management authorities
Early warning and alert	Assess need for international intervention	**X**		**X**		x
	Determine affected area	**X**	**X**	**X**		x
Situation awareness	Assess incident	**X**	**X**	**X**	**X**	**X**
	Assess affected population		**X**	**X**	**X**	x
	Assess damage		**X**	**X**	**X**	x
	Assess critical infrastructure and key assets		**X**		**X**	x
	Assess indirect or secondary effects		**X**		**X**	x
Provide efficient response	Camp coordination and camp management		x		x	
	Logistics		**X**		x	
	Early recovery		x		x	
	Emergency telecommunications					
Provide relief to affected population	Health (death, injured, need for medical care)		x		x	
	Emergency shelter		x		x	
	Nutrition		x		x	
	Protection				x	
	Water, sanitation, and hygiene				x	

Note: x indicates areas where information is typically available for a particular need (this can vary with disaster type). **Bold Xs** indicate areas that are at least partially covered by the Global Disaster Alert and Coordination System (GDACS).

OCHA sends disaster assessment and coordination (UNDAC) teams to the affected area to collect information, sends search and rescue teams (through the INSARAG network) to rescue affected people, sets up an On-Site Operations Coordination Center (OSOCC) and/or humanitarian information centers (HIC) and disseminates all information through a Web site (ReliefWeb). However, many of these mechanisms are deployed only if needed. This decision requires information from other sources.

- The international media are a rich source of information. However, not everything reported in the media is complete and reliable. Automatic collection and analysis of news (e.g., European Media Monitor, see Best et al., 2005) has the advantage of quantity: many news sources can be processed. Manual collection and analysis of news (e.g., ReliefWeb) has the advantage of quality: the resulting information is more reliable.
- Automated impact analysis is an alternative source of information: after collecting global data sets of sufficient detail on population, vulnerability, key assets and critical infrastructure, transportation lines, and populated places, these data sets can be analyzed and relevant information can be extracted.
- Early warning and alert systems: timely knowledge about the occurrence of a natural hazard is critical and can be provided by geophysical, meteorological, or other measurement systems, optionally combined with a humanitarian impact assessment.

Information systems play an increasing role in producing, handling, storing, or processing information from all of these information sources. The latter two (automated impact analysis and early warning and alert) are fully automatic and, therefore, produce information in near-real time. Media analysis can be automated to a certain extent by information systems that process the wealth of online media sources. But also information that traditionally has been exchanged through telephone, telex, or fax can now be shared through Web-based platforms. GDACS covers aspects of all five information sources for several information needs (as indicated by bold Xs in Table 13.1). This chapter will discuss each in turn.

Impact Equation

To understand the impact of a natural hazard event, it is important to understand the contributing elements. The impact of an event is determined by three independent factors (Schneiderbauer and Ehrlich, 2005): the size of the hazard, the element exposed to the impact (e.g., population or property), and the vulnerability or resilience of that element to the hazard. When one of these elements is nonexistent, the risk or impact is zero. This relation is often expressed as an equation:

$$\mathit{Impact} = \mathit{hazard} \times \mathit{exposure} \times \mathit{vulnerability}$$

Impact is proportional to the size of the hazard and the size of the exposure. The more people in the affected area, the more will be affected. Vulnerability covers both aspects of susceptibility to the hazard (increasing vulnerability) and capacity to cope with the consequences (decreasing vulnerability). When there is population, the disaster will require international intervention only if the local community cannot cope. Coping capacity is an essential element to consider in the context of humanitarian aid. Coping capacity (Schneiderbauer and Ehrlich, 2005) includes local population vulnerability (e.g., quality of housing, income, insurance policies, and family structure) but also resilience built into the society (e.g., civil protection authorities, strong and functioning government, and presence of Red Cross).

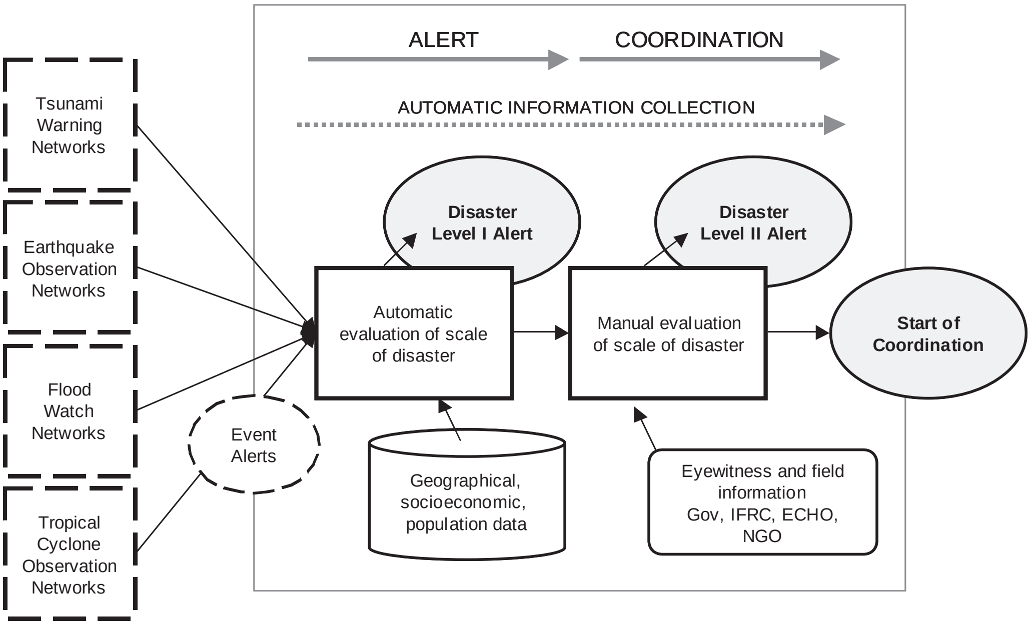
The next section deals with the hazard component. The area affected must be known in sufficient detail to be able to evaluate the impact. The subsequent section deals more with exposure: it describes how a number of elements can be affected by a hazard. Vulnerability, while a critical component in evaluating the impact, will not be discussed in this text.

Near Real-Time Global Disaster Impact Analysis

In practice, a system that performs near real-time impact analysis should be part of a larger system that also integrates the other sources of information of Table 13.1. The typical workflow of such a system is explained in Figure 13.1. Observation networks pass physical parameters of new events immediately to a consequence analysis system. This calculates the likely impact, using geographical, socioeconomic, and demographic databases. A preliminary alert can be sent at this time. Automatic data collection, through scanning of media and targeted Web sites for information on a particular event, can already be started at this time. Next, human experts start evaluating information (through SMS alerts, e-mail reports, and Web applications for sharing information) and fine-tuning the evaluation of likely humanitarian impact. Information from eyewitnesses, and field information from local emergency management agencies or other local organizations is integrated in the information-sharing platform.

One aspect that is not covered in the workflow of Figure 13.1 is the use of impact analyses in the preparedness phase of disaster management. If one defines disaster scenarios, consequence analysis systems can provide valuable input for better preparedness by identifying worst-case scenarios. In this case, the consequence analysis system is used on its own.

Figure 13.1 **Workflow of Near Real-time Disaster Information System**



Note: GOV = National government, IFRC = International Federation of the Red Cross/ Red Crescent, ECHO = European Commission Humanitarian Office, NGO = Nongovernmental Organization.

Standards

Sharing of data between information systems inevitably implies that systems must be interoperable. Interoperability of systems is achieved if the information from one system is correctly ingested in another system, preserving meaning and context. The easiest way to achieve this is through the use of standards for data exchange (allowing other systems to read the data) and data content (allowing other systems to interpret the data).

In many areas, such standards have been developed. The Open Geospatial Consortium (OGC) has worked since 1994 on the development of standards to exchange geospatial information. These are now mature and implemented by most information systems. The W3C consortium's mission is to develop interoperable technologies for the Web, and develop such standards as Web services and XML (Extensible Markup Language). However, now data exchange formats are created continuously and sometimes significantly change the way systems communicate (e.g., Google's KML standard for geospatial information).

Because of the multidisciplinary nature of complex systems, it is not possible to create the perfect standard for information exchange. Rather, systems must be able to deal with many different standards, in order to be interoperable with as many systems as required. This was one conclusion of the Global Symposium 5+ on "Information for Humanitarian Action" (United Nations, 2007).

A good example is the Global Disaster Alert and Coordination System. This system collects information from many organizations. Not all organizations follow the same standards if they follow standards at all. Nevertheless, GDACS is advanced in two aspects:

- First, it "reads" many (standard and nonstandard) formats. For example, for seismological information, it can read RSS (Really Simple Syndication), HTML (HyperText Markup Language), text files, and so on. For tropical cyclones, it reads information from text files, FTP (File Transfer Protocol) sites, and OGC Web Feature Services.
- Second, GDACS publishes information using well-defined standards, therefore turning the heterogeneous input data into homogeneous standard feeds.

Some of the standards used by GDACS are:

- RSS (Really Simple Syndication): a standard developed by the Berkman Center for Internet & Society at Harvard Law School, useful for listing information items (http://cyber.law.harvard.edu/rss/rss.html). GDACS extends the RSS standard with two namespaces for special information: *gdas* for linking information from different organizations and *asgard* for impact assessment information.
- DC (Dublin core): interoperable online metadata standards (http://dublincore.org/).
- OGC Web Mapping Service (WMS), Web Feature Service (WFS) (www.opengeospatial.org/).
- KML (Keyhole Markup Language): a standard developed by Google, but now taken up by OGC. Useful for showing geolocated events on Google Earth or Google Maps (http://code.google.com/apis/kml/).
- ISO three-letter country codes: useful for unambiguous identification of a country (www.iso.org/iso/country_codes.htm).

- CAP (Common Alert Protocol): developed by the Organization for the Advancement of Structured Information Standards (OASIS) and useful for conveying detailed information on disaster events (www.oasis-open.org/committees/download.php/15135/emergency-CAPv1.1-Corrected_DOM.pdf).
- Information is also presented in audio format (MP3 and podcast).

While other systems of systems can use other standards, the importance of using well-defined system interfaces is clear.

EVENT DETECTION: THE CASE OF FLOODS

Hazard Event Detection

Near real-time global disaster impact analysis starts with detecting new or imminent hazard events. Yet, there is no unique global monitoring system for all natural hazards (see Table 13.2). Several scientific communities have developed advanced monitoring systems for particular hazards, but not all hazards are covered yet.

Because seismic energy propagates easily through the Earth's crust, global earthquake monitoring became feasible early on. In 1892, John Milne deployed a first global network of forty seismographs. When technology improved and monitoring of nuclear explosions became an issue, more complete and extensive global seismological networks were deployed. Today, earthquakes—which are also the main source of tsunamis—anywhere in the world are detected, sized, and located geographically within twenty minutes by more than one network, including the United States Geological Survey, the German Geofon system, the European Mediterranean Seismological Centre, Japan's Meteorological Survey, and Russia's EMERCOM.

The same is true for extreme weather events, in particular, tropical cyclones. Coordinated by the World Meteorological Organization, National and Regional Meteorological Centers share information and models to observe and forecast tropical cyclone strength and movement. Deployment of satellite and remote sensing technology and a global telecommunications infrastructure since the 1960s allowed global continuous measurement of such variables as wind speed, humidity, and clouds.

However, for floods and volcanic eruptions there are currently no global networks that provide scientific information. Most large volcanoes have their own observatory, but they do not always

Table 13.2

Existing Event Detection Methodologies for Various Natural Hazards

	Hazard occurrence	Appropriateness for humanitarian relief
Earthquake	Seismological networks	Sufficient, delays less than 20 minutes
Cyclone	World Meteorological Organization Regional specialized meteorological centers	Sufficient, 6-hour advisories with 72-hour forecasts
Volcano	Media monitoring; reports from volcano observatories	No global, consistent, and accurate list of eruptions available
Tsunami	Earthquakes of magnitude 7 and higher occurring underwater	Sufficient for large tele-tsunamis; delay of 20 minutes
Flood	Media monitoring; reports from national authorities	Global list of floods available, but not regularly updated

have a Web page where they publish changes in status, let alone do this in a standard way. The Global Volcanism Program of the Smithsonian Institute produces weekly bulletins based on such information, but does not yet disseminate this information in a standard format. The International Volcano Research Centre maintains a list with daily updates, but also without the use of standards for explosivity, alert level, or magnitude.

For floods, some countries have developed advanced monitoring systems that can even forecast floods up to ten days in advance, while others have no means of monitoring such events. Currently, the most comprehensive global list of floods is maintained by the Dartmouth Flood Observatory (DFO), which, in partnership with JRC, collects information through media monitoring. However, this is not done in a sustainable manner and other systems are needed to provide greater detection of floods.

Developing new monitoring systems does not necessarily mean international treaties, large government financing, and deployment of costly infrastructure globally. The combination of making raw observational data available in near-real time over the Internet and using Web and data standards to serve these data makes it possible to combine such data sources in novel ways to develop new systems. One example is a tsunami warning system: such a system relies on existing earthquake detection systems, combined with knowledge on bathymetry and wave propagation. Another example is described below. The Joint Research Centre and Dartmouth Flood Observatory have jointly developed a global flood detection system, based on data from a satellite that was not designed to detect floods.

Global Flood Detection System

Of all natural disasters, floods are the most frequent (46 percent) and cause the most human suffering and loss (78 percent of the population affected by natural disasters). They occur twice as often and affect about three times as many people as tropical cyclones. While earthquakes kill more people, floods affect more people (20,000 affected per death compared with 150 affected per death for earthquakes) (EM-DAT, 2006). In general, a third of humanitarian aid goes to flood-related disasters and the European Commission alone has spent €36 million on floods since 2002 (excluding funds for the tsunami of 2004).

Nevertheless, emergency responders do not have many information sources at their disposal to learn about flood disasters. Currently, they have to rely on international media or their own global network of colleagues. Most developed countries have reasonably sophisticated flood-prediction systems that are based on models using real-time reporting of extreme precipitation and other surface meteorological variables from in situ, radar, and, in some cases, satellite observations (Bates and De Roo, 2000; Beven and Kirkby, 1979; De Roo et al., 2000; Galland et al., 1991; Horritt and Bates, 2001). Such sophistication does not extend, however, to the developing world. For instance, in the Mozambique floods of 2000, only a handful of precipitation stations in the country were reporting over the World Meterological Organization Global Telecommunication System—a quantity that makes it unfeasible to implement predictive modeling (Lettenmaier et al., 2006).

If floods cannot be forecasted, they may be detected in near-real time. Recent availability of daily satellite observations can provide the means to do so. While the use of sensors in the visible or infrared portion of the spectrum is limited due to cloud cover, the microwave portion of the spectrum can penetrate clouds. Early work on active (Smith, 1997) and passive (Sippel et al., 1994) microwave sensors for flood monitoring could not rely on satellites with daily revisit times. Since 1997 a set of new generation microwave instruments has been launched with improved performance and daily revisit capability. One of these, the Advanced Microwave Scanning Radiometer-Earth Observing System (AMSR-E) instrument onboard the NASA EOS Aqua satellite (launched in 2002) has an extremely efficient data distribution mechanism making the data available for public download only hours after their acquisition. The U.S. National Snow and Ice Data Center (NSIDC) provides preliminary swath data within sixteen to seventy-two hours of acquisition onboard. Since its launch in 2002, researchers have looked at using these data for soil moisture monitoring (Njoku et al., 2003), rainfall monitoring (Hossain and Anagnostou, 2004), and flood forecasting (Bindlish et al., 2004; Lacava et al., 2005), but not flood detection.

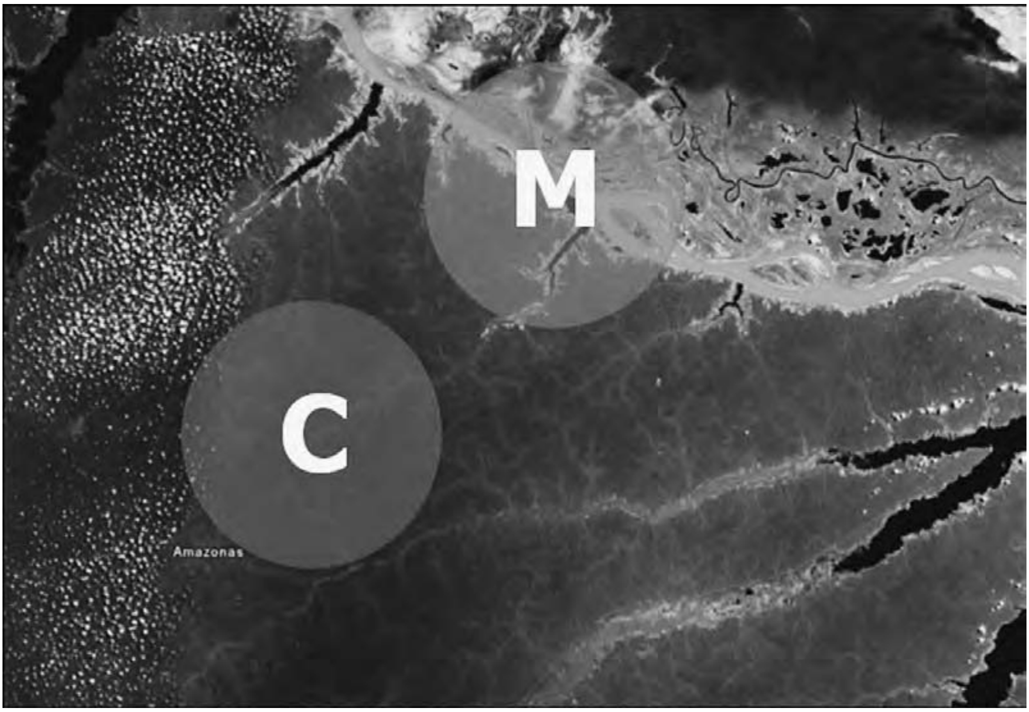
Methodology

In 2005, Brakenridge and colleagues (2005) developed a methodology for daily monitoring of river systems around the globe based on AMSR-E data. The researchers demonstrate that, using a strategy first developed for wide-area optical sensors (Al-Khudhairy et al., 2002; Brakenridge et al., 2007), AMSR-E can measure river discharge changes and river ice status. The methodology uses the 36GHz H-polarization band of the descending (night) orbit of AMSR-E with a footprint size of approximately 8 × 12 km, available in a geolocated level-2A product. The aim of the method is to detect water surface area change or, in other words, observe riverine inundation increase (land cover change) of a flood event from a passive microwave sensor. Due to the different thermal inertia and emission properties of land and water the observed microwave radiation in general accounts for lower brightness temperature values for water and higher for land. This makes it possible to detect inundation change of a river site in a subpixel dimension, since most of the observed river channels are not as wide as the observation footprint. However, in spite of the great radiation dissimilarity of water and land cover, the raw brightness temperature observations cannot be used to reliably detect changes in surface water area. This is because brightness temperature measures are influenced by other factors such as physical temperature, permittivity, surface roughness, and atmospheric moisture. While the relative contribution of these factors cannot be measured, they are assumed to be constant over a larger area. Therefore, by comparing a “wet signal” received over a river channel of a potential inundation location with a “dry signal” without water cover (Figure 13.2), the mentioned noise factors can be reduced. Thus normalization of the wet signal by the dry observation was implemented. The brightness temperature values of the measurement/wet signal were divided by the calibration/dry observations (referred to as the M/C ratio).

The JRC and DFO implemented this principle and automated the methodology on a near real-time basis to monitor the major river sites globally from AMSR-E satellite data. A fully automatic system was set up to download and process satellite imagery. Observation sites over river channels were set up around the globe. The list of sites initially monitored at DFO—about 100 locations—was extended at the JRC to over 2,500 sites along 1,435 rivers in 126 countries. Sites were selected along river channels where large floods occurred in the past four years (according to the flood catalogue of the DFO). Selection was made manually at the DFO, based on historical flood extent maps created from optical satellite images. Calibration pixels were selected to be close to the measurement pixel—to enable the assumption of constant vegetation, soil moisture, and meteorological conditions—but far enough not to be affected by inundation (see also Brakenridge et al., 2007).

To detect flood events from microwave observations, the time series of the given site has to be analyzed. Higher M/C signals generally account for higher discharge values (Brakenridge et al., 2007). Extreme events, or major floods, should represent anomalies in the time series of a given site. However, in order to detect anomalies, the reference value of normal flow must be

Figure 13.2 **Observation Site over the River Amazon in Brazil**

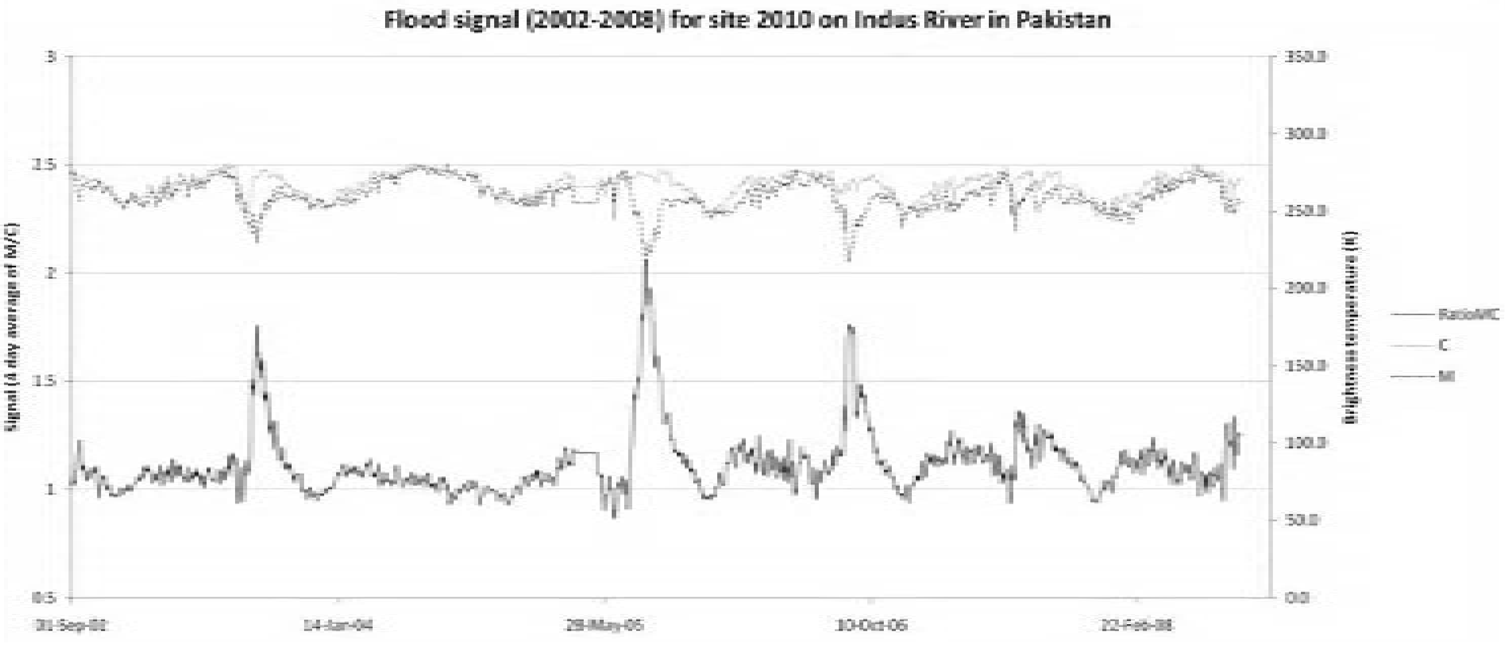


Note: "M" dot refers to the footprint of the "wet" measurement pixel, "C" dot to the "dry" calibration pixel. (Background: Google Earth)

determined first. This reference value was calculated as the average M/C value for the site since the launch of the satellite in 2002. The complete archive of AMSR-E data was downloaded at the JRC and processed according to the described method. Because most sites have been chosen based on the presence of a major flood in the past four years, this time series is sufficiently long to represent normal flow and flood hydrological conditions. On the other hand, this time series is not long enough to correctly identify the recurrence interval of floods for these sites or to determine the hydrological status in other areas where no major floods have occurred in the past four years. Flood level thresholds were then calculated for each site based on the statistics of the time series: a major flooding event is defined as a signal in the 95th percentile (more than 2 standard deviations from the mean) of the cumulative histogram.

Site 2010 on the Indus River (Figure 13.3) in Pakistan is a good example of the procedure of the Global Flood Detection System (GFDS). Figure 13.4 shows the signal retrieved from the AMSR-E images since 2002. The dry signal (c) varies over time due to, among other influences, temperature and atmospheric vapor changes. The wet signal (m) is subject to the same variations, but is also sensitive to changes in water surface. In the event of a flood, the wet signal drops significantly below the dry signal. The ratio of M and C represents the water surface changes, which is also strongly correlated to the discharge in the river channel. When a certain threshold (95th percentile) is exceeded, we assume that water gets over the bank, flooding the surrounding area. This happened three times (August 2003, 2005, and 2006) in the past four years for the given site

Figure 13.3 **Example of Time Series for Site 2010 on the Indus River in Pakistan**



Notes: M = measurement brightness temperature; C = calibration brightness temperature.

Figure 13.4 **Number of Days the Signal Exceeded the 95th percentile, per month, for site 2010**

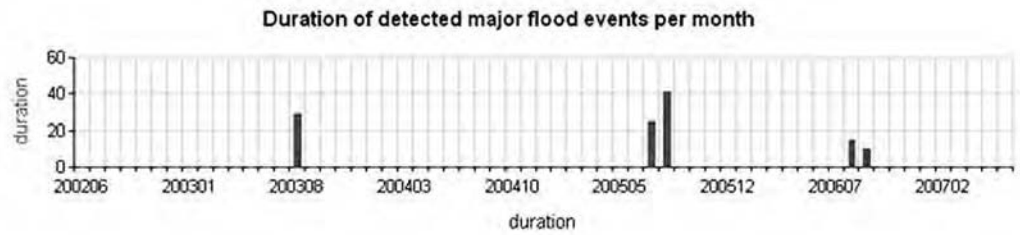
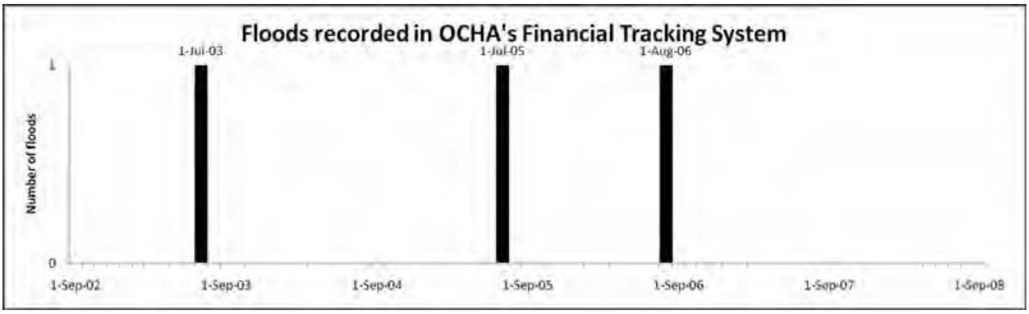


Figure 13.5 **Floods in Pakistan for Which Humanitarian Aid Was Delivered**



Note: As recorded in the Financial Tracking System of OCHA. There is clear correspondence to the detected floods.

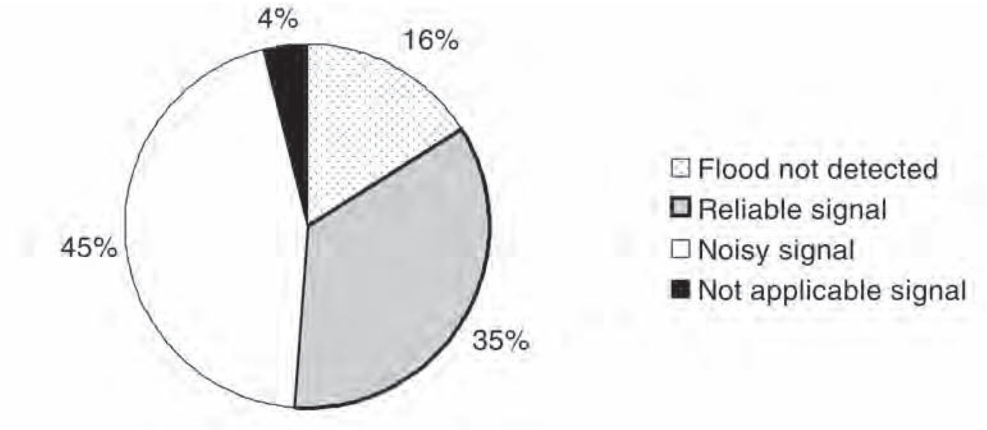
along the Indus River (Figure 13.4). These were major floods for which humanitarian aid was delivered according to the Financial Tracking System of OCHA, confirming the remotely detected events (Figure 13.5).

Results and Discussion

The reliability of hazard detection systems is extremely important. Emergency responders can base their decisions only on information they can trust. In the case of flood alerts, all major floods should be detected, while the false alarms should be minimized. Inevitably, there will be situations where high ratio values result from conditions other than major floods, but the methodology should be designed to minimize those (e.g., using filtering techniques). The system as a whole can cause errors when one of the components is not working (e.g., when the Internet connection fails, there are delays in the publishing of satellite data, or there are software or hardware failures). In all other cases, the methodology should be robust enough to provide correct results. However, not all sites provide a useful signal. Depending on local site characteristics (e.g., topography, wetland, vegetation cover), a signal may be very noisy. This can also happen when the calibration site is too far from the measurement site. Signals for such sites cannot be used for reliable flood detection. These sites must be eliminated from the system or otherwise improved. Further, the 2,500 sites do not cover all river basins in the world. In order to avoid omission of major floods, additional sites must be included in the system.

In order to validate all 2,500 sites for correct performance, two different approaches were considered. In a first approach, the GFDS flood events can be compared with flood events recorded in flood catalogues or databases. GFDS will perform well if all major floods were detected and all

Figure 13.6 **Result of the Manual Validation Process**



Note: Eighty percent of the sites are detecting flood events. However, for 45 percent the performance can be improved by reducing noise levels.

detected floods really occurred. This was done by comparing flood events (per month) with floods in the same country and the same month recorded in at least one of four flood databases (DFO Archive, EM-DAT [2005], GLIDE Number, and OCHA's Financial Tracking System). Because the data in the databases were not recorded in a similar way and often cannot be located below country level, matching records provide only indicative evidence. Yet, 80 percent of the known flood events from databases are observed with GFDS, which indicates that certain areas of the world are not covered sufficiently by the 2,500 existing sites. However, for only 20 percent of GFDS flood alerts was there evidence in one or more of the flood databases that the flood actually occurred. While inconclusive, this might indicate either that the flood databases are incomplete or that the thresholds for major flood in GFDS are low.

A second approach to verify the performance of the GFDS is to analyze in detail a limited number of major floods. For this, the ten biggest floods of each year since 2002 were selected (based on the humanitarian impact in terms of the number of people killed, the estimated costs of damages, and the area of the inundation). For each flood, all sites on the affected river basin were analyzed together. When available, arrival times of the flood wave were considered. As a result, 80 percent of sites observe floods reliably, about 35 percent with a very low level of noise. In these cases the normal flow conditions refer to a stable low signal with low or medium standard deviation. In case of a flood event the signal peaks by a sudden change with more than 1.5 standard deviation of the normal conditions. These sites are performing well to provide a physical measurement for flow conditions. The remaining 20 percent of the sites either are not detecting the given events or their signal is too noisy to be relied on, a result in agreement with the first approach (Figure 13.6).

Another aspect of the GFDS is the delay in detecting floods. Only if flood events can be detected in a timely fashion will the GFDS contribute to better humanitarian relief. Humanitarian aid for floods needs to be delivered after several days. Typical aid is in the form of food, shelter, and medical aid. Most urgent in case of flooding is the provision of uncontaminated drinking water, which should happen in the first twenty-four hours after the flooding (OCHA, 2006b). In spite of these urgent needs, international humanitarian aid is more often than not requested only after several days or even weeks (Kugler, 2003). Countries are often hesitant to request international assistance for internal political factors or in fear of being perceived as unable to handle their internal affairs

(Boyd, 2003; Stoddard, 2004). The relevant time frame for flood information for the humanitarian community is therefore on the order of days. The GFDS can detect floods on average twenty-four hours after image acquisition, which is sufficient for humanitarian use.

Based on these results, the GFDS must be further improved before it can reliably provide global flood detection. In particular, underperforming sites must be eliminated and sites must be added in river basins that are currently not monitored. However, a prototype version of the flood detection system is already available online (see www.gdacs.org/floods/). Data for individual sites can be queried in the form of tables and graphs. Their geographical location is visualized on maps. The main page contains all alerts issued for the current day, compared with information about flood disasters from other sources, including the automatic news filtering of EMM (Europe Media Monitor; http://emm.jrc.it), the DFO's manual news scraping, and the global satellite precipitation estimates of the Global Flood Alert System (GFAS; http://gfas.internationalfloodnetwork.org).

HAZARD MODELING: TSUNAMI PROPAGATION

Hazard Modeling

When a hazard occurs, its impact depends largely on who and what are present in the affected area. However, the impact is not uniform in the affected area. For earthquakes, zones near the epicenter experience more damage than zones that are farther away. The intensity of shaking is a continuous field with its maximum near the epicenter. This field can be described in certain detail, given knowledge of the local fault geometry, orography, geology, and soil (Wald et al., 1999). In the case of floods, the affected area can be clearly defined (i.e., the flooded area), although it is very difficult to measure. Not only is the flooded area not a continuous area, but it also changes with the propagation of the flood wave and rainfall. Even then, impact will depend on the water surface elevation, which is not uniform over the flooded area. While the flooded area can be modeled theoretically (e.g., Bates and De Roo, 2000; Chow, 1959), this is not possible in practice due to the need for detailed topographical, meteorological, and hydrographic data. For volcanoes, the affected area depends on the type of eruption (lava flow, ash clouds, lahars, etc.) and is in some cases determined by meteorological conditions (e.g., wind speed and direction) and in others by the geometry of the volcano slopes. Similarly, tropical cyclones impact a coastal zone with high winds, storm surge, and extreme rainfall, and by spawning tornadoes. The area affected by each effect can be modeled based on the characteristics of the storm (e.g., Holland [1980] and Knaff and DeMaria [2006] for wind speed, and Turk et al. [2003] for rainfall).

In most cases, hazard modeling requires a lot of precise data about the characteristics of the hazard. In practice, for real-time monitoring, only very limited data are available. Typically, earthquakes are approximated as a point source, while in reality fault ruptures can extend hundreds of kilometers. And even then, the uncertainty associated with this point source is significant (in particular, for the depth). Cyclones are characterized by a central pressure and a maximum wind speed, which do not describe the asymmetric vortex in detail. Location of floods is often only described textually by the province or district name.

The challenge for near real-time hazard modeling is to determine an affected area given only a few parameters of the hazard. One of the simplest methods is to assume a circular area around the hazard with a radius that is representative for an average hazard. However, for most hazards better models are already available (Table 13.3).

As an example, we describe a tsunami propagation model we developed for GDACS, which calculates the affected coastline (including arrival times and wave heights) using only an earthquake magnitude, major fault lines, and ocean bathymetry.

Table 13.3

Some Methods to Determine the Affected Area of Natural Hazards

	Determine affected area
Earthquake	Fixed radius of 100 km around epicenter Intensity modeling (e.g., Wald et al., 1999)
Cyclone	Fixed radius of 200 km around track points Wind radii from infrared imagery (e.g., Knaff and DeMaria, 2006) Wind field modeling (e.g., Holland, 1980) Tropical Rainfall Potential TRaP (Turk et al., 2003)
Volcano	Fixed radius around volcano Eruption modeling Ash cloud observed from infrared satellite data (e.g., Rose et al., 2000)
Tsunami	Wave propagation and height modeling (see below)
Flood	Media monitoring
	Satellite observations (interpretation of near real-time MODIS* images)

*Moderate Resolution Imaging Spectroradiometer.

Tsunami Wave Propagation

Tsunamis are large waves caused by, among other sources, underwater earthquakes. They can be local (affecting only the nearest coast) or tele-tsunamis, which affect all land on the ocean’s basin (sometimes up to 8,000 km away). Damage is caused by the huge mass of water behind the initial wave front, flooding the coastal area and destroying buildings by the speed of the flow. The area affected by a tsunami comprises all coastal areas where the wave arrived up to a certain height.

The actual height of a tsunami wave in open water is often less than one meter. The energy of a tsunami passes through the entire water column to the seabed, unlike surface waves, which typically reach down to a depth of only several meters. The wave travels across the ocean at speeds from 500 to 1,000 km/h. As the wave approaches land, the sea shallows, with two effects: the wave slows down and the wavefront becomes steeper and taller.

In the aftermath of the 2004 Boxing Day Tsunami, the JRC developed a model for the evaluation of the wave propagation time of a hypothetical tsunami (Annunziato, 2005). The model was published in May 2005 and further integrated in GDACS, enabling GDACS to alert for tsunamis and anticipate the wave arrival time in case of a large earthquake. Next, the JRC developed a second model for the tsunami wave height (Annunziato, 2006). This model was integrated in GDACS in May 2007 and provides, among other information, detailed maps of the affected area.

Methodology

In case of a tsunamogenic earthquake, the following mechanisms occur:

1. Subsidence fault movements can result in raising part of the earth and lowering the opposite section (a seismic horizontal movement does not generally determine a tsunami).
2. The water above the fault rises accordingly (slip).

3. A pulse wave is generated.
4. The wave may travel thousands of kilometers in the ocean, reducing its height due to energy distribution on a larger surface. Focusing mechanisms, due to reflections of the bathymetry or of the coasts, may influence the wave height.
5. An increase of the height (shoaling effect) and a reduction in width and speed occur as the tsunami approaches the shore.

Therefore, the tsunami wave prediction model must perform the following tasks: (a) evaluate the earth deformation caused by the earthquake and impose an initial water displacement as initial condition of the calculation, (b) calculate water wave movement, and (c) evaluate arrival times and water heights. Further constraints are that the calculation time must be minimal in order to produce information in a timely fashion for emergency response.

Earth deformation and initial water displacement: The knowledge of the fault length and orientation allows avoidance of a point source approximation. In the case of the 2004 Boxing Day Tsunami, this had a great influence because the calculations performed with the earthquake epicenter were very different from the real case in which a 1,000 km fault caused a much-focused propagation and different travel times. Ambrassey and Douglas (2003) demonstrated a relation between the fault length (L) and the magnitude of the earthquake (M_w) of the form log $L = A \cdot M_w + B$. Parameters A and B have been measured for many earthquakes and described in the literature. We adopt the values, proposed by Ward (2002), that are most suitable for strong earthquakes. For the orientation of the fault, we assume that the fault will be aligned along the nearest tectonic plate boundary. The program searches for the orientation of the nearest major fault line and assumes parallel orientation for the tsunami fault. Along the fault, an increase of the water level occurs. The level increase is proportional to the fault length. Ward proposes a simple expression for the water level increase (slip) as $D_u = 2\ 10_{-5}$ L, with D_u in km.

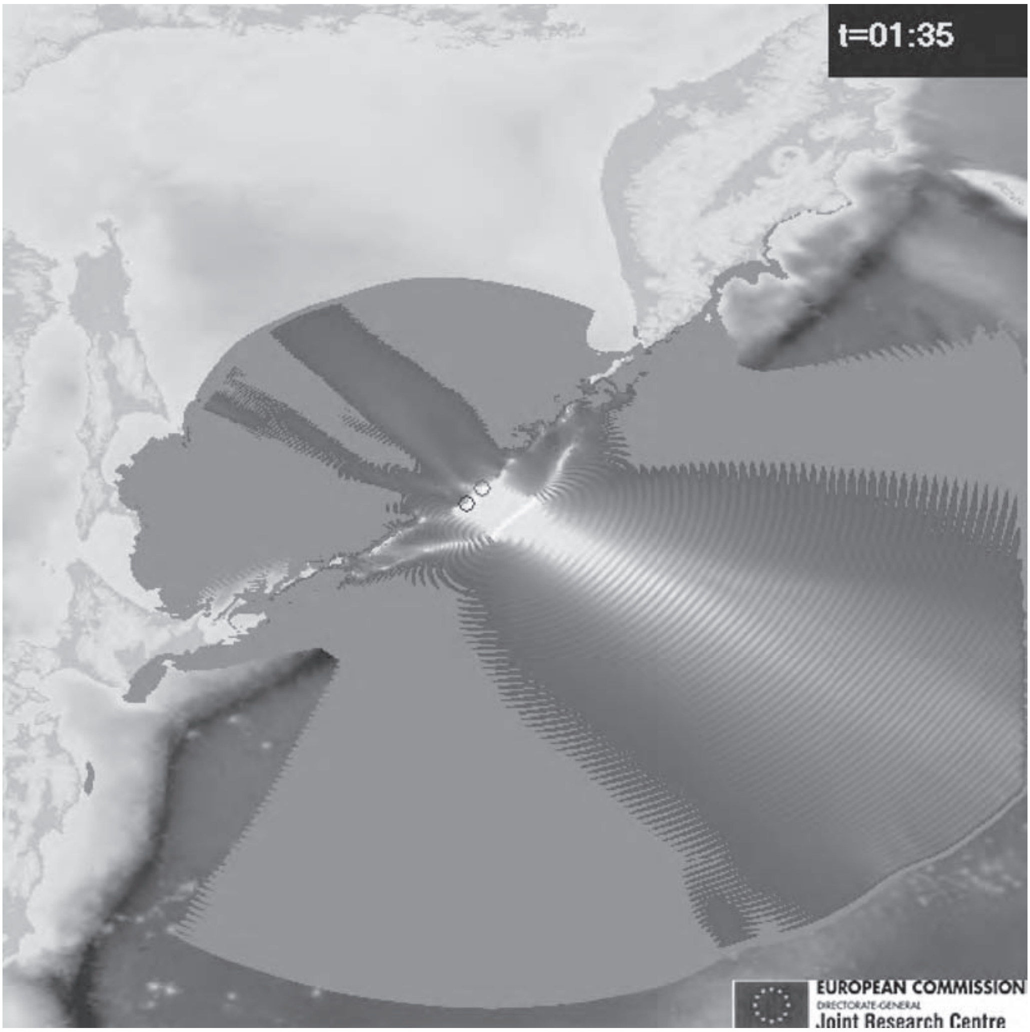
Tsunami propagation in the ocean: Tsunami propagation is described by shallow water equations. These were modeled numerically by Mader (2004) into the SWAN code. The model uses the mass and momentum conservation equations in two dimensions, with the approximation of constant velocity along the height. This theory is valid when the ratio of wavelength over the water depth is low. Assuming a maximum water depth of 4 km, this condition holds for tsunamis with wavelengths over 40 km (i.e., a ratio of 10). The mass conservation equation is:

$$\frac{\partial H}{\partial t}+\frac{\partial[(D+H)U_x]}{\partial x}+\frac{\partial[(D+H)U_y]}{\partial y}=0 \tag{1}$$

and the momentum conservation equations are:

$$\begin{aligned}\frac{\partial U_x}{\partial t}+U_x\frac{\partial U_x}{\partial x}+U_y\frac{\partial U_y}{\partial y}-FU_y+g\frac{\partial H}{\partial x}&=-\frac{1}{\rho}\frac{\partial P}{\partial x}+A^{(x)}\\ \frac{\partial U_y}{\partial t}+U_x\frac{\partial U_x}{\partial x}+U_y\frac{\partial U_y}{\partial y}+FU_x+g\frac{\partial H}{\partial y}&=-\frac{1}{\rho}\frac{\partial P}{\partial y}+A^{(y)}\end{aligned} \tag{2}$$

Figure 13.7 **Maximum Wave Height for November 15, 2006 Tsunami in the Kuril Islands**



Note: As calculated by JRC SWAN model. Model results were consistent with Japanese gauging measurements.

Where *D* is the water depth (underwater is positive depth, mountains are negative depths), *H* is the local water level, U_x and U_y are the velocities in the two directions, *P* is the pressure derivative, which is expressed as water level difference, and *A* contains tide-generating forces.

The above equations are integrated over control volumes, and finite difference equations are obtained. The original code by Mader in Fortran has been rewritten in *C* and integrated with a Visual Basic driver into the SWAN-JRC code. The integration grid is obtained by the available bathymetry. Typically, a tsunami propagation analysis is performed with a bathymetry grid of 20 min (36 km at the equator); local analyses are calculated with 2 min (3.6 km). Run-up calculations, to evaluate the flooding extent, need to be performed with even higher resolutions (i.e., 150–200 m, or 4.5 to 6 sec).

Evaluation arrival times and wave heights: Using geographic information system (GIS) data on coastlines, cities, and their populations, the SWAN-JRC code lists arrival times and wave heights for each city. This information is published progressively during the calculation (Figure 13.7 shows an example).

Results and Discussion

The JRC tsunami propagation model is an integral part of GDACS alerts. It has been validated with historical tsunamis and recent tsunamis, with gauging measurements if available. Because the running time is limited to thirty minutes and the necessary input parameters are available from seismological networks in real time, the model is appropriate for real-time emergency management.

IMPACT MODELING: EXAMPLES FROM GDACS

While the ultimate assessment of needs is done through the local government or through international assessment teams (e.g., UNDAC), geographic information systems can contribute to estimating such needs on a near real-time basis. This is possible because consequences of natural hazards are determined mostly by local factors, which can be stored and processed in GIS. For instance, absence of human population and infrastructure will determine whether a hazard event is of relevance to the humanitarian community. A typical entry strategy for an international organization always requires a certain number of casualties or affected people (ECHO, 2004). Therefore, one straightforward way to eliminate irrelevant hazard events is by comparing the affected area with local population density. When there is population (see Table 13.4 for data sources), the disaster will require international intervention only if the local community cannot cope. Coping capacity is an essential element to consider in the context of humanitarian aid.

A disaster affects population through direct damage (e.g., destroyed shelter), indirect damage (through secondary effects such as landslides after earthquakes or inundation after tropical cyclones), direct socioeconomic losses (loss of family or job), and indirect socioeconomic losses. In most cases, modeling of damage and losses requires detailed information on census, building stocks, and local business and industry, which is becoming available on a continental scale (e.g. in the HAZUS-MH system for North America, FEMA, 2006), but not yet on a global scale.

However, knowledge of exact consequences of a disaster is not necessary to estimate the overall humanitarian impact. Humanitarian needs for earthquakes—as well as for other disasters—are generally proportional to the population (Gutierrez et al., 2005). The denser the population, the more shelter and transportation infrastructure there is. Statistical models using the event magnitude, the affected population, and the vulnerability of the population are able to predict the level of expected humanitarian needs (De Groeve and Eriksson, 2005; De Groeve et al., 2006).

With the currently available global data sets, it is not possible to have a detailed and accurate assessment of disaster consequences and humanitarian needs, as it is possible on a national scale in certain countries (FEMA, 2006). However, global geographical databases are becoming available on an increasingly larger scale, provided by research organizations, government organizations, or international organizations. With every new global data set, new aspects of consequence models can be implemented.

In spite of this strong data dependence, relevant information can be extracted from the currently available global data sets (Peduzzi and Herold, 2005). Even if information on potential consequences can have low confidence (such as the probability of a dam burst after an earthquake),

Table 13.4

Data Sources for Affected Population

	Sources	Methodological notes	EQ	TS	TC	VO	FL
Population density (raster)	LandScan (Bhaduri et al., 2002), GPW (CIESIN, 2005)	If the affected area is defined as a polygon, the values of the pixels within the affected area can be added. The total number of people affected is required, for instance, to estimate the overall impact.	X		X	X	
Cities	Meridian World Data, Global Discovery (Europa Technologies), ESRI World2006	Cities (and their populations) are more useful for time-dependent disasters such as tropical cyclones and tsunamis where arrival times vary.		X	X		
Administrative boundaries	Meridian World Data, Global Discovery (Europa Technologies), ESRI World2006	If the affected area is not well defined, the population at higher administrative level (provinces, regions) can be used.					X
Hotels	Meridian World Data	In case of coastal disasters (tsunami, tropical cyclone) the tourist population must be considered.		X	X		
Media	EMM (JRC; Best et al., 2005)	When the affected area is unknown, media reports can be used to estimate the population affected.					X

Note: EQ = earthquake, TS = tsunami, TC = tropical cyclone, VO = volcano, FL = flood.

Table 13.5

Consequence Analyses in GDACS

	Earthquake	Cyclone	Volcano, tsunami, flood
Assess critical infrastructure and key assets	Neighborhood analysis of global data sets Datasets available on nuclear plants, hydrodams, airports, ports, etc.		
Assess indirect and secondary effects	Tsunamis Landslides: report on slopes in affected area (from *digital elevation models*, e.g., SRTM, Werner, 2001)	Damage to agriculture by flooding: report on land use in affected area (from *global land cover*, e.g., GLC2000, Bartholomé and Belward, 2005)	—
Provide information for logistics	Neighborhood analysis of transport-related global data sets Data sets available on roads, airports, ports		

Table 13.6

Data Sources for Critical Infrastructure

	Sources
Nuclear plants	Joint Research Center, International Atomic Energy Agency, World Association of Nuclear Operators, International Nuclear Safety Center
Airports, ports, hydro dams, chemical plants, energy infrastructure	Meridian World Data, Global Discovery (Europa Technologies), ESRI World2006

Note: If the affected area is well defined, the critical infrastructure within it can be listed.

information on the absence of consequences can have high confidence (no dam burst because there are no dams in the affected area). Knowledge about potential factors that can complicate intervention is very relevant for planning response.

Table 13.5 shows the current consequence analyses provided by GDACS. A geographical analysis of the affected area (which is either obtained from a data source or modeled) can offer valuable information for (1) evaluating potential damage to critical infrastructure and key assets (Table 13.6), and (2) logistics through the transportation network (Table 13.7).

Moreover, the likelihood of disaster-specific secondary effects can be assessed based on the presence or absence of critical conditions. For instance, landslides cannot occur without slopes and tsunamis cannot occur above water. Indirect socioeconomic effects of the disaster can also be estimated to a certain extent through geographical analysis: for example, floods can cause crop loss only in areas with significant agricultural areas (Table 13.8).

It must be clear that the information that can be provided by automated consequence analysis will rapidly gain in importance in the coming years. New technology (such as new satellite sensors) and software (such as Google Earth) allow the collection of more and more detailed data sets either through direct measurement or as a community effort.

Table 13.7

Data Sources for Logistics

	Sources	Methodology notes
Airports and roads	Meridian World Data, Global Discovery (Europa Technologies), ESRI World2006	In particular, transport infrastructure outside the affected area is of interest. Airports outside the affected area are likely to function. However, information on transport infrastructure inside the affected area is also necessary.
Hospitals	Meridian World Data	Available hospitals are important to organize the rescue of the injured.
Weather	Climate Prediction Center/NOAA*	Local weather forecasts are important to organize response and relief delivery (e.g., need of shelter).
Other	ReliefWeb travel documents, CIA Factbook	It is also important to know the updated political, social, and economic situation of the affected country/countries.

*National Oceanic and Atmospheric Administration.

Table 13.8

Data Sources for Modeling Potential Secondary Effects

	Sources	Methodology notes	Disaster type
Digital Elevation Model (DEM)	GTOP030 (United States Geological Survey), Shuttle Radar Topography Mission (NASA)	The maximum slope of the affected area can be retrieved from the DEM. If the maximum slope is high (more than 60%), the risk of hazard-induced landslides is high.	Earthquake, cyclone, and volcano
Land Cover	GLC2000 (Global Land Cover) (Joint Research Centre of the European Commission)	Agriculture-related land cover in the affected area can indicate economic losses, in particular, for flood-related events.	Cyclone and flood

OTHER INFORMATION TOOLS FOR SITUATIONAL AWARENESS

Media and Open Content Monitoring

Besides hazard detection and impact assessment systems, the international media are a rich source of information in the immediate aftermath of a disaster. This can be seen in the large sense as any information that is published relevant to the disaster, including scientific data and expert reports. Information systems, such as GDACS, can be automatically configured to collect such information from the Internet.

When a new disaster is detected by GDACS, the system starts a targeted collection of media reports using a direct interface with the European Media Monitor (Best et al., 2005), an online newspaper-scanning system developed at the JRC. This information is dynamically published on the GDACS Web site and in GDACS reports. In addition, GDACS collects specialized humanitarian information sources from partner organizations, including ReliefWeb news and situation reports and UNOSAT maps.

Depending on the disaster type, different organizations provide scientific data or expert information that is of use for response planning. Automated collection of this information and dissemination through a single Web site increases the efficiency response. Examples of such information collected by the GDACS system include earthquake intensity maps (ShakeMaps) from the United States Geological Survey, near real-time flood extent maps from the Dartmouth Flood Observatory, and earthquake mortality estimates from the World Agency for Planetary Monitoring and Earthquake Risk Reduction.

In particular, for scientific information and expert reports it is important to present only information that is relevant to a given disaster. Even if the definition of "disaster" varies widely in different professional disciplines, there is currently a de facto standard for identification of disasters that is used in GDACS and by GDACS partners to relate information. This standard is the GLIDE number, a globally common unique ID code for disasters (Tschoegl et al., 2006).

Operations Coordination Center

Computer systems cannot predict the detailed consequences of a disaster. The most important information on the situation must come from observations of the affected area. Since OCHA has the mandate to coordinate international relief, it is the information hub between the many organizations involved in a response (including aid donors, international NGOs, local relief workers, and the local emergency management authorities). In response to a growing need for structured information exchange between first responders in an international humanitarian disaster, OCHA developed the Virtual On-Site Operations Coordination Centre (Virtual OSOCC). The Virtual OSOCC is an online information exchange and coordination tool for disaster managers and international response organizations. It is used by responders during major disasters to exchange information in order to facilitate their decision making for international assistance. Since 2006, the Virtual OSOCC has been integrated into the Global Disaster Alert and Coordination System.

By combining both automatically collected and modeled information (available before or immediately after a disaster strikes) with field-based information from responders (typically available hours after the disaster), GDACS is able to fill the critical information gap at the onset of the disaster before an OSOCC has been set up in the affected area.

In some cases the professional response community continues to use GDACS after the establishment of an OSOCC as a private platform to exchange unofficial information. It is an alternative source of information for needs assessment and response planning, besides other OCHA information tools including ReliefWeb (dissemination OCHA Situation Reports) or, for large disasters, a Humanitarian Information Centre in the affected area.

Local Emergency Management Authorities

Last but not least there are the local emergency management authorities. Unless the disaster has disrupted the local chain of information, the LEMA has the means to obtain the most reliable information on disaster consequences and relief needs. Thanks to targeted promotion and training by OCHA, LEMAs are increasingly being included in GDACS. This is extremely important for an efficient and effective response from the international community. Not only can LEMAs provide critical information to the international community, but they can also be aware of what relief is available and is being deployed.

SUMMARY

Any global near real-time all-hazard disaster impact analysis system cannot be other than a system of systems. The many scientific disciplines involved, the sensor infrastructure to be deployed and maintained, the computing power necessary to run complex models, and the manpower to keep everything operational cannot be provided by a single organization.

Rather, a global all-hazard system is one that is able to collect or calculate, in near-real time, information that is relevant for humanitarian actors. More and more observational data are being published online in a timely fashion using open standards. Global data are not always provided by a single specialized provider, such as the space industry. Data can also be provided by many local observatories or individual people, each publishing a small part of data in open and common standards. The latter model might be appropriate for volcano observatories or landslide monitoring. While systems that relied on remote data sources were traditionally vulnerable to network problems, the Internet is becoming more reliable with ever-increasing bandwidth. The combination of reliable networks and increasing availability of data opens the way to develop new hazard detection systems based on novel uses of existing data sources that were not originally intended by the data providers.

Of critical importance in such a design is the use of standards: standards for data content, standards for data exchange, standards for quality control, and standards for system availability. Many standards are emerging (such as RSS for data exchange, Common Alert Protocol or CAP for alert messages, GLIDE numbers for disaster identification, and geographical information standards as developed by the Open Geospatial Consortium), and GDACS proves that systems of systems can be built.

Currently, global hazard consequence analysis is still very much limited by data availability. There are sophisticated models waiting to be deployed once new data sets are available. For instance, when a global dataset of buildings becomes available (and it will with the development of automated feature extraction algorithms for very high resolution imagery), existing earthquake impact models developed by the earthquake engineering community can be applied globally, resulting in much better estimates of damage and injured and killed people. Another limiting factor in near real-time hazard modeling is the lack of data on the initial conditions. With developments in observation technology and Internet technology to better disseminate such information, more complex models can be applied. Moreover, computing power increases yearly, allowing more computing-intensive models to be deployed in a time critical system.

Many new data sets and information products are produced by research groups all over the world. It can be expected that information for humanitarian response to natural disasters will only improve and thereby contribute to more effective humanitarian assistance.

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CHAPTER 14

TOWARD STANDARDS-BASED RESOURCE MANAGEMENT SYSTEMS FOR EMERGENCY MANAGEMENT

KAREN HENRICKSEN AND RENATO IANNELLA

Abstract: *A key challenge in emergency management is the efficient management of resources—both human (e.g., response teams) and material (e.g., tents and food supplies). A large-scale event such as a cyclone/hurricane, earthquake, or tsunami can potentially involve tens of thousands (or more) of resource requests and offers. Sophisticated information systems are required for managing the necessary information exchanges between resource requesters, owners, coordinating agencies, and other parties, and for tracking the status of deployed resources. These systems must be scalable and support cross-organizational cooperation. To meet these requirements, they should ideally be based on open standards that allow interoperation between different resource management system (RMS) implementations, as well as interoperation and integration with other types of emergency management software. While some of the software systems already in use within the emergency sector do provide support for selected resource management tasks, open standards-based software for resource management does not yet exist. This chapter reviews the current state of the art in software for resource management, provides an overview of the Resource Messaging standard under development within the Organization for the Advancement of Structured Information Standards (OASIS) standards organization, and introduces a prototypical RMS that we are developing based on this emerging standard.*

Keywords: *Resource Management System, Emergency Information Standards*

Emergency management hinges on successful management of resources—both human and material. Regardless of the scale of incident, resource management generally spans multiple agencies and organizations, and requires basic agreements and protocols between these parties to be in place. A small traffic incident may require resources from police, fire, and ambulance departments, while a large-scale natural disaster such as a cyclone may require involvement from local, state, and federal government departments, volunteer organizations, critical infrastructure providers, and so on. In the latter case, the number of resources deployed over the response and recovery phases can easily number in the tens of thousands (or more).

Resource management is a term that can apply at any stage of incident management and includes:

- *pre-incident:* creating and managing resource inventories; mobilizing resources in preparation for anticipated disasters such as cyclones/hurricanes;

- *during response/recovery:* requesting, dispatching, and tracking resources; managing resource offers/donations;
- *during and post response/recovery:* deactivating and recalling resources.

For routine, small-scale incidents such as traffic accidents, the protocols governing these tasks are generally well established and corresponding information and communication technology (ICT) support (e.g., computer systems for dispatching and tracking ambulance and fire crews) is in place. However, resource management for large-scale incidents often happens in a more ad hoc and unstructured fashion, and is less well supported by ICT systems. It is not uncommon for resource inventories to be tracked during emergencies using improvised tools such as whiteboards and spreadsheets; nor is it unusual for resource requests to be exchanged via telephone, e-mail, radio, and fax, with no easy means of tracking and coordinating the requests (Iannella and Henricksen, 2007). Following recent large-scale natural disasters such as Hurricane Katrina in the United States and Cyclone Larry in Australia, it is increasingly being recognized that better ICT systems are required. As large-scale events require the involvement of many organizations, these ICT systems must be scalable, and must be able to coexist with a wide variety of existing policies, procedures, and systems—including operational policies and procedures, as well as organizations' ICT security policies and legacy software. Open standards that support interoperability will therefore play an important role in the success of future ICT systems for emergency management.

This chapter reports on progress toward developing standards-based ICT systems that will support resource management for emergencies, with an emphasis on the requirements of large-scale events (although these systems will also be applicable to smaller events). We view a resource management system (abbreviated RMS in this chapter) as a crucial component of a larger crisis information management system (CIMS). As we discuss in Iannella and Henricksen (2007), we regard a CIMS as an ICT system that aims to "deliver the right information to the right people in the right format in the right place at the right time." In addition to resource management, a CIMS may support diverse functions such as situational awareness, notification/alerting, document management, and financial management (Iannella et al., 2007).

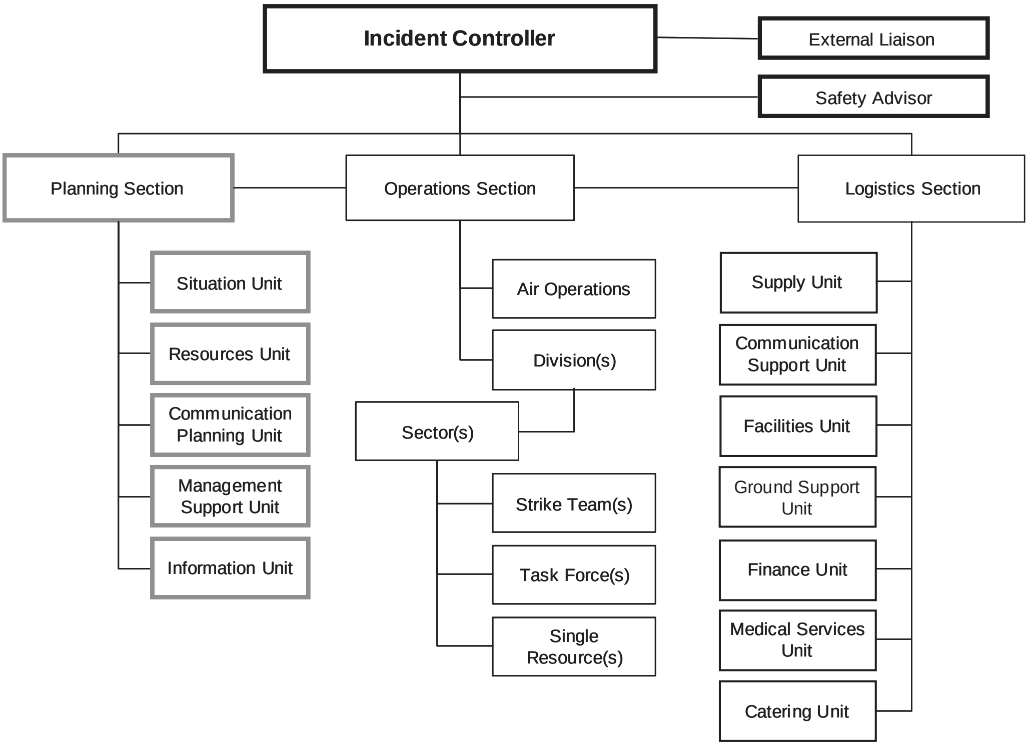
The chapter begins with an overview of current emergency management practices and frameworks in Australia and the United States, and also gives an overview of the current state of the art in ICT support for resource management, focusing on commercial product offerings in the CIMS space (to our knowledge, there are currently no examples of dedicated RMS software). After setting the current context, the chapter proposes some requirements for the development of future CIMS/RMS software.

As part of the *Organization for the Advancement of Structured Information Standards (*OASIS) Emergency Management Technical Committee (TC), we have been involved in the development of information standards for use in the emergency sector, including the recent development of a language for exchange of resource messages such as requests, requisitions, offers, and returns (EDXL Resource Messaging) (OASIS, 2007a). We present an overview of this language, followed by a discussion of a proposed RMS based on the standard. Finally, we discuss a set of open challenges and future directions for this area.

CURRENT EMERGENCY MANAGEMENT PRACTICES AND FRAMEWORKS IN AUSTRALIA AND THE UNITED STATES

Emergency management practices, including resource management practices, are governed in Australia by the Australian Inter-service Incident Management System (AIIMS) (Australasian Fire

Figure 14.1 **AIIMS Structure**



Source: Adapted from Australasian Fire Authority Council (2004).

Authority Council, 2004) and in the United States by the National Incident Management System (NIMS) (U.S. DHS, 2004a). As AIIMS was originally based on NIMS, there are many similarities. Both describe structured “command, control, and coordination” frameworks that facilitate cross-organizational cooperation by describing common roles, concepts, and processes for incident management. In NIMS, this command, control, and coordination structure is called the Incident Command System (ICS). Both ICS and the corresponding AIIMS control structure describe the relationships between the key roles/sections in incident management, including incident command/control/coordination, logistics, planning, and operations. Depending on the scale of the incident, there may be one or more people acting in each of these roles as well as a number of people responsible for support functions such as situation assessment, communication planning, and management support. Figure 14.1 shows the AIIMS control structure.

In this structure (and similarly in ICS), the resource management functions are distributed across the three main sections—planning, operations, and logistics. The planning section (or more specifically, its resources unit) is responsible for establishing a Resource Management System,[1] for tracking resources allocated to the incident, with support from the logistics section. This involves maintaining information about where resources are located and their status (allocated, available, en route, demobilized, or unserviceable). It also entails managing lists of key personnel and resources used in the incident, and assisting with planning for demobilization and changeover of resources.

The operations section is responsible for directly managing and supervising the resources (people and equipment) involved in the incident in accordance with the Incident Action Plan. The AIIMS structure classifies resources as strike teams, task forces, or single resources (see Figure 14.1). In a large incident, resources will be divided into multiple sectors, which in turn will be part of larger divisions. A single identification system must be adopted in each incident to allow resources to be uniquely identified (however, AIIMS does not dictate the form that this identification system must take).

Finally, the logistics section is tasked with acquiring new resources when needed. This may include human and physical resources, facilities, services, and materials. The logistics section's supply unit is the primary unit responsible for acquiring, storing, and distributing resources, however, additional units may be responsible for specialized resource types (for example, a communications support unit may be established specifically for the acquisition, installation, and maintenance of communications equipment).

NIMS has much in common with AIIMS (notwithstanding many superficial terminology and structural differences), but is more mature, and in many respects is more specific and detailed in its recommendations. In relation to resource management, it goes further than AIIMS by establishing a Resource Typing System (U.S. DHS, 2004b) that can be used to describe resource types in a uniform way across all incidents. This provides a common protocol for describing resources in terms of categories, kinds, components, metrics, and typing definitions, and also provides definitions for 120 commonly used resource types across eight categories—Animal Health, Emergency Management, Emergency Medical Services, Fire/HazMat, Health and Medical, Law Enforcement, Public Works, and Search and Rescue.

The NIMS Resource Typing System has been developed as part of the broader National Mutual Aid and Resource Management System initiative. This initiative also focuses on establishing pre-incident agreements such as mutual aid agreements, creating a national inventory of resources that would be voluntarily maintained by government agencies and private sector entities involved in disaster response activities, and creating an Automated Resource Management System (ARMS) to allow emergency management personnel to access and search the inventory, and to request, order, and track specific resources. Since 2006, all U.S. state, territorial, tribal, and local jurisdictions have been required to adopt NIMS Resource Typing for their inventories of response assets, but the ARMS remains under development. In the meantime, the process of locating and ordering resources generally relies on e-mail, faxes, and phone calls (NIMS Resource Center, 2007a)—similar to resource management practices in Australia.

Recently, the prototype NIMS-Incident Resource Inventory System[2] (NIMS-IRIS) has been announced. The system will allow emergency responders to enter the NIMS typed resources and select specific resources for mutual aid purposes based upon mission requirements, capability of resources, and response time. Initially, NIMS-IRIS will provide the basic database management tool to enter the 120 typed resources into a common shared single database. Future versions will support advanced functionality in placing of resource requests, tracking of resources, and resource recovery.

The fact that AIIMS and NIMS make few specific recommendations about the use of ICT systems in emergency management (as their focus is at a higher level) has led to varying levels of technology uptake across the many public and private sector organizations that implement the two incident management systems. The state of the art in ICT systems is discussed in the following section, again with a focus on resource management; however, the majority of organizations involved in emergency management use systems that are considerably simpler than the state of the art. The United States is currently more advanced than Australia in pursuing interoperable ICT systems and has established the NIMS Resource Center (NIMS Resource Center, 2007b) to develop data standards, as well as systems such as ARMS, as future components of NIMS.

STATE OF THE ART IN SOFTWARE SUPPORT FOR RESOURCE MANAGEMENT

A variety of software products is available today in the emergency sector to support effective sharing of information, decision making, alerting, and related functions. These are mainly designed to support the tasks of staff working in Emergency Operations Centres (EOCs). Although some of the products are very narrow in scope—such as those that provide specialized emergency alerting and notification services (CPC, 2007; OVIS, 2007) or Computer-Aided Dispatch (CAD) functionality—there are also many broader products that fit the CIMS definition presented earlier.

A survey and evaluation of ten CIMS products by the U.S. Department of Justice in 2002 (National Institute of Justice, 2002) revealed that all supported some form of resource management. All ten products enabled the user to maintain an inventory of resources and to assign tasks to resources, while more than half supported related functions such as cost accounting, status tracking, and alerts. Today, the CIMS landscape remains quite similar. The following section provides a flavor of the types of resource management functions supported by CIMS software, covering four example CIMS implementations—WebEOC (Emergency Services Integrators, 2007), L-3 Crisis (Ship Analytics, 2003), ResponseVision (Emergency Visions, 2007), and Contora (Seros, 2007).

Four Modern Crisis Information Management Systems

The CIMS products discussed in this survey primarily serve the U.S. market, which is currently the most developed market for CIMS products internationally; however, some have also been deployed outside the United States. The survey shows that there are still gaps in the current level of support for resource management, and there are currently no comprehensive RMS solutions that are based on open standards.

WebEOC is one of the most mature and well-known CIMS products. It provides a number of customizable status boards that enable the tracking and management of information about significant events, tasks, resources, situation reports, press releases, shelters, and so on. WebEOC also manages contact information and provides internal communication using chat and messaging features. It can support geographic information systems (GIS) integration, and provides a full suite of ICS/NIMS forms for the U.S. market. In relation to resource management, WebEOC provides functionality for:

- maintaining and searching a resource inventory;
- tracking and updating resource deployments, and generating summary information about the overall quantity and cost of deployments;
- sending simple resource requests; and
- tracking donations.

Resource typing in WebEOC follows the NIMS Resource Typing System.

The status board functions of WebEOC are largely independent of one another—for example, there is no support for using donations information to update resource inventories or for translating requests for assistance into specific resource requests. As a result, many resource management tasks remain predominantly manual tasks in WebEOC.

L-3 CRISIS offers a large set of modules that provide similar functions to WebEOC boards, such as duty roster, finance, GIS, shelter management, and briefing modules. However, it differs from many other CIMS implementations in that it also includes scientific prediction and damage assessment modules. These facilitate tasks such as predicting impact areas for certain kinds of disasters, and carrying out economic and environmental damage assessments.

Its resource management functionality is split across several of the modules. The *acquire* module supports the management of lists of available equipment, supplies, suppliers and personnel, and allocation and de-allocation of resources as required. The *resource/logistics/staging* (RLS) module enables viewing and updating of location and status information for equipment and personnel, including GIS-based support for tracking location. The *organizational* module is used to build a picture of the overall structure of the units involved in disaster operations, and can be used as a basis for assigning equipment and personnel to particular units. Finally, the *message* module is used to transmit resource requests (as well as other types of requests and information), and provides a facility similar to e-mail except that it provides centralized message logging and tracking of related messages (so that all messages concerned with a particular resource request can be easily identified, for example). As in WebEOC, management of the overall resource lifecycle remains a largely manual task carried out using a number of disjoint software functions.

ResponseVision is a set of seven software modules designed to serve the needs of U.S. public and private sector organizations by directly implementing various aspects of NIMS/ICS. The modules address cataloguing of human and material assets (ResourceVision), vulnerability assessment (CheckVision), development of emergency response plans (PlanVision), alerting (AlertVision), simulations and exercises (SimDrillVision), incident command and control (CommandVision), and recovery activities including damage assessment and resource/financial management (RecoveryVision). We focus on the resource management component. Like WebEOC, ResourceVision uses the NIMS Resource Typing System. Although it can support integration with GIS and real-time location-tracking systems based on RFID (radio-frequency identification) and GPS (global positioning systems), ResourceVision is in essence little more than a relational database with a Web (ASP) interface. It does not provide any facilities for exchanging and managing resource-related messages, such as resource requests.

Contora is designed as a set of distributed Web portals for emergency response, linked together via a messaging infrastructure. This design makes Contora more suitable for distributed, multiorganizational environments than most of the other CIMS solutions. It supports a variety of messaging models, including publish/subscribe and single-destination communications. Using these forms of messaging, portals can selectively exchange information to build up a common picture of the situation, subject to information-sharing policies.

The main functions of the Contora portals are concerned with alerting, shared situational awareness, incident reporting, and tasking. Contora concentrates largely on map-based presentation of information, as distinct from the status-board or list-based presentations favored by some of the other CIMS products. For example, incident reports and events from chemical, biological, radiological, and nuclear sensors are presented on an incident report map. Maps can also be used to control the area in which alerts are disseminated, with location-based messaging being supported through integration with a third-party phone, e-mail, and pager notification service called Message911. Contora's support for resource management is fairly limited: it does not provide inventory management functionality as in the other CIMS products; however, it supports real-time asset and personnel tracking using a GPS-based system called LunarEye. Once again, this feature uses a map-based display.

Analysis

Many of the modern CIMS products, including those covered here, emphasize the need for integration with external software systems—among other features, they provide support for integration with sensor, GIS, public alert, CAD, and weather services. To support this integration, they rely on open/standardized interfaces and information formats. One example of the latter is the Common Alerting Protocol (CAP) (OASIS, 2005), an information format for public alerting standardized by the OASIS Emergency Management Technical Committee. WebEOC, for instance, can support CAP-encoded Watches, Warnings and Advisories produced by the U.S. National Weather Service.

Most of the standards in use today—like CAP—are narrow in scope. However, further standards for the emergency sector have recently emerged or are in the pipeline, and the adoption of these in CIMS products in the near future will be crucial to the further development of the sector. As shown in our survey, many of the current CIMS products are closely tied to the needs of the U.S. market. Emerging standards that are designed for international use will help to open up the market so that products can be more easily applied in a number of countries and jurisdictions without the major customizations that are currently necessary. Further, the standards should create opportunities for interoperability between CIMS solutions from different vendors—not only between CIMS and other specialized systems such as GIS, CAD, and public alert software.

The resource management functionality provided in CIMS products today mainly supports inventory management, basic resource allocation and tasking, and equipment and personnel tracking using GPS and other location-tracking technologies. Exchanging resource-related messages, such as resource requests, typically relies on general purpose messaging systems provided by the CIMS. The L-3 CRISIS messaging system is one of the most advanced in that it allows related resource messages to be chained together so that it is easier to determine the status of a particular resource request (in contrast to e-mail-like messaging systems, which make it difficult to piece together a thread of related messages). However, the adoption of standard formats for resource messages—in place of plain-text messages—would represent a significant step forward by increasing opportunities for automation. For example, a resource request could automatically be checked against the current inventory, and a resource status message could trigger an immediate update to a resource tracking system or status board. In addition, a standard format should reduce the ambiguity of resource-related messages and the number of messages that contain incomplete or inconsistent information. As we discuss later in the chapter, we have been contributing to the development of a standard format for resource messages (EDXL Resource Messaging) within the OASIS Emergency Management Technical Committee as an enabling step toward these future advances.

REQUIREMENTS FOR FUTURE RESOURCE MANAGEMENT SYSTEMS

In addition to incorporating open standards, future resource management systems should be developed with current resource management practices and frameworks in mind, as well as with a thorough knowledge of the problems, challenges, and constraints faced in Emergency Operations Centres. We have already discussed current resource management practices as covered by incident management systems such as NIMS and AIIMS. In this section, we summarize some general requirements related to the operational environment in which resource management takes place during an emergency situation, based on our observations during emergency services exercises in Queensland, Australia, which dealt with the preparedness and short-term response activities surrounding a mock category 4 cyclone. Exercises provide useful insights into both the challenges faced in EOCs and the processes adopted by EOC staff. Others (Militello et al., 2007) have found from similar studies that improved tools can be created to support better coordination and information flows in EOCs.

Exercises allow the “ideal” practices set out in frameworks like AIIMS and NIMS to be tested and evaluated. The challenges would naturally be more pronounced and more numerous in a true emergency situation, and behaviors would change to some extent under pressure. We aim to make further observations during a real disaster situation, but have not yet had the opportunity, to observe the realities of the AIIMS framework.

Response activities for a natural disaster such as a cyclone generally take place in a distributed fashion, with the involvement of numerous public and private sector organizations. In Queensland, a hierarchy of Disaster Coordination Centres, supported by various government departments and organizations such as critical infrastructure providers, is formed according to the structures of the AIIMS framework. Depending on the scale of the incident, coordination centers are activated at local, district, state, and federal levels. The cyclone exercise we attended involved four Local Disaster Coordination Centres (LDCCs), a District Disaster Coordination Centre (DDCC), and the Queensland State Disaster Coordination Centre (SDCC). The organization of these coordination centers is described in detail in (Iannella and Henricksen, 2007).

The process of identifying and handling resource requirements typically occurred in the exercise as follows. Requests for assistance came in from members of the public (simulated by the exercise control team), mainly at the local level. These requests—for example, for medical aid or assistance with structural damage—often triggered one or more requests for specific resources (human and/or material). Many of the resource requests could not be handled directly at the local level, and were delegated up to the district or state levels. At these levels, staff in the disaster coordination centers would draw on their networks of resource suppliers and other contacts to source the required resources on behalf of the local communities. Resource requests were mainly communicated informally via e-mail, telephone, and fax, with the additional use of logistics request and order forms prepared using office document templates. Messages and actions taken were recorded manually in an operations log in spreadsheet applications.

This approach to managing resource requests suffered from the following shortcomings:

1. Knowledge about the status of particular requests mainly resided with the one or two people responsible for handling them, and there was a general lack of feedback on progress at the lower levels of the hierarchy. This made it difficult for the staff handling the requests for assistance at the local level to know whether resource requests were still in progress or had been lost.

2. Because there were no centralized repositories of information about the status of resources and resource requests, there could be no overall coordination. This meant that resource requests could be acting at cross-purposes or duplicated, and that resource allocations across the incident were in general not as efficient as they could have been.

3. There were a number of problems surrounding shift changeovers in the Disaster Coordination Centres. For example, when personal e-mail accounts and informal communication channels were used, much of the information that had been exchanged with outside people in relation to particular resource requests was lost when another person took over at the end of a shift. In addition, a great deal of time was spent updating contact lists in order to handle shift and other personnel changes.

Appropriately designed RMS/CIMS software could easily alleviate these problems—for example, by supporting role-based communications and centralized tracking of messages and resource status information.

Overall, the tasks handled at the various levels in the hierarchy of Disaster Coordination Centres were quite different, as were the operating environments and levels of technology (and other resources). RMS/CIMS software therefore needs to be customizable to support a number of different functional and information views. At the local level, the software needs to manage the very detailed information coming from people on the ground in a high-pressure environment. At higher levels, the software should enable a cohesive view of the “bigger picture” to allow overall coordination and decision making. This requirement is not well addressed by the currently available CIMS products, and suggests the importance of pursuing standards-based interoperability between a number of different CIMS implementations, rather than pushing for uniform adoption of generic "closed" systems.

EDXL RESOURCE MESSAGING

To date, there have been no general standards for exchanging resource-related information to support resource management for emergency response. The IEEE 1512 family of standards, which is discussed in Henricksen and Iannella (2006), addresses a number of elements of asset management (including requests for assets and exchange of asset status information), but was developed with the U.S. transportation industry in mind and is intended primarily for managing traffic incidents. To fill the current standards gap, we have been involved in the efforts of the OASIS Emergency Management Technical Committee to develop a general format for exchanging resource-related messages, known as the Emergency Data Exchange Language Resource Messaging (EDXL-RM) specification (OASIS, 2007a). EDXL-RM provides a suite of closely related messages for:

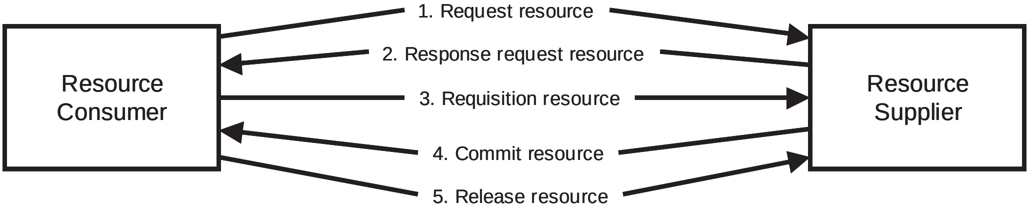
- requesting resources and responding to resource requests;
- requisitioning and committing resources;
- requesting resource information and responding to requests for information;
- offering unsolicited resources and responding to offers;
- releasing resources;
- requesting the return of resources and responding to return requests;
- requesting quotes and responding to requests for quotes;
- requesting and notifying resource deployment statuses; and
- requesting extended use of a resource and responding to extension requests.

A total of sixteen different messages are supported by EDXL-RM, all of which share many common features, but still provide the end users with a complex range of functions. Such complex specifications will need good software requirements engineering and user-centered design patterns, which is now being recognized in the emergency sector (Montells et al., 2006).

The EDXL-RM specification describes the message formats, in terms of the message elements that are required, optional, and conditional (depending on which other elements are present and their values) for each message type. Message elements are represented as Extensible Markup Language (XML) (W3C, 2006) elements, and each message type is defined by a distinct XML Schema. The EDXL-RM specification does not dictate the message flow sequences, except to specify the valid responses for each of the message types. An example message exchange is shown in Figure 14.2 for illustrative purposes. This message exchange involves only two parties—the resource consumer and resource supplier. In more complex scenarios, other parties (such as additional suppliers and resource approvers) may be involved, and a larger subset of the EDXL-RM message types may be required. An example "Request Resource" message (the first message type in our example exchange) appears in Figure 14.3. This shows a request for two electrical power restoration teams. The example illustrates the core element types; however, a wide variety of optional elements can also be included—such as incident information, further resource requests, additional scheduling information, and details about required credentials and certifications. Detailed examples for each of the EDXL-RM message types can be found in the EDXL-RM specification (OASIS, 2007a).

There are several other areas, besides the message flow sequences, in which EDXL-RM provides a considerable degree of flexibility, allowing for compatibility with incident management systems

Figure 14.2 **An Example EDXL-RM Message Exchange**



such as NIMS and AIIMS. In particular, EDXL-RM offers several alternative mechanisms for identifying resources (by identifier, name, or an externally defined type structure), enabling the use of resource typing schemes such as NIMS Resource Typing. Additionally, it supports existing standards for describing location and contact information, including a small set of Geography Markup Language (GML) (OGC, 2004) elements for describing geospatial coordinates and areas, and elements from the extensible Party Information Language (xPIL) and extensible Address Language (xAL) (both developed by the OASIS Customer Information Quality Technical Committee [OASIS, 2007b]. The use of these standards helps to make EDXL-RM suitable for international use, despite the fact that its initial development was driven by the United States.

EDXL-RM is closely related to another specification in the Emergency Data Exchange Language family—the EDXL Distribution Element (EDXL-DE) (OASIS, 2006). EDXL-DE is used as the container for distributing any message payloads and supporting the routing of these messages to the appropriate recipients. EDXL-DE provides elements such as the target area for a message (in order to support location-based message delivery); information about the sender; the target address, if applicable; keywords describing the message content; and the type and “actionability” of the message (actual, exercise, test, etc.).

EDXL-DE was formally adopted as an OASIS standard as of May 2006, and EDXL-RM became an OASIS standard in November 2008.

TOWARD A STANDARDS-BASED RESOURCE MANAGEMENT SYSTEM

We are currently developing a demonstrator RMS based on the EDXL-RM standard. This is part of a broader CIMS prototype called CAIRNS (Iannella et al., 2007), which also showcases flexible information distribution and alerting using OASIS standards including EDXL-DE and CAP.

The current resource management support in commercial CIMS offerings is primarily concerned with resource/inventory management in individual organizations. Our goal is to show a broader RMS solution that targets collaborative, cross-organizational resource management activities, both for day-to-day activities and crisis situations. Our proposed RMS addresses the problems of how to coordinate resource supply and tracking across organizational boundaries, assuming a situation where each organization may already have its own processes and/or information systems in place for allocating, managing, and tracking resources. EDXL-RM and EDXL-DE together provide the framework for structured information sharing and negotiation between organizations.

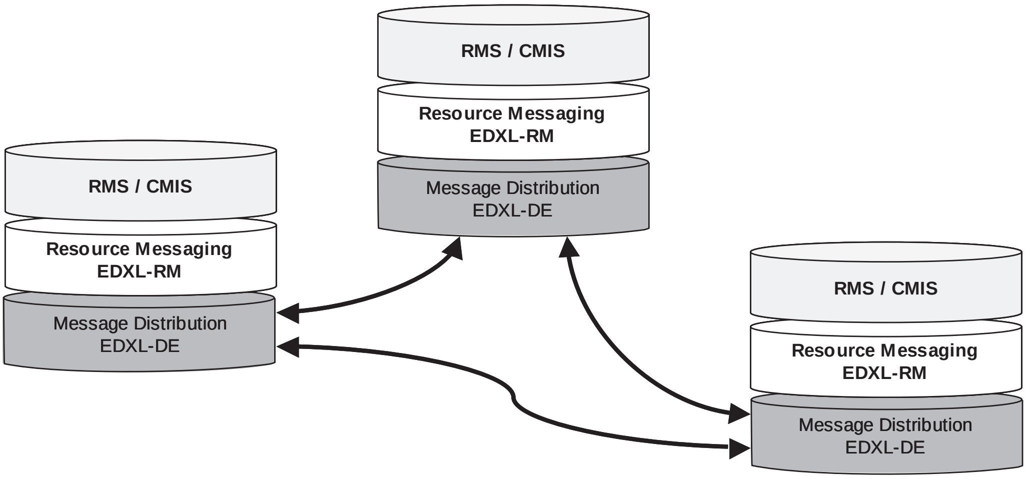
The proposed system incorporates the following functionality:

1. Support for composition of resource messages (resource requests, requisitions, commits, requests for quotes, statuses, and returns) based on the standard EDXL-RM message formats.

Figure 14.3 **Example EDXL-RM “Request Resource” Message**

```
<EDXLResourceMessage xmlns="urn:oasis:names:tc:emergency:EDXL:RM:1.0:RequestResource"...>
    <MessageID>3478</MessageID>
    <SentDateTime>2007-05-24T10:16:00+10:00</SentDateTime>
    <MessageContentType>Request Resource</MessageContentType>
    <OriginatingMessageID>3478</OriginatingMessageID>
    <ContactInformation>
        <rm:ContactRole>Sender</rm:ContactRole>
        <rm:AdditionalContactInformation>
            <xnl:PartyName>
                <xnl:PersonName>
                    <xnl:NameElement xnl:ElementType="FirstName">Alex</xnl:NameElement>
                    <xnl:NameElement xnl:ElementType="LastName">Jones</xnl:NameElement>
                </xnl:PersonName>
                <xnl:OrganisationName>
                    <xnl:NameElement>Dept. of Emergency Services</xnl:NameElement>
                </xnl:OrganisationName>
            </xnl:PartyName>
            <xpil:ContactNumbers>
                <xpil:ContactNumber xpil:MediaType="Telephone">
                    <xpil:ContactNumberElement xpil:ElementType="AreaCode">
                        7
                    </xpil:ContactNumberElement>
                    <xpil:ContactNumberElement xpil:ElementType="LocalNumber">
                        1234 5678
                    </xpil:ContactNumberElement>
                </xpil:ContactNumber>
            </xpil:ContactNumbers>
            <xpil:EmailAddresses>
                <xpil:EmailAddress>a.jones@emergencyservices.gov.au</xpil:EmailAddress>
            </xpil:EmailAddresses>
        </rm:AdditionalContactInformation>
    </ContactInformation>
    <ResourceInformation>
        <SequenceNumber>001</SequenceNumber>
        <Resource>
            <TypeStructure>
                <rm:ValueListUrn>urn:x-hazard:vocab:resourceTypes</rm:ValueListUrn>
                <rm:Value>Electrical Power Restoration Team</rm:Value>
            </TypeStructure>
        </Resource>
        <AssignmentInformation>
            <Quantity>2</Quantity>
        </AssignmentInformation>
        <ScheduleInformation>
            <ScheduleType>RequestedArrival</ScheduleType>
            <DateTime>2007-05-25T09:00:00+10:00</DateTime>
            <Location>
                <rm:Address>
                    <xal:Locality>
                        <xal:Name>Cairns</xal:Name>
                    </xal:Locality>
                    <xal:Thoroughfare>
                        <xal:NameElement>Main St</xal:NameElement>
                        <xal:Number>27</xal:Number>
                    </xal:Thoroughfare>
                    <xal:PostCode>
                        <xal:Identifier>4870</xal:Identifier>
                    </xal:PostCode>
                </rm:Address>
            </Location>
        </ScheduleInformation>
    </ResourceInformation>
</EDXLResourceMessage>
```

Figure 14.4 **Distributed Architecture Based on EDXL-RM and EDXL-DE**

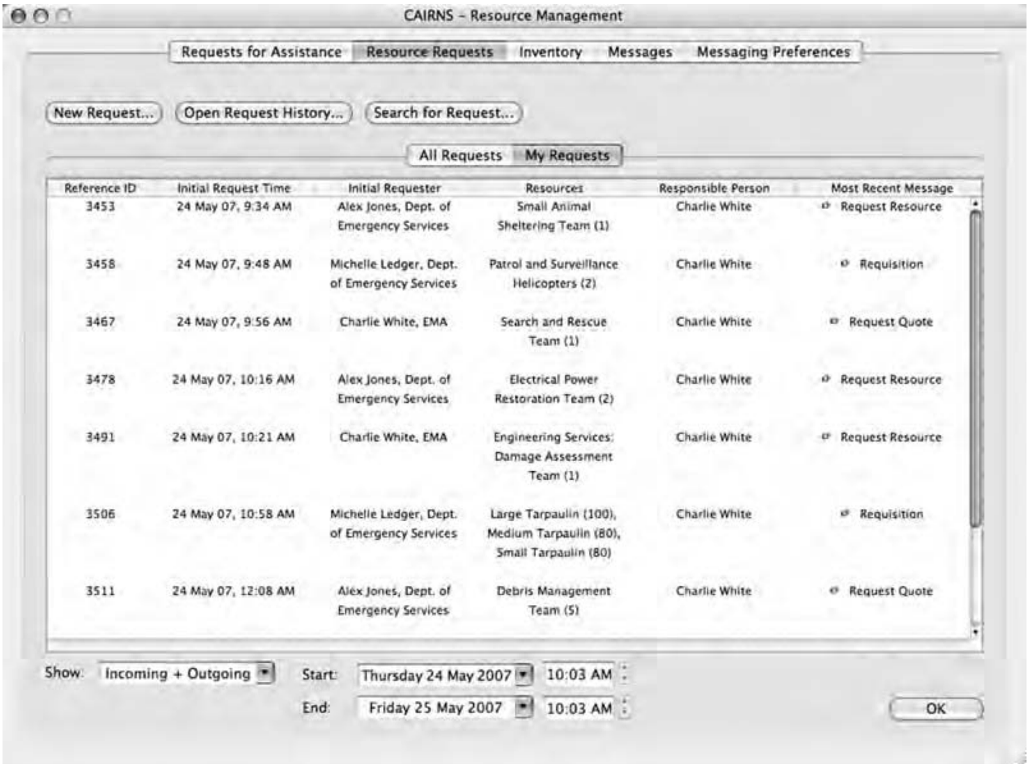


2. Support for dissemination of resource messages using the flexible addressing mechanisms of EDXL-DE. For instance, resource requests can be delivered to recipients based on resource keywords, role, or geographical area, as well as using direct addressing, whereby the sender explicitly specifies the intended recipient(s). This allows opportunistic resource discovery to occur, in addition to conventional discovery and allocation through preestablished supply channels.
3. Support for flexible message subscription and delivery preferences, so that message recipients can control which kinds of messages they receive and by which method (for example, e-mail, SMS alert, or RSS feed). Messages can also be diverted to other people or roles as required.
4. Logging and management of message histories to simplify the process of tracking the progress of a given resource request and for accountability.
5. Support for storing amounts of resources from various agencies, including offers of resources from external parties. This is then used to map with incoming resource requests from which allocations can be generated.
6. The ability to visualize current resource locations onto a geospatial map, including uncommitted and committed resources, and resources in transit.

Architecturally, the system consists of a set of distributed RMS/CIMS systems connected via a common messaging substrate (EDXL-RM) based on EDXL-DE routing services. This design is illustrated in Figure 14.4. The distribution layer is responsible for routing of resource messages (and other types of information exchanged by the systems) over the network according to users' messaging subscriptions and EDXL-DE message elements such as target area, recipient role, keyword, or explicit address. The resource messaging layer supports composition of EDXL-RM resource messages at the sender's side, validation and parsing of messages at the recipient's side, and logging of all messages.

The RMS or CIMS systems that sit above these two layers can be customized according to the requirements of each organization to provide appropriate user interfaces and integration with existing software. As proof of concept, we are developing such a system that demonstrates the

Figure 14.5 **CAIRNS Resource Management-Resource Requests View**



Reference ID	Initial Request Time	Initial Requester	Resources	Responsible Person	Most Recent Message
3453	24 May 07, 9:34 AM	Alex Jones, Dept. of Emergency Services	Small Animal Sheltering Team (1)	Charlie White	Request Resource
3458	24 May 07, 9:48 AM	Michelle Ledger, Dept. of Emergency Services	Patrol and Surveillance Helicopters (2)	Charlie White	Requisition
3467	24 May 07, 9:56 AM	Charlie White, EMA	Search and Rescue Team (1)	Charlie White	Request Quote
3478	24 May 07, 10:16 AM	Alex Jones, Dept. of Emergency Services	Electrical Power Restoration Team (2)	Charlie White	Request Resource
3491	24 May 07, 10:21 AM	Charlie White, EMA	Engineering Services: Damage Assessment Team (1)	Charlie White	Request Resource
3506	24 May 07, 10:58 AM	Michelle Ledger, Dept. of Emergency Services	Large Tarpaulin (100), Medium Tarpaulin (80), Small Tarpaulin (80)	Charlie White	Requisition
3511	24 May 07, 12:08 AM	Alex Jones, Dept. of Emergency Services	Debris Management Team (5)	Charlie White	Request Quote

Show: Incoming + Outgoing
Start: Thursday 24 May 2007 10:03 AM
End: Friday 25 May 2007 10:03 AM

resource messaging and subscription features described above, as well as integrated inventory management and “Request for Assistance” (RFA) tracking. The inventory management feature exploits the formal semantics of EDXL-RM resource messages, enabling resource database updates to be performed automatically based on the content of messages that are sent and received via the resource messaging layer. For example, sending a commit message for 100 tarpaulins can trigger a database update that changes the status of the items from “available” to “committed.” The goal of integrated RFA tracking is to capture the relationships between incoming requests for assistance and the outgoing resource requests that are triggered as a result, in order to provide better tracking of RFAs through to completion and generate process traces for accountability purposes.

Figures 14.5–14.7 show a series of screenshots to illustrate a subset of our RMS system’s functionality. The system supports a number of views: a *Requests for Assistance* view, which displays RFAs and associated functions for adding, modifying, and searching requests; a *Resource Requests* view, which we describe in detail below; an *Inventory* view, which provides functions for browsing, managing, and searching the resource database; a *Messages* view, which allows users to manage their incoming and outgoing messages (both resource messages and other message types); and a *Messaging Preferences* view, which allows users to describe their message delivery preferences and create customized message subscriptions by specifying relevant roles (e.g., “EOC Manager,” “Logistics Officer”), keywords of interest (“medical supplies,” “tarpaulins”), and so on.

The *Resource Requests* view is shown in Figure 14.5. It provides functions for creating a new resource request, which may be one of several types supported by EDXL-RM, including a

Figure 14.6 **CAIRNS Resource Management—New Request Window**

Message Type: Request Resource

Contact Information:

Sender: Alex Jones
Dept. of Emergency Services

Resource Information:

Resource Type: Small Animal Sheltering Team
Quantity: 1
Special Requirements: A qualified vetinary surgeon
Schedule Information:

Requested Arrival: 26 May 2007, 9:00 AM
Innisfail Animal Refuge
27 Downing St
Innisfail QLD 4860
Estimated Departure: 4 June 2007, 4:00 PM

Resource Type: Patrol and Surveillance Helicopters
Quantity: 3
Anticipated Function: Arial surveillance to determine extent of flooding
Schedule Information:

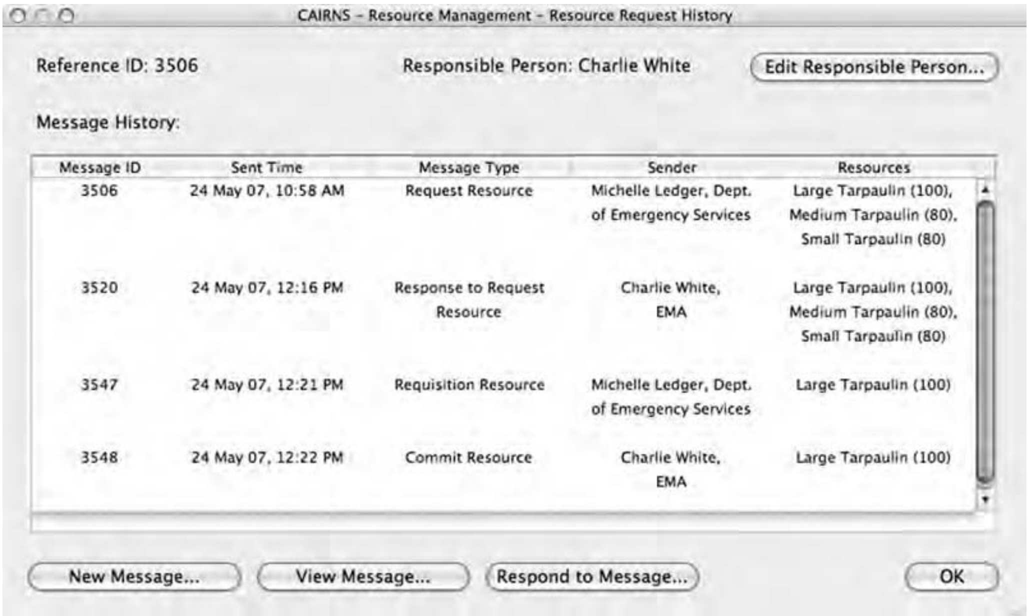
Requested Arrival: 26 May 2007, 9:00 AM
Innisfail Airport

"Request Resource," "Requisition," or "Request Quote"; viewing and managing request histories, where a history is a sequence of related resource messages and associated information, such as the responsible person or role; and searching resource requests.

The view also provides a listing of all pending requests (or, more accurately, request histories), either for the entire organization or the current user. The listing can be filtered according to date and time, and whether the initial request was an incoming or an outgoing one.

Figure 14.6 shows the message composition window that appears when the user clicks on the

Figure 14.7 **CAIRNS Resource Management—Resource Request History Window**



CAIRNS – Resource Management – Resource Request History

Reference ID: 3506

Responsible Person: Charlie White

Message History:

Message ID	Sent Time	Message Type	Sender	Resources
3506	24 May 07, 10:58 AM	Request Resource	Michelle Ledger, Dept. of Emergency Services	Large Tarpaulin (100), Medium Tarpaulin (80), Small Tarpaulin (80)
3520	24 May 07, 12:16 PM	Response to Request Resource	Charlie White, EMA	Large Tarpaulin (100), Medium Tarpaulin (80), Small Tarpaulin (80)
3547	24 May 07, 12:21 PM	Requisition Resource	Michelle Ledger, Dept. of Emergency Services	Large Tarpaulin (100)
3548	24 May 07, 12:22 PM	Commit Resource	Charlie White, EMA	Large Tarpaulin (100)

“New Request” button in the *Resource Requests* view—in this case, the request corresponds to an EDXL-RM “Request Resource” message. Figure 14.7 shows the window that displays a resource request history when the user clicks on the “Open Request History” button.

CHALLENGES AND FUTURE DIRECTIONS

The CAIRNS demonstrator we have described represents a first attempt to build an RMS implementation that is based on open standards and offers a flexible messaging model. Several aspects of the system remain untested and will need to be validated in future work. First, the EDXL-RM specification is very new and has not yet been used in any working system. The need for refinements or extensions may become apparent as more experience is gained through the implementation of systems such as CAIRNS. Two areas that EDXL-RM does not address at present are resource allocation methods and management of human resources, including tasking of personnel. Extensions of the EDXL-RM message formats to support humans as “resource” activities may be required in the future and could be accommodated within EDXL-RM. A greater challenge is to automate and assist in the allocation of resources. During a major incident hundreds of requests would be likely, and this would need innovative mechanisms for real-time planning (Minciardi et al., 2007) and resource allocation (Schattenberg and Biundo, 2002; Ulieru and Unland, 2004) under such crisis conditions to assist the EOC staff.

The use of flexible message delivery mechanisms based on EDXL-DE to address the types of communication challenges (related to shift changeovers, management of contact lists, and so on) appears promising but requires further research. Emergency management presents a number of critical requirements in terms of timeliness of message delivery, avoiding information overload, and satisfying accountability requirements. Our CAIRNS prototype will need to be carefully evaluated with respect to these issues. EDXL-DE provides a great deal of flexibility about the kinds of message routing that can be supported; the challenge lies in determining the most appropriate ways in which to apply its capabilities. In particular, further work is needed to determine what feedback mechanisms are needed at the sender's side about the delivery status of particular messages, and to what degree it is appropriate for the recipient, rather than the sender, to control which messages they receive (e.g., via keyword or location-based subscriptions).

We intend to deploy our CAIRNS prototype at future emergency services exercises. This will allow us to evaluate both the current design and the underlying messaging formats (EDXL-RM and EDXL-DE), and to identify areas for refinement and further development.

CONCLUSIONS

Effective management of resources is a crucial part of emergency management, and resource management functionality features prominently in many currently available CIMS products. However, this functionality is mainly concerned with the management of resources in a single organization (for example, management of the organization's inventory and real-time tracking of its deployed resources). There is currently a push, particularly in the United States, toward more open systems that better support cross-organizational cooperation. Many CIMS products have already implemented information standards such as the Common Alerting Protocol (CAP), but to date there have been no suitable standards related to resource management.

This chapter reported on a proposed OASIS standard to support the exchange of resource-related messages (EDXL-RM), and also on a prototypical Resource Management System that we are developing based on the standard. Our prototype demonstrates the potential of structured resource messages to automate some aspects of resource management, to reduce the ambiguity of messages, and to improve the tracking of pending resource requests. It also demonstrates flexible types of message routing that enable opportunistic resource discovery and address the communication challenges we have observed in Disaster Coordination Centres during emergency exercises. Although further research and validation is needed—both for our proposed RMS design and the current EDXL-RM specification—this work sets the future direction for standards-based RMS implementations.

NOTES

1. Note that the term "Resource Management System" is used here in accordance with its meaning within the AIIMS framework, rather than with the semantics we use elsewhere in this chapter. The AIIMS framework assigns the term a broader meaning, which does not necessarily entail any software implementation.
2. See www.fema.gov/emergency/nims/rm/iris.shtm for details.

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CHAPTER 15

REQUIREMENTS AND OPEN ARCHITECTURE FOR ENVIRONMENTAL RISK MANAGEMENT INFORMATION SYSTEMS

THOMAS USLÄNDER AND RALF DENZER

Abstract: *Risk management constitutes the set of preventative, integrated actions taken to deal with risk identification, analysis, and required measures during disasters. The ability to share all relevant data, especially in disasters that cross international borders, is often very limited because environmental risk management tasks are mainly handled by public institutions on a variety of administrative levels, each with their own information technology systems for the provision of data and services. The present chapter motivates and describes a generic and open service-oriented architecture evolving from well-established standards of ISO, OGC, W3C, and OASIS. It represents the results of the European project ORCHESTRA (www.eu-orchestra.org). The design principles are derived from the analysis of the triangle "user requirements," "system requirements," and "state-of-the-art technology." The resulting architecture basically follows a three-step approach. The first step focuses on the combined generic and platform-neutral specification of the conceptual service and information model. The second step is to map the abstract specification to one or more chosen service platforms (e.g., W3C Web Services). The third step comprises the engineering of service networks with a definition and enforcement of operational policies, for example, in the field of discovery and access control. The chapter concludes with a description of pilot scenarios, lessons learned from the perspective of risk and emergency managers, and an outlook about possible enhancements.*

Keywords: *Environmental Risk Management, Service-Oriented Architecture, OGC, ORCHESTRA, Reference Model*

RISK MANAGEMENT VS. EMERGENCY MANAGEMENT

The increasing intensity and frequency of natural disasters, including in Europe, in the past few years have led to a heightened awareness of safety issues relating to environmental risk and emergency management at both the political and public levels. Following the terminology used by the Committee on Planning for Catastrophe of the U.S. National Research Council (2007) the term *emergency* is understood in this chapter to mean a sudden, unpredictable event that poses a substantial threat to life or property. Furthermore, "emergency management is the organization and management of resources and responsibilities for dealing with all aspects of emergencies" and covers the following phases: preparedness, response, recovery, and mitigation. When analyzing requirements and concepts for effective information technology (IT) support for these phases, emergency situations in the response phase need a specific consideration, as this is the phase during which immediate action has to be carried out possibly under high time pressure and with limited resources. In this chapter, the focus is on the other phases in which the management of emergency risks is in the spotlight, whereby the term *risk*, according to the glossary of CEDIM,[1] denotes “the probability and the amount of harmful consequences or expected losses resulting from interactions between natural or human induced hazards and vulnerable conditions.” Furthermore, risk management is understood in this chapter as the set of preventative, integrated actions taken to deal with risk identification, analysis, and measures that are required during emergencies. It thus encompasses all of the activities related to the identification and management of hazards, the analysis of vulnerabilities as well as the assessment and analysis of risks in a spatial-temporal domain.

The objective of this chapter is to discuss an open IT architecture for environmental risk management with a focus on the preparedness, recovery, and mitigation phases. Within each of these phases similar methods and tools are used by the stakeholders. Some of them may also be relevant as background information and services in the response phase, but then their access must be assured by a dependable infrastructure. Some of the methods and tools are risk-neutral, while others are specialized by risk domain (e.g., fire, flood, seismic, coastal zone, and technological). Moreover, results from earlier phases are often reused in later phases, that is, results from consequence/simulation models can be reused in a recovery phase or even during emergency response. However, the ability to share all relevant data, especially when considering emergencies that cross international borders, is often very limited because risk management tasks are mainly handled by public institutions on a variety of administrative levels, each with their own IT systems for the provision of data and services. Thus, the main problem today is that in any given activity in any given phase of the emergency management cycle, decision makers and stakeholders do not have easy access to the information that they need in order to fulfill their goals. For instance, a typical question that is often posed is “what are the risks that exist on my territory.” The response depends on the phase of the emergency management cycle and on to whom the question is posed. Currently, there is no single integrated system architecture that can fulfill this request, and information produced in each phase is often incompatible.

VISION

The vision of an open architecture for environmental risk management information systems has driven the work of the European Integrated Project ORCHESTRA[2] (Open Architecture and Spatial Data Infrastructure for Risk Management). ORCHESTRA has been carried out between 2003 and early 2008 with the objective of contributing to a future “ideal” IT infrastructure support for environmental risk and emergency management (Klopfer and Kannellopoulos, 2008). Such ideal support would make information available on demand for end users and would enable service providers to offer high-quality services at considerably lower cost. One part of this ideal support would be an IT infrastructure that provides seamless access to resources (information, services, and applications) across organizational, technical, cultural, and political borders, thus overcoming real-world heterogeneity and assuring a sustainable investment for the support of future, still unknown requirements. The final goal is to plug and play with environmental risk management resources, and provide end users with cross-border services for risk and disaster management, which they lack today.

The chapter continues with a general discussion of IT integration challenges, followed by a presentation of the requirements for an open architecture. The architectural approach of the ORCHESTRA project is described, followed by a discussion of relevant IT standards. After a detailed technical description of the ORCHESTRA Architecture, ORCHESTRA pilot applications are presented. The chapter concludes with lessons learned and future outlook.

INTEGRATION CHALLENGES

Environmental Information and Decision Support Systems are often complex information processes on top of complex information collections. They support end users in (often) complex decisions (Denzer, 2005). The complexity of such systems is increased considerably when it comes to integrating information and business processes across different existing systems for the purpose of cross-boundary information management and use of services. In recent years it has been recognized that the issue of cross-boundary integration is an important topic, in particular in the European Union. Many obstacles have prevented the realization of the vision described above in the past. Denzer and colleagues (2005) carried out a discussion of several fundamental challenges based on a simple system-of-systems model, that is, a model that focuses on the integration of systems into meta-systems. A system of systems can be considered an additional or new system integrating at the data, operations (services), and/or workflow levels in order to produce new data, services, and workflows as a new system (a model). Adopting this model for an "IT infrastructure for environmental risk management," the design challenges may be grouped into four categories: syntactic interoperability, semantic interoperability, organizational context, and generics.

Syntactic Interoperability

Systems can "talk" to each other and understand the same syntax. This challenge is concerned with overcoming technical heterogeneity of all kinds. In the context of a service-oriented architecture (SOA), this mainly means technical interoperability of different middleware, published open interfaces, and schema mapping.

Syntactic interoperability does not necessarily guarantee any understanding of the same meaning.

Semantic Interoperability

Semantic interoperability concerns the fact that two pieces of information can be syntactically equivalent but may still have different meanings when different end users or systems interpret them. Semantically interoperable systems are capable of overcoming ambiguities. Semantic interoperability is a research topic that is clearly relevant for risk management applications.

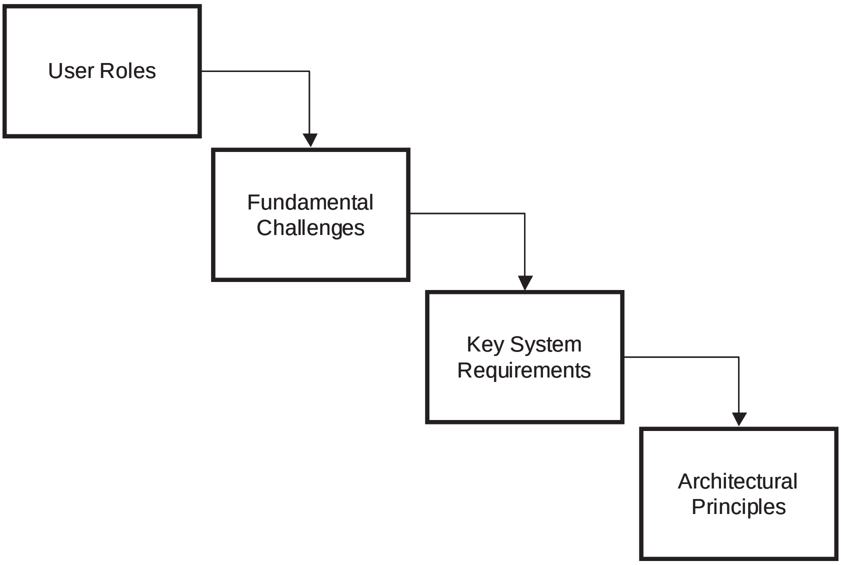
Organizational Context

The organizational context is of utmost importance, in particular, in cross-border applications. The issues of granting access rights (including controlling their execution), information policies, security, cost, and rights management need to be addressed in a transparent way. From a system-level point of view, the issue of integration between the new applications and the existing systems is crucial. Note that heavy reengineering of existing systems for the purpose of integration is not a viable solution.

Generics

Technical and semantic interoperability, and support for dealing with the organizational context, are to be achieved in a most generic way, wherever possible. This is necessary for several reasons (including cost), the most important being that only a generic infrastructure is open for cross-domain integration and adaptation to future requirements.

Figure 15.1 **From User Roles to Design Principles**



The ORCHESTRA project has chosen to define *generic* as the combination of two properties: independence of the application domain and independence of an organizational context. In practical terms this means: (a) that the same infrastructure can be used for management of fire risks as well as for flood risks and other risks; and (b) the same application (e.g., a forest fire application) can be used in Italy as well as in Spain, although the underlying business processes and organizational context vary in different countries.[3]

REQUIREMENTS OF LARGE-SCALE INTEROPERABLE ARCHITECTURES

Environmental risk and disaster management infrastructures, due to their cross-border nature, must deal with the requirements that concern building and operating large-scale service networks. In the ORCHESTRA project, such requirements were discussed and defined in system requirements activity.

System requirements for the ORCHESTRA Architecture encompass all functional and non-functional aspects that need to be considered in order to enable interoperability between systems. Interoperability here is defined as the capability to communicate, execute programs, or transfer data among various functional units in a manner that allows the user to have little or no knowledge of the unique characteristics of those units. System requirements for the ORCHESTRA Architecture are requirements for the infrastructure, and they are closely related to end-user needs. System requirements are expressed in generic technical terms, that is, independent of application domains. Within the project, these system requirements originate in the combined expertise of the consortium in the area of solutions interoperability. The system requirements in the ORCHESTRA project were developed through a systematic process as illustrated in Figure 15.1.

From the user roles, the fundamental challenges for system integration are first derived. These challenges are used to define a set of key system requirements that affect the design principles in order to build a sound large-scale architecture (Usländer, 2007).

Figure 15.2 **Design Principles for Large-scale Architectures**

User Roles			Fundamental Challenges	Key System Requirements			
Service developer/ system administrator	Service provider	End user		Openness	Scalability	Usability	Accountability
✔			Scale and scope	✔	✔		
	✔	✔	Integration / Collaboration	✔			
	✔	✔	Long lifetime	✔	✔	✔	
	✔	✔	Quality		✔	✔	✔
✔	✔	✔	Transparency			✔	
	✔		Access control		✔	✔	✔

Architectural Consequences	Openness	Scalability	Usability	Accountability
Rigorous use of concepts and standards	✔			
Loosely coupled components	✔	✔		
Technology independence	✔			
Evolutionary development—Design for change	✔	✔		
Component Architecture Independence	✔			
Generic infrastructure	✔		✔	
Self-describing components			✔	✔

The result of the process is summarized in Figure 15.2. The check marks in the table indicate the interaction between the different steps followed during the system requirements development process. For instance, the challenge “Scale and scope” is of utmost importance for “Service developers” and “system administrators” and itself imposes the requirements “Openness” and “Scalability” on the architecture. Note that in order to fully understand the links between the different categories, the accompanying documentation explains why a certain type of user has a certain challenge, or a certain challenge requires a system that fulfills certain key system requirements. In addition, all terms have a clear definition in the documentation.

Note that project OASIS[4] (IP OASIS, 2005) was working on command-and-control-type emergency management systems in parallel. Also note that in some cases one might argue that a category is more a design principle than a key system requirement. The details may be argued further, but it is more important that the key issues of large-scale architectural design are captured in an overall sense. Issues of dependability and security have not been considered explicitly during the project because the ORCHESTRA "mission" as defined by the European Commission (the funding organization) was to look mainly into nonemergency risk management. This also implies that the ORCHESTRA Architecture can be used as an information backbone for emergency management systems, but additional functionalities not provided by ORCHESTRA would have to be implemented in order to guarantee dependability in crisis situations. Issues of dependability would certainly become an issue if the ORCHESTRA Architecture were used in an emergency management context.

BREAKDOWN OF USER REQUIREMENTS

The paradigm of a *service-oriented architecture (SOA)* has been chosen by ORCHESTRA because its basic approach of loosely coupled components and its rich technological foundation currently provide the best starting base to satisfy the design principles. It enables sharing of geospatial resources, that is, data and services with an explicit or implicit geospatial reference, and composes them to higher-level entities across organizational and administrative boundaries. This is essential for environmental risk management applications, such as early warning systems of natural disasters, insofar as natural phenomena are not limited to boundaries drawn by humans.

Up to now, although SOA has become the established mainstream technology for distributed applications, there is no established methodology for the design of SOAs. Most of the SOA tools focus on improving SOA development at the programming level and on SOA governance and assume that the expectations of a user have already been expressed as formal use cases and workflows, for example, specified in UML.[5] The existing software engineering process models, such as the Rational Unified Process (Kruchten, 2000), are tailored to the design of applications that, although potentially distributed, comprise tightly coupled components with an object-oriented programming interface. Instead, the design of SOAs must explicitly consider side conditions such as the obligation to match requirements with a (potentially) huge number of already existing functions. In an SOA, these functions are offered in terms of interacting loosely coupled services, either specified according to a service meta-model, registered in service registries (catalogues), or even already deployed in an existing service network with self-describing capabilities.

The following simple example illustrates the basic analysis and design problem. As part of a forest fire risk assessment process in Spain, the need to access "historical forest fire data sets" and "vulnerable infrastructure in Catalonia" was identified in order to generate a hazard map based on a given algorithm. The service platform offers the capability of a generic feature (object) access service that supports spatial data selection, that is, queries with geospatial filters, and a generic processing service. An example of such a service is the Web Feature Service (WFS), a standard service of the Open Geospatial Consortium (OGC). Currently, it is up to the SOA designer to establish a conceptual relationship between "forest fire" and "infrastructure in Catalonia" and the concept of "features" as defined by the WFS and the related huge set of OGC specifications, for example, the OGC Reference Model. Beyond the sheer complexity and size of these standards, there is a huge gap between the way the functional requirements of the user are usually expressed (e.g., in terms of a simple textual description) and the formal WFS specification (its concepts are described in UML and its interface is described in the Web Service Description Language [WSDL]). It is up to the SOA designer to bridge this gap and mentally resolve the following thematic class hierarchy in order to propose the WFS as a solution for the functional requirement:

- “Road” ≤ “Infrastructure element” ≤ “Feature”
- “Forest fire” ≤ “Hazard” ≤ “Feature”
- “Catalonia” ≤ “Geographical concept”

Although this may look quite straightforward for this simple example, it becomes much more complicated for more sophisticated requirements and also when including nonfunctional requirements for performance, dependability, and security.

Furthermore, the SOA designer is not free in his design. For geospatial applications, there are important design guidelines and constraints such as corresponding standards of ISO and the stakeholders. Standards exist on both the abstract (i.e., platform-neutral) and the concrete (i.e., platform-specific) level in order not to be fixed to one service platform, for example, Web services.

Due to the lack of an established SOA design methodology in this context, ORCHESTRA has chosen a multistep breakdown process across several abstraction layers. Starting from an analysis of the problem domain, user requirements are derived, iteratively refined, prioritized, and then mapped to the capabilities of an abstract service platform. The next step, mapping to the concrete service platform (currently Web services) is supported by a (semi)automatic process. This basic design approach is illustrated in more detail in the next section.

DESIGN APPROACH

Before the technical approach of ORCHESTRA, that is, the ORCHESTRA Reference Model, is described in more detail, some benefits of an open design approach are discussed and a summary of the ORCHESTRA offering is presented.

Benefits of Using ORCHESTRA

The trend toward SOAs for the setup and deployment of distributed environmental risk management systems is not only a technical discussion about the best middleware for such systems. Above all, it is a technological answer to the user request for efficient and effective cross-domain information and service integration. Such systems of systems require long-term thinking and sustainable design. Designers and modelers of these distributed system architectures are those who may benefit from the ORCHESTRA approach in the first place. The amount of well-specified functionality and information models both on the generic architectural level and on the risk management level may dramatically reduce the effort when breaking down user requirements into reusable components. ORCHESTRA gives the designer the foundation and important building blocks for the architecture. Furthermore, because elements of the ORCHESTRA Architecture are being fed into the standardization process at OGC and strategic European initiatives such as INSPIRE[6] and GMES,[7] the resulting system architecture is already in line with future developments.

Nevertheless, ORCHESTRA also provides immediate support for software developers who are about to design and implement geospatial applications and service-oriented architectures today, possibly directly for the Web services platform with the need to integrate existing OGC-compliant services. In this case, the existing software development tools and frameworks as well as the series of ORCHESTRA implementation specifications and service components may be used immediately. This boosts software productivity, reduces the testing effort and increases the level of interoperability.

The ORCHESTRA Offering

The offering of the ORCHESTRA project is multifold and targeted at both designers and software engineers of a geospatial SOA. It encompasses the following elements:

- a reference model based upon an ISO standard (RM-ODP) and tailored to the design and engineering of geospatial SOAs;
- an open abstract architecture containing design rules for information and service models;
- specifications, both at the abstract level and specific to the W3C Web services platform, of the most important generic architecture services derived from but not restricted to the needs of environmental risk management applications;
- software engineering components, mostly offered under an open source license, for the development of service networks including:
    * a Java-based software framework called the ORCHESTRA Service Container Framework (see Schmieder et al., 2007) that comprises programming interfaces for common service functionality (e.g., the service capabilities, access control) and an implementation of indispensable architecture services;
    * adapters to industry standard services, for example, the ORCHESTRA catalogue service as described in Hilbring and Usländer (2008);
    * design support for the mapping of service and information models from the abstract level to the Web services platform;
    * a Java-based software framework for the integration of source systems (e.g., for relational databases) into an ORCHESTRA service network; and
    * utility applications (e.g., for user management, service monitoring, catalogue navigation).
- specification and implementation of risk management services based on clear end-user requirements and validated in real-world pilot applications.

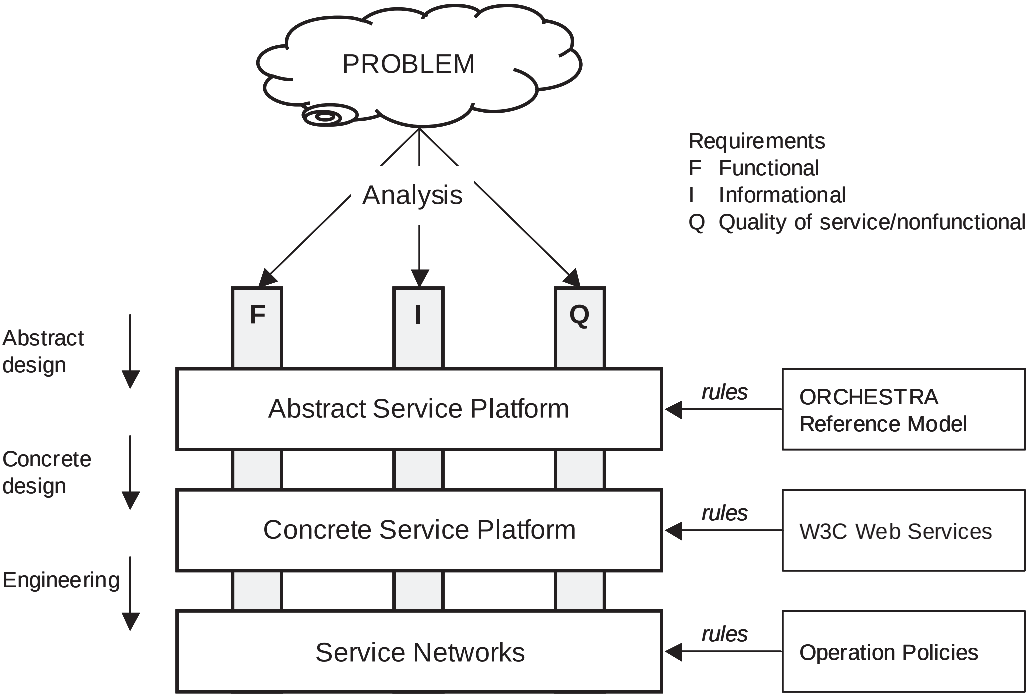
The ORCHESTRA Reference Model

The ORCHESTRA approach has been specified in a Reference Model for the ORCHESTRA Architecture (RM-OA) (Usländer, 2007). It is built upon two main pillars: a *process* model and a *conceptual* model.

The ORCHESTRA process model follows an incremental, iterative approach for the analysis and design phases across several abstraction layers. ORCHESTRA distinguishes between an abstract service platform that is specified independently of a given middleware technology and a concrete service platform (see Figure 15.3):

- In the analysis phase, the model together with the user analyze the "problem" and transform it into a set of requirements. These are categorized as functional requirements (F) that describe the use cases and processes that an SOA system has to support; the informational requirements (I) that describe the major terms and concepts the SOA system has to deal with; and the qualitative requirements (Q) that describe nonfunctional requirements dealing with quality, dependability, and security aspects.
- The abstract design phase leads to platform-neutral specification following the rules of the abstract service platform provided by the ORCHESTRA Reference Model. They represent the functional requirements (leading to abstract service specifications), informational require-

Figure 15.3 **Abstract and Concrete Service Platforms**



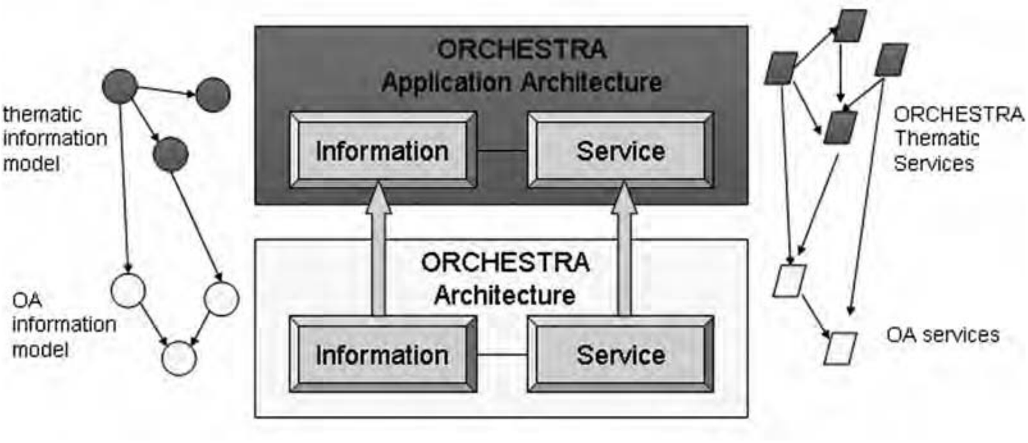
ments (leading to information models), and nonfunctional requirements (leading for instance to a specification of the quality of service of the problem domain).

- The concrete design phase maps the abstract specifications to a chosen concrete service platform. In the current ORCHESTRA project this is the ORCHESTRA Web Services platform consisting of the rules of the W3C Web services and a profile of the Geography Markup Language (GML) as the current mainstream service platform technologies for geospatial applications.
- In the engineering phase the platform-specific components are organized into service networks taking into account the qualitative requirements and translating them into operational policies.

In practice, these individual phases are often interlinked and repeated in an iterative fashion. Sometimes the abstract design phase is not required in the first place. Furthermore, existing services and OGC service standards for Web services make a pure top-down approach unsuitable. Thus, in practice, a middle-out design approach is often the appropriate method.

A clear structure for the documentation of the ideas and the results of the design phases is required. As OGC, ORCHESTRA has adopted the ISO Reference Model for Open Distributed Processing (RM-ODP) for this task. RM-ODP subdivides the specification of a complete system into so-called viewpoints. However, as the RM-ODP was originally conceived in the spirit of distributed object-oriented middleware, the ORCHESTRA process model has adapted the RM-ODP viewpoints to the design of geospatial service networks:

Figure 15.4 **ORCHESTRA Application Architecture**

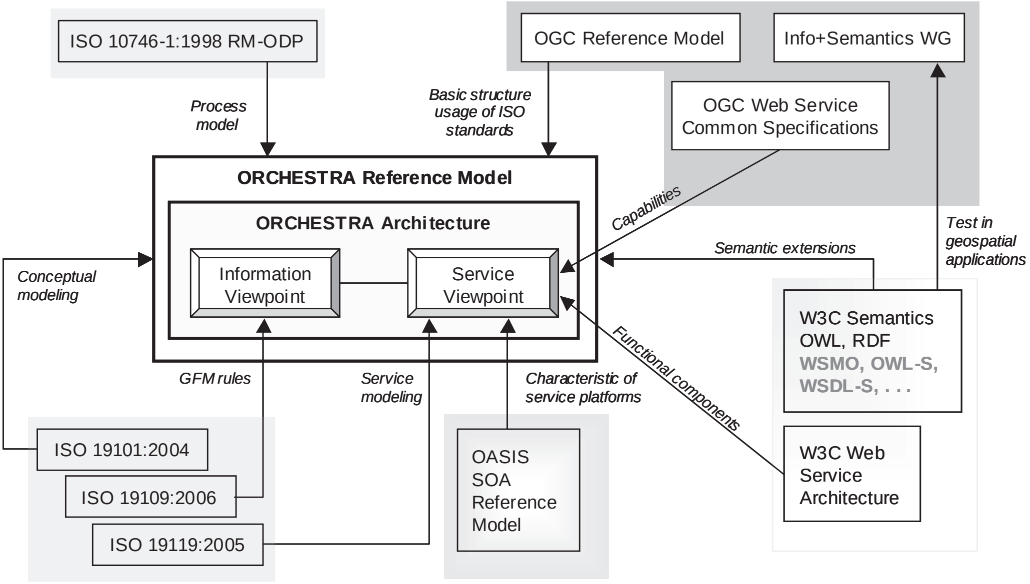


- In the *Enterprise Viewpoint* the user requirements, in terms of their functional, informational, and qualitative aspects, are analyzed and documented.
- The Computational Viewpoint is referred to as *Service Viewpoint* in ORCHESTRA in order to stress that the focus is not on providing a distributed computing support with tightly coupled components, but on interconnecting functionalities and information in terms of services. Thus, the Service Viewpoint classifies and specifies the functional requirements in terms of services. Specific to ORCHESTRA is the aim of specifying the services first in a platform-neutral manner (e.g., in UML) in order to be able to map to different service platforms as required.
- The *Information Viewpoint* classifies and specifies the informational requirements in terms of an information model. As for the services, the aim is to do this first in UML to be platform-independent.
- The *Technology Viewpoint* specifies the characteristics of the service platform upon which the services and information models are to be mapped for a specific geospatial service network.
- The *Engineering Viewpoint* specifies the mapping of the service and information model specifications to the chosen service platform(s). Furthermore, the operational policies of the service networks are derived from the qualitative requirements.

In light of these viewpoints, the specification of the Information and Service Viewpoints resulting from requirements of the Enterprise Viewpoint leads to an abstract architecture. Abstract here means that the service and information models are neutral with respect to a specific service platform and do not contain any particular dependencies on the peculiarities of a given platform. The ORCHESTRA Architecture provides significant help in this design phase as it provides a generic modeling toolbox in terms of predefined but generic information and service types upon which the functional and informational user requirements may be mapped. It is specified itself as an abstract architecture (see Figure 15.4).

Usually, not all thematic requirements may be directly mapped to existing generic information and service models. Thus, the ORCHESTRA Architecture also comprises a conceptual model[8] that provides detailed rules about how to specify in UML an information model[9] and a service model (additional interface and service types) that fit the predefined ones and adapt them for a particular

Figure 15.5 **The ORCHESTRA Architecture and Its Relation to Architecture Standards**



thematic domain and corresponding applications. Such additions lead to ORCHESTRA Application Architectures tailored to satisfy dedicated thematic user requirements, which are expressed in thematic information models and thematic services.

However, ORCHESTRA does not stop at the abstract level but also provides an ORCHESTRA Implementation Architecture for the ORCHESTRA Web Services platform. Here, ORCHESTRA delivers a software toolbox comprising implementation specifications and implementation components derived from and compliant with the abstract specifications. For the thematic information and service models of an application architecture, tools are provided to map them to this platform.

THE STATE OF THE ART: EXISTING STANDARDS OF OGC, W3C, AND OASIS

On one hand, thinking about an open architecture for risk management must target an ideal future IT infrastructure. On the other hand, it is essential to consider and to start from state-of-the-art technology in order to enable rapid implementation and migration. Today, besides the products and the technology available on the IT market, such an open approach requires considering in detail the work of standardization bodies. In the case of geospatial SOAs this approach results in a complex braiding as illustrated in Figure 15.5.

As stated in the previous section, the ORCHESTRA Architecture is not exclusively tailored to risk management applications. It builds upon existing reference models and architecture specifications of different standardization organizations in the geospatial and Web service community. The relationship between the ORCHESTRA Reference Model and the individual architecture standards is illustrated in Figure 15.5 and explained below.

ISO[10] is a network of national standards institutes of 157 countries, on the basis of one member per country, with a Central Secretariat in Geneva, Switzerland, that coordinates the system.

- The process model as applied in the RM-OA has been taken from ISO 10746–1:1998 RM-ODP,[11] but interpreted for its application in the design of an SOA.
- The conceptual modeling of the ORCHESTRA Architecture has been performed according to the basic concepts (such as feature) of ISO 19101:2004. Geographic information—Reference model.
- The ORCHESTRA meta-model for information is an evolution of the General Feature Model (GFM) as defined in ISO 19109:2006. Geographic information—Rules for application schema.
- The ORCHESTRA meta-model for services is derived from ISO 19119:2005. Geographic Information—Services.

OGC[12] is a nonprofit, international, voluntary consensus standards organization that leads the development of standards for geospatial and location-based services. On the architectural level, the following OGC standards have influenced the ORCHESTRA Reference Model:

- The OGC Reference Model (OGC, 2003) describes a framework for the ongoing work of OGC, that is, its specifications and implementations of interoperable solutions and applications for geospatial services, data, and applications. The OGC Reference Model has influenced the basic structure of the RM-OA and the usage of the pertinent ISO standards (see above).
- The OpenGIS Service Architecture (OGC, 2002) equivalent to and denoted in Figure 15.5 as ISO 19119:2005 (see the list of ISO standards above).
- The OpenGIS® Web Service Common Implementation Specification (OGC, 2005) details many of the aspects that are, or will be (because harmonization efforts are under way), common to all OGC Web Service interface Implementation Specifications. This idea has been adopted for the specification of common service characteristics in terms of reusable interfaces, for example, for the specification of their capabilities.
- W3C[13] develops interoperable technologies (specifications, guidelines, software, and tools) to lead the Web to its full potential.
- The Web Services Architecture (W3C, 2004) identifies the functional components and defines the relationships among those components necessary to achieve the desired properties of the overall architecture. Although not applied identically, the ORCHESTRA meta-model for services reuses some of the concepts and their relationships as identified in the W3C Web Services Architecture document.

OASIS[14] is a not-for-profit, international consortium that drives the development, convergence, and adoption of e-business standards. The OASIS Reference Model for Service Oriented Architecture (OASIS, 2006) specifies the common characteristics of SOAs, independent of a particular service platform implementation. The ORCHESTRA Architecture assumes these characteristics as requirements for service platforms upon which the platform-neutral ORCHESTRA Architecture may be mapped.

Furthermore, there is ongoing research work in the field of semantic extensions of the Web (Semantic Web) which has already led to a series of basic W3C recommendations such as:

- RDF[15] (Resource Description Framework) as a general method of modeling information as statements about resources in the form of subject–predicate–object expressions, called triples in RDF terminology.
- OWL[16] the W3C Web Ontology Language to define and instantiate ontologies with an increasing expressiveness according to the subvariant of the language used (OWL Lite, OWL DL, OWL Full).

Work on semantic extensions of Web Services (Semantic Web Services) has been carried out in various research projects and has been reflected in competing submissions to the W3C such as WSMO[17] (Web Service Modeling Ontology) and WSMX[18] (Web Service Execution Environment), OWL-S[19] (Semantic Markup for Web Services) and WSDL-S[20] (Web Service Semantics), resulting finally in SAWSDL[21] (Semantic Annotations for WSDL and XML Schema). SAWSDL is now a W3C recommendation that defines how semantic annotation is accomplished using references to semantic models, e.g. ontologies.

Currently, there is no standardized architecture that unifies the approaches of OGC, W3C, and OASIS for spatial and nonspatial information in a harmonized and consistent way. There are partial solutions addressed by various projects, for example, in the context of the OGC, semantic Web technologies have been applied to geospatial applications in 2005 in a Geospatial Semantic Web Interoperability Experiment (Lieberman et al., 2005) and submitted to W3C as a position paper. Current activities toward a geospatial semantic Web are being pursued in the Geo-Semantics Working Group (WG) of the OGC.

The ORCHESTRA Architecture team is convinced that it will be a challenge of the next several years to address the integration of the different approaches, not for the sake of integration but purely for the practical needs of real-world end users. Most likely, it will be up to the OGC to address the harmonization of the current OGC Reference Model with the W3C and OASIS work on service-oriented architecture and its semantic extensions.

The ORCHESTRA Reference Model and the ORCHESTRA Architecture may be seen as a test case or architectural blueprint for such harmonization activity. The requirements for the ORCHESTRA Architecture are derived from risk management applications, a field which in itself is very broad and requires generic approaches. Lessons learned from ORCHESTRA can well be extrapolated to even more general application domains.

ELEMENTS OF THE ORCHESTRA ARCHITECTURE

Functional Domains of the ORCHESTRA Service Network

The ORCHESTRA Architecture has to face the problem of integrating environmental risk management systems that are networked across and between organizations. This is the objective of the ORCHESTRA Service Networks as running instances of the ORCHESTRA Architecture.

The running components of an ORCHESTRA Service Network are the *ORCHESTRA Service Instances.* These offer functionality and interact among each other according to the *ORCHESTRA protocol,* that is, the set of ORCHESTRA rules given by the ORCHESTRA Meta-model as described below. By their joint functionality and interaction, they resolve the gap between the information demand of the user and the existing resources (data and services) offered by source systems. ORCHESTRA Service Instances (OSI in Figure 15.6 on page 358) are organized in the following functional domains.

Software components in the *User Domain* provide the interface to a user component (a human or another software component). Their interaction is outside the scope of an ORCHESTRA service network, that is, they may use a native protocol. However, when interacting with an ORCHESTRA Service Instance, they have to follow the ORCHESTRA protocol. Service Instances in the *Mediation and Processing Domain* provide the main functional part of an ORCHESTRA service network. They mediate the service calls from the User to the Integration Domain based on meta-information exchanged with the components of the Integration Domain (e.g., by means of a publishing pattern or a retrieval pattern). Service instances in the *Integration Domain* provide support for the integration of source systems into an ORCHESTRA service network. The service instances in this domain have two-sided interfaces. On one hand, they interact with other service instances according to the ORCHESTRA protocol. On the other hand, they interact with the components of the Source System Domain according to their native protocol. The *Source System Domain* incorporates the so-called source systems, that is, the systems and system components (e.g., a relational database) of a thematic application area (e.g., risk management) to be integrated into an ORCHESTRA service network. In practice, this means that their data and functionality have to be wrapped with an ORCHESTRA-compliant service interface. In order to facilitate this reengineering process, ORCHESTRA provides a dedicated software framework (see above).

Abstract Service Platform

On the level of the abstract service platform, the ORCHESTRA Architecture provides the following elements:

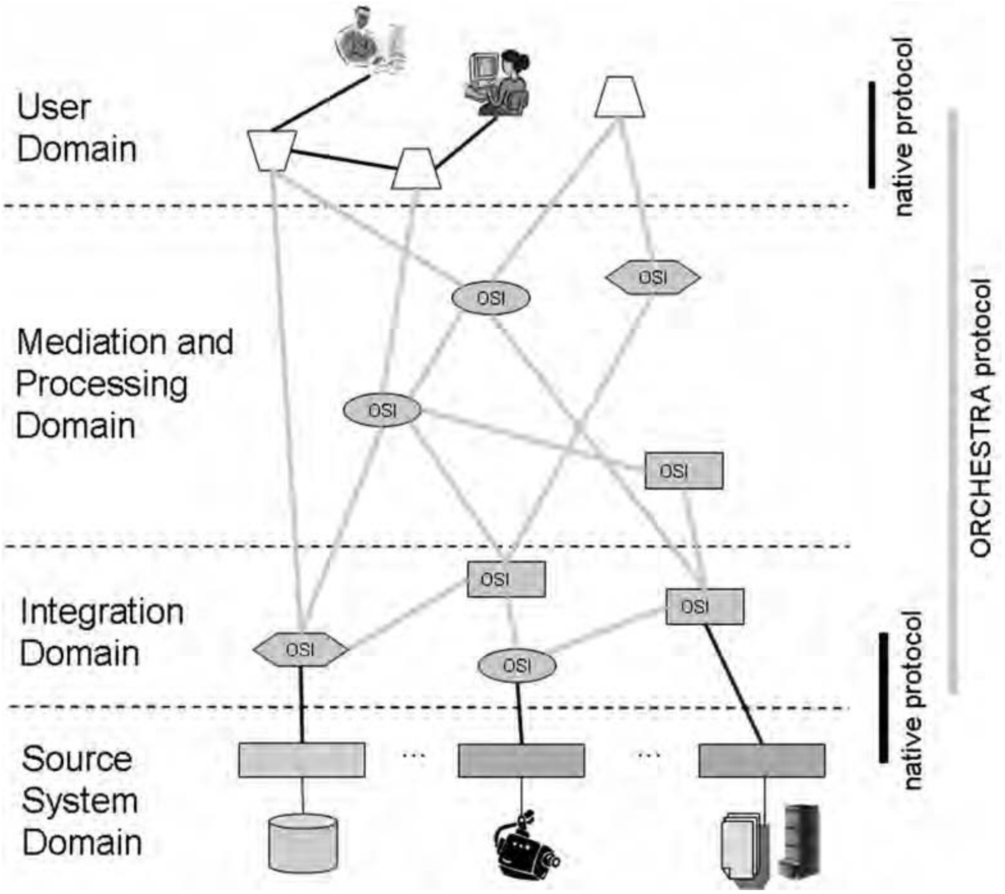
- A description framework and document templates for the textual specification of interface and service types.
- A coherent set of rules to specify interface, service, and feature types in UML and to organize them in service and information models. This rule set is referred to as the ORCHESTRA meta-model. The key aspects of the ORCHESTRA meta-model are:
  * It is an extension of the General Feature Model as used in the OGC Reference Model. It treats both information and service aspects in a consistent manner.
  * The information part of the ORCHESTRA meta-model does not prescribe a particular meta-information model, it just provides rules about how to specify meta-information models. This goes beyond the mandatory usage of ISO 19115/19119 in the General Feature Model. This approach leads to greater flexibility since meta-information in ORCHESTRA is considered to be purpose-specific, for example, for the purpose of discovery, a different set of meta-information elements may be defined than that for service composition (Schimak et al., 2007).
  * The service part of the ORCHESTRA meta-model puts the interface type into the spotlight for reusability. Interface types are specified such they may be reused across several service-type specifications. Examples of the application of this concept include the service capabilities interface type that is mandatory for all ORCHESTRA service types or the schema mapping interface type that is reused in a variant of the ORCHESTRA Feature Access Service.
- A specification of important feature types (e.g., document types) that may be reused and refined in information models.
- A specification of a series of generic interface and service types that may (and should) be reused by service modelers in the design of their geospatial SOA: starting from the interface types as the reusable specification unit, assembling them to service types, and possibly enriching them by domain-specific functionality.

Table 15.1 on page 359 lists and briefly describes the currently specified architecture service types.

Concrete Service Platform

The ORCHESTRA meta-model also provides rules that describe how to map the abstract specifications to a concrete service platform. There are software tools available from ORCHESTRA

Figure 15.6 **Functional Domains in an ORCHESTRA Service Network**



that support this mapping process for the ORCHESTRA Web services platform. In this mapping process, UML information models have to be translated to XML/GML whereas UML interface and service models have to be mapped to WSDL documents. For the service types listed in Table 15.1 ORCHESTRA provides the corresponding implementation specifications and implementations, most of them integrated in the common ORCHESTRA Service Container Framework and offered under an open source license.

When following a pure top-down approach with a 1 : 1 mapping from the abstract to the concrete service platform, the resulting Web services may not be compliant with existing OGC specifications. The ORCHESTRA answer to this problem is manifold:

- Those ORCHESTRA services that are concerned here because of their functional overlap with OGC services (e.g., Feature Access Service vs. OGC Web Feature Service, Map and Diagram Service vs. OGC Web Map Service, Catalogue Service vs. OGC Catalogue Service) may be (and mostly have been) implemented on top of existing OGC-compliant services in order to allow reuse of existing investments.
- ORCHESTRA aims at providing OGC-compliant facades for its service implementations.

Table 15.1

ORCHESTRA Architecture Services

Service and interface type name	Overview description
Basic Interfaces	Interface types enabling a common architectural approach for all ORCHESTRA Services: • self-description of service instances (capabilities) • synchronous and asynchronous interactions • transactional support
Authentication Service	Proves the genuineness of principals (i.e., the identity of a subject that may be a user or a software component) using a set of given credentials. Selected authentication mechanism is up to implementation specification
Authorization Service	Provides an authorization decision for a given authorization context. Selected authorization paradigm is up to implementation specification
Catalogue Service	Ability to publish, query, and retrieve descriptive information (meta-information) for resources (i.e., data and services) of any type: • not tied to a particular meta-information standard (e.g., ISO 19115) • supports application schemas for meta-information that are designed according to the ORCHESTRA rules • May be used as a data catalogue, service registry, or both • may be cascaded with OGC catalogues or OASIS UDDI • includes an adapter to Internet search engines (e.g., Yahoo!) • includes ontology-based query expansion and result ranking
Document Access Service	Supports access to documents of any type (textual documents, images). A document is referenced by a document descriptor, which is considered to be a specific kind of a feature type
Feature Access Service	Selection, creation, update, and deletion of feature instances and feature types available in a service network Features provided are instances of a certain feature type defined in an ORCHESTRA Application Schema. Interface may be reused by more specific access services using interface inheritance
Map and Diagram Service	Enables geographic clients to interactively visualize geographic and statistical data. Transforms geographic data (vector or raster) and/or numerical tabular data into a graphical representation using symbolization rules. The main output of this service is an image document that may be a map, a diagram, or a thematic map (visualization of the spatial distribution of one or more statistical data themes)
Name Service	Encapsulates the implemented naming policy for service instances in a service network, for example, creates globally unique service instance names using a defined naming policy. Important if several service networks across different platforms are to be interconnected
Ontology Access Service	Supports the storage, retrieval, and deletion of ontologies as well as providing a high-level view on ontologies. As an optional Knowledge Base interface, it provides operations to query and update models contained in a knowledge base
Sensor Access Service	Basic interface for accessing sensor data, configuring a sensor, and publishing sensor data. Will be replaced by services of the OGC Sensor Web Enablement initiative through the developments of the Integrated Project SANY (Havlik et al., 2006)
Service Monitoring Service	Provides an overview of service instances currently registered within service network, for example, • Actual status (e.g., running, stopped, offline) • Statistical information (e.g., average availability, response times)
User Management Service	Creates and maintains subjects (users or software components) including groups (of principals) as a special kind of subjects

Table 15.2

ORCHESTRA Thematic Services

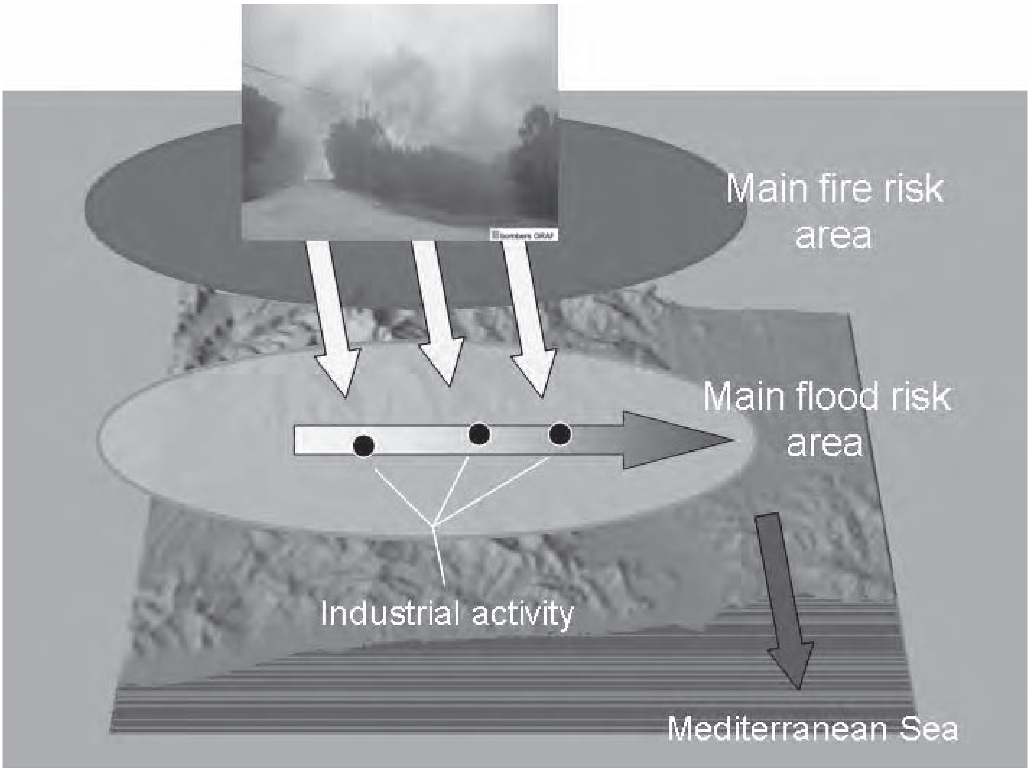
Pilot	Thematic support services	Risk-neutral services	Risk-specific services
Catalonia		Common risk calculation Differential risk calculation	Fire spread engine Hydrological/hydraulic response simulation Vulnerability calculation Altered conditions calculation
French-Italian Routes		Cost calculation Hazard data access Road acceptability criteria access Road network access Supplementary time and distance calculation Traffic information access Historical event access	
Pan-European Hazards	Processing • Join/aggregation • Normalization • Classification • Map algebra	Hazard map/feature access	
German Bight	Simulation management Simulation data		

- In the context of semantic extensions of the ORCHESTRA Architecture, the aim of the ongoing investigation is to identify how the mapping process could be made more flexible such that the discovery and invocation of OGC-compliant service operations would be mediated on the basis of the ORCHESTRA service specifications.

PILOT APPLICATIONS

The ORCHESTRA platform has been used in the development of four different pilots across Europe, and one federated pilot demonstrating how several service networks can be combined in a new service network. All four pilot applications have been carefully designed according to real-world end-user needs, and in consultation with these end users. While on one hand such end-user needs have been a priority to show the real feasibility of ORCHESTRA in the real world, on the other hand the project also tried to balance the inclusion of new and innovative aspects into the pilots. At the end of the project, pilot applications will be made available to stakeholders in the risk management community such that they can assess their usability for their operational systems. Implementation of the pilot use cases is based on the ORCHESTRA Architecture services listed in Table 15.1. Furthermore, each pilot defines an ORCHESTRA Application Architecture by developing pilot-specific ORCHESTRA thematic services according to the ORCHESTRA rules. They are summarized in Table 15.2.

Figure 15.7 **Multirisk Scenario in Catalonia**



Source: ORCHESTRA Consortium, 2007.

Floods and Forest Fire Risk Prevention Assessment in Catalonia

In the Tordera basin (Catalonia, Spain), flash floods and forest fires are two of the most important risks that regional administrations have to face every year. The pilot studies the influence of forest fire response policies and its consequences for risk planning in the Tordera river basin (Caballero and Esbrí, 2007). Although specific annual and master plans have been designed and developed for each risk by specific regional services, a new challenge, that of combined multirisk planning, entails a demand for a high level of collaboration and interoperation among the involved actors and information entities, for example, the civil protection agency and the regional water agency.

Figure 15.7 illustrates the chain of events considered in this multirisk scenario:

- Forest fires: a great part of the basin surface is made up of forests, which have often suffered fires
- Hydrology (link to erosion and landslides): after a fire, there is a change in the rain transformation into flow
- Hydraulics (link to floods): an extraordinary stormy event results in a flood
- Sediment transport due to erosion and floods
- Pollution (substances transport due to forest fire, industrial spill, or flooding of industrial zone) may be triggered by flooding of industrial areas

- Riverside and floodplain ecology (link to environmental damage) may be affected by sediment transport, pollution, and even by flooding alone
- Public health: may be affected by sediment transport, pollution, and even by flooding alone

Analysis of the problem domain has led to the following use cases:

- Calculate the danger level of a flash flood or forest fire event
- Produce a risk map of a given event (fire or flood)
- Produce a common risk map of a multirisk scenario (fire and flood)
- Consider the changes in soil properties due to a forest fire event
- Produce a differential risk map of flash flood (with and without a fire event)
- Manage the vulnerability rules for risk estimation

Assessment of Risk Associated with Roadblocks in the French-Italian Border Region

This pilot deals with risks due to disruptions in the road network (Douglas et al, 2007). Road transport plays an important role in the economic, functional, and social life of a region. For example, roads enable the transport of commodities from their source (e.g., a factory) to the distribution center (e.g., a shop) and of consumers from their homes to the distribution center. Therefore, disruption to a road can have a dramatic impact and lead to extra costs, inconvenience, and, within the post-event phase of the disaster cycle, difficulties in accessing affected communities. Roads can be disrupted (e.g., blocked) by a number of different events, for example, direct surface rupture or liquefaction caused by an earthquake, landslides (however caused), fire (forest or otherwise), floods, chemical incidences, avalanches, volcanoes, and storms (for example, by the falling of trees). Focusing on the effect of an event, where the cause of the event is not vital, makes the proposed pilot multirisk. In addition, since the risk does not need to be specified, all of the ORCHESTRA thematic services required are risk-neutral. Analysis of the problem domain has led to the following use cases:

- Find routes cut off by a possible event
- Find roads exposed to hazard
- Find alternative routes after a route is cut off
- Calculate loss of revenue and cost of route unavailability due to the closure of road sections
- Calculate estimated time of unavailability

The implementation of these use cases demands access to sensitive data of multiple stakeholders. Thus, there is a need for a sophisticated access control policy. In this context, the pilot investigates whether and how the concepts of rights management may be implemented based on the ORCHESTRA services for user management, authorization, and authentication.

Pan-European Hazard Assessment

This pilot is meant to test the ORCHESTRA Architecture within the setting of various pan-European hazard-assessing use cases. The pilot focuses on risks related to natural hazards, more precisely, on the hazards of flooding, droughts, and forest fires (Bernard et al., 2007). The results of the pilot support decision makers in the European Commission to assess the risk of forest fires in the member states of the European Union, to support forest fire prevention, and to provide tools for the assessment of damage caused by disastrous events such as floods and storms in the member states of the European Union according to different scenarios and historical events. The pilot on pan-European hazard assessment basically considers two use cases:

- Integration, aggregation, classification, and visualization of national forest fire records at a regional or pan-European level
- Development of tools for user-driven or scenario-based damage assessment caused by natural hazards at a regional and pan-European level

The proposed pilot focuses on a number of technical aspects:

- Automatic schema mapping from (heterogeneous) national data sources (spatial and nonspatial data) into a common pan-European model
- Combination of spatial information and spatial decision support (functionalities for geostatistical analysis, classification, aggregation, multicriteria decision support) while exploring the semantic orchestration of services
- Support of the assessment of hazards and related vulnerabilities by offering not only static maps but applications that allow users to define criteria and related weights and integrate additional information in an interactive manner thus providing a more transparent way to generate vulnerability maps
- Define and use of ontologies to describe complex hazard and vulnerability analysis tasks targeted toward the generation of risk maps

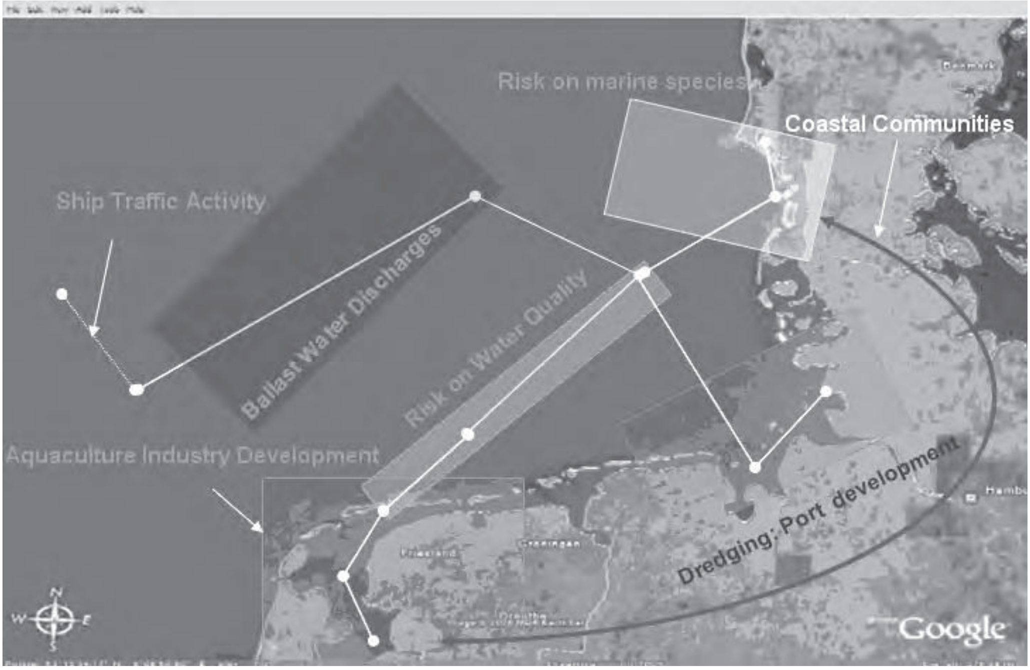
Environmental Risks Due to Ship Traffic in the German Bight

The pilot focuses on the evaluation of the multiple risks that ship traffic activity may generate in the marine area of Germany, Denmark, and the Netherlands (called the German Bight). Chemical pollution from ships can represent a multirisk management situation in coastal regions, particularly for fishing, aquaculture, marine and coastal conservation areas, and tourism. In addition to the biological and physiological effects on marine organisms, there can also be adverse effects on the environmental food chain (including humans) and the balance of various marine ecosystems. As a result, it is important to address such issues by providing information to operators and regulators for monitoring and quantifying the impact of ship traffic activity and the possible discharge of antifoulants, toxic chemicals, or other hazardous substances in the German Bight region (see Figure 15.8). Based on models and simulation runs, the user is able to dynamically determine geospatial risk maps for the probability of the risk of exceedance of antifoulants exposure in the German Bight. For instance, the core object model “Ship Traffic Risk Evaluation And Management” will initially provide simulation runs of antifoulant exposures from ship traffic activity in a yearly period around the German Bight for user-defined traffic route scenarios.

These risk maps will cover the German Bight and can be shared by the various coastal operators and regulators across the three European member states. Once established, the simulation model, through the ORCHESTRA infrastructure, will be able to expand the dissemination of information to stakeholders with other types of risks within the coastal zone, rather than antifoulants, for example:

- Environmental and health risks associated with ballast water discharge;
- Ships’ emissions and risk of atmospheric pollution;

Figure 15.8 **Ship Traffic Risks in the German Bight Region**



Source: Source of background map: Copyright © 2005 Google™.

- Risks of changes in seawater temperature;
- Risks associated with increased nitrate levels; and
- Ships' risk of collision and risks of oil (or chemical spill) including effects.

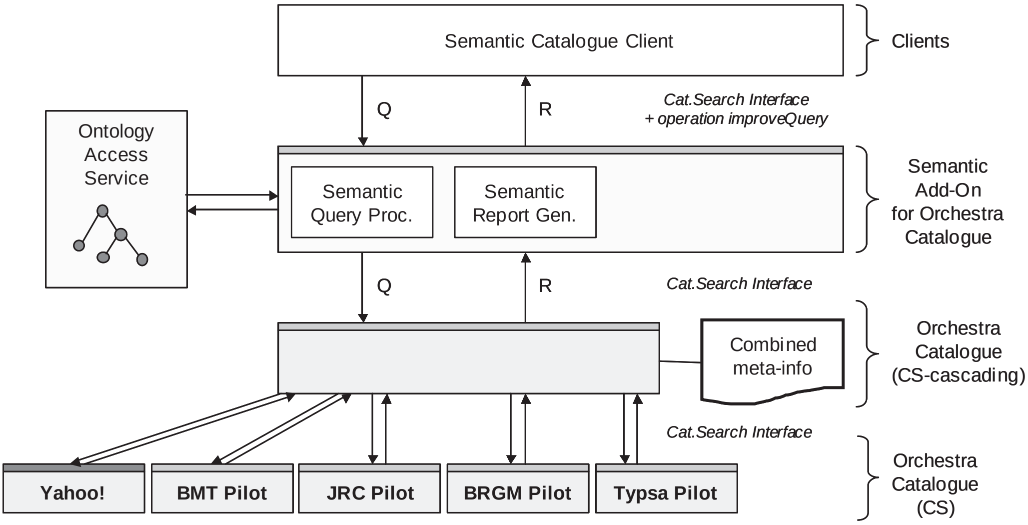
LESSONS LEARNED AND NEW OPPORTUNITIES

The design of an open architecture for environmental risk management applications is a balancing act between two opposed requirements: on the one hand, the need for long-lived systems that can survive ongoing technology changes, especially in the field of IT infrastructure, and on the other hand, the need to observe important de facto and de jure standards in order to exploit the potential current state-of-the-art technology and have immediate acceptance on the market.

The lessons learned from the ORCHESTRA project in view of this conflict are manifold:

- There is a need to jointly think about a long-term strategy on IT infrastructure. A common decision must be made between the emergency and risk managers and the IT providers on how "generic" the design of the application should be.
- An iterative architectural design with clear deployment milestones that focus on the most important functionalities is best suited to minimize architectural design risks. However, such a strategy sometimes conflicts with existing tender regulations and practices of public agencies.
- A good generic design of architecture services enables use in different domains including cross-domain applications.

Figure 15.9 **The Semantic Catalogue in the ORCHESTRA Federated Pilot**



- An established standard service infrastructure does not solve the problem of semantic interoperability. New approaches and technologies stemming from the research domain of the Semantic Web are promising candidates for improving the level of interoperability. However, they will be successful only if there is a willingness to agree on content standards such as domain models and domain ontologies, at least in dedicated communities and possibly in a modular way.

The possibility of combining the ORCHESTRA services in a flexible manner and enriching them by semantic technologies opens the door to new opportunities. An example is the ORCHESTRA federated pilot that provides a common entry point for resource discovery in ORCHESTRA service networks. This federated pilot is implemented by semantic enhancements of the ORCHESTRA Catalogue Service. Catalogues are important tools for mediated access to resources, that is, they support the discovery of information and services for the user (Hilbring and Usländer, 2008). They return descriptive information (meta-information) about a resource, including a handle to access it. Thus, the meta-information stored in the catalogue is mainly used to discover resources (i.e., sources of information or operational service instances). It is structured according to that purpose. Catalogues may be cascaded in order to combine different discovery domains. Semantic enhancements as implemented by ORCHESTRA focus on two aspects: (1) User queries may be expanded by exploiting defined relations between concepts in an ontology or by exploiting statements in a knowledge base. For the retrieval of ontological concepts and the ontology management in the context of the catalogue service the ORCHESTRA Ontology Access interface is used. (2) The search results may be annotated (i.e., linked to ontological concepts) using the ORCHESTRA Annotation Service. This helps a user to better classify the information received and relate it to his/her thematic domain.

This approach is now used for the federated pilot (see Figure 15.9). An “ORCHESTRA demonstration ontology” contains all the relevant information about the ORCHESTRA project (project structure, partners, publication, etc.) and all the important concepts of the ORCHESTRA Architecture, such as the list and structure of the ORCHESTRA service types. A user can now query the semantic catalogue with “Thematic Services.” The federated pilot catalogue expands the query to all thematic service types known in the ontology, forwards the query to all pilot catalogues, and collects the results. It organizes the individual results according to the structure of the ontology and gives back to the user a combined result, in this case, descriptive information about all thematic services available in all pilots. Using a dedicated adapter, the query may also be sent to an Internet search engine (e.g., Yahoo!) in order to retrieve in addition all published information (e.g., documents, Web sites) about ORCHESTRA thematic services. Note that the result set of the cascaded catalogue search changes when the ontology is replaced. Ongoing research investigates how the ranking of elements in the result set may be determined by its degree of relevance with respect to the ontology.

RESULTS AND OUTLOOK

The ORCHESTRA Reference Model as presented above was accepted as best practices document (OGC 07–097) by the Open Geospatial Consortium in September 2007. Its process model is already being reused by other initiatives such as the European Integrated Project SANY[22] (Havlik et al., 2006) for the specification of a Sensor Service Architecture (Usländer, 2009) and the GMES Heterogeneous Mission Accessability (HMA)[23] project for the design of a uniform data access architecture of heterogeneous earth observation missions. Today, the focus of the conceptual model of the ORCHESTRA Reference Model lies on syntactic interoperability. The thorough analysis of user requirements has led to the specification of a series of generic services that provide powerful and indispensable functionality for the design of geospatial SOAs in the domain of environmental risk management and beyond. Implementation specifications for the W3C Web services platform and corresponding implementations are available and will be offered under an open source license.

However, the ORCHESTRA Architecture has already opened the door to future enhancements. More powerful service platforms currently being specified by the Semantic Web Services community are emerging (OASIS, 2006). Ongoing activities aim at extending the ORCHESTRA Reference Model such that these new technologies may be embedded and exploited. The application of semantic ORCHESTRA services in pilot test beds (Bügel and Hilbring, 2007) are the first steps in this direction and will provide important feedback about how semantics can be used in real-world use cases. Further extensions such as the inclusion of sensor Web environments and the integration of information fusion technologies are being investigated in the SANY project.

APPENDIX 15.1

LIST OF ACRONYMS

GMES	Global Monitoring for Environment and Security
GML	Geography Markup Language
HMA	Heterogeneous Mission Accessibility
INSPIRE	Infrastructure for Spatial Information in Europe
ISO	International Organization for Standardization
OASIS	1. IST FP-6 project: Open Advanced System for Improved Crisis Management 2. Organization for the Advancement of Structured Information Standards
OGC	Open Geospatial Consortium
ORCHESTRA	Open Architecture and Spatial Data Infrastructure for Risk Management

OSI	ORCHESTRA Service Instance
OWL	Web Ontology Language
OWL-S	Web service ontology based on OWL
RDF	Resource Description Framework
RM-OA	Reference Model for the ORCHESTRA Architecture
RM-ODP	Reference Model for Open Distributed Processing
SAWSDL	Semantic Annotations for WSDL and XML Schema
SANY	Sensors Anywhere
SOA	Service-oriented Architecture
UDDI	Universal Description, Discovery and Integration
UML	Uniform Modeling Language
W3C	World Wide Web Consortium
WFS	Web Feature Service
WSDL	Web Service Description Language
WSMO	Web Service Modeling Ontology
WSMX	Web Service Execution Environment
XML	Extensible Markup Language

NOTES

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1. Center for Disaster Management and Risk Reduction Technology (CEDIM), located at the University of Karlsruhe (TH) and the Geoforschungszentrum (GFZ) in Potsdam (available at www.cedim.de/english/905.php, accessed on May 18, 2009).
2. The complete definition in ORCHESTRA is a follows: "A service is generic, if it is independent of the application domain. A service infrastructure is generic, if it is independent of the application domain and if it can adapt to different organisational structures at different sites, without programming (ideally)." See www.eu-orchestra.org (accessed on May 18, 2009).
3. www.oasis-fp6.org (accessed on May 18, 2009).
4. ISO/IEC 19501 Unified Modeling Language.
5. Open Geospatial Consortium, www.opengeospatial.org (accessed on May 18, 2009).
6. Infrastructure for Spatial Data in Europe, http://inspire.jrc.it (accessed on May 18, 2009).
7. Global Monitoring for Environment and Security, www.gmes.info (accessed on May 18, 2009).
8. In modeling terms, this conceptual model is a meta-model.
9. In modeling terms, also referred to as application schema consisting of feature types and their relationships.
10. International Organization for Standardization.
11. Information Technology—Open Distributed Processing—Reference model.
12. Open Geospatial Consortium, www.opengeospatial.org (accessed on May 18, 2009).
13. World Wide Web Consortium, www.w3.org (accessed on May 18, 2009).
14. Organization for the Advancement of Structured Information Standards, www.oasis-open.org (accessed on May 18, 2009).
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CHAPTER 16

EMERGENCY RESPONSE INFORMATION SYSTEMS

Past, Present, and Future

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

Abstract: *This chapter briefly reviews some of the history of information systems for emergency preparedness and response, and then focuses on current issues and some important themes that were not adequately covered in the previous chapters. It ends with a review of some of the major problems that remain in bringing about integrated systems to facilitate all phases of emergency preparedness and management.*

Keywords: *Emergency Response Information Systems, Muddling Through*

> *A Seer upon perceiving a flood should be the first to climb a tree.*
> —Kahlil Gibran

In the process of compiling this book we have certainly encountered an amazing amount of useful and extraordinary material for anyone who is interested in the subject of emergency management information systems (EMIS). However, we also uncovered a great many challenges and problems that inhibit the design, creation, and utilization of useful systems.

In 2004 a workshop was held in Brussels (Van de Walle and Turoff, 2006) on this topic, which led to a paper on the design of these systems based upon a keynote offered by the first author of this chapter (Turoff et al., 2004a). This workshop, at which only a handful of professionals were expected, had to close the doors after eighty registrations because of a lack of space. Some of the important observations that became clear at that event were the following.

First and foremost, it became obvious that current research and development (R&D) in the field is very strongly compartmentalized by specific application areas within the field of emergency preparedness and management (e.g., fire, law enforcement, medical, infrastructures, etc.) because of the way funds are dispensed along application subfields. This was as true of the efforts in Europe as for those in the United States. There was a lack of current opportunities for those concerned with the design of better systems to consider the large basic set of problems that cut across all application areas:

- Metaphors for design that treat underlying fundamentals such as workflow, roles of participants, integration of data across separate application domains.

- Lack of understanding with respect to integration across the complex array of phases in both the consideration of terrorism as well as natural and other man-made disasters:
  - * Planning (for all phases or functions)
  - * Mitigation (long-term reduction of risk)
  - * Training (for all phases)
  - * Detection and warning (for all disaster types)
  - * Preparedness (pre-disaster event readiness)
  - * Response (to a disaster event usually short term)
  - * Recovery (which is very dependent on all of the other phases).
- Lack of commonality with respect to interface design, visualization, and decision support, making it difficult for practitioners to master a range of very different systems necessary to their concerns.
- The separation of threats by source (terrorism, natural disasters, and man-made disasters) with very different priorities for different phases and dissimilar activities.
- Lack of major integration requirements across organizations.

The above properties result from a web of deeper problems that tend to prevent the actions and developments that are needed. For example, the common perception is that the response phase of an emergency will last only a week or two. However, this was not the case with the anthrax emergency in the United States, and clearly, the response phase of Hurricane Katrina was far in excess of what usually occurs in urban areas. If we ever encounter a true pandemic, the response phase will last years. Fundamental issues of this sort greatly impact the design of information systems to deal with all of the phases that can occur in any of these events. In this chapter we raise a number of such issues that need to be more explicitly exposed, investigated, and treated to ensure that information systems can deal with likely future occurrences as well as to ensure an understanding the implications of past ones. We also suggest that near-future R&D in EMIS include especially applications of social computing that can coordinate citizen action in disaster preparedness and response. The specific sections on challenges for the future are:

- The lack of an integrated structure and ethical policy for dealing consistently with all types of disasters, at least in the United States
- The problem of information overload for emergency management professionals
- The critical processes of cooperation, coordination, and collaboration
- The planning, policy analysis, and decision process of “muddling through”
- Social computing, community involvement, and citizen participation as the future road to successful emergency preparedness and management
- Quality of information problems and issues
- Risk analysis, stakeholder analysis, and community systems

LACK OF GOVERNMENT TRANSPARENCY AND AN ETHICAL STANCE

In the United States prior to the mid-1970s, before the termination of the Office of Emergency Preparedness (OEP) in the Executive Office of the President, a general ethical stance governed the laws passed by Congress and the operational practices of OEP triggered by executive orders for exercising civilian command and control over any declared national emergency. OEP could utilize all necessary federal resources to restore the situation that existed (as far as possible) before the disaster. The ethical stance that it operated under was:

> No person or organization should profit from a disaster.

This meant that all federal actions and programs were clearly interpreted to bring an individual, town, or region back to the same state it was in prior to the disaster. This had its problems. For example, if a federal program put in money to help rebuild infrastructure such as a bridge, it would only put in enough to rebuild the same bridge. If the bridge was weak relative to serious recurrent floods, it would be swept away again in the next disaster. The last director of OEP, General George A. Lincoln (1968–1973), had this policy changed so that the local community or state could put in more funds to build a better bridge. However, knowing the government would do it again, the local communities rarely decided to improve the infrastructure. We see this today in the growing age of all forms of infrastructure where maintenance and improvement are easy areas for officials to reduce spending in tight budget times and leave the problem for future years and future officials to deal with. The paradox of this policy is also illustrated by the example of bringing in new trailers bought on the open market to house those who have lost their homes. If these were poor sharecroppers who had lived in tin shacks, they would have the use of the trailers only until the tin shacks could be rebuilt.

Whatever the faults of this clear ethical stance, everyone knew what to expect when a disaster occurred and what they could expect from all levels of government given a disaster situation. Today there is no way a U.S. citizen or an organization can be assured of what to expect from local, state, or federal government if they face a disaster. We have extremes where either little or nothing is provided to some (Katrina) or very generous compensation is given to others (9/11). This area of concern needs to be a more recognized public policy issue.

In terms of the pragmatics of developing information systems, how can an emergency management professional plan for many of these areas without knowing what will be expected in terms of recovery and vulnerabilities, because meaningful mitigation and preparedness policies are lacking? If the planner cannot plan, how can the designer and developer create systems to meet unknown requirements? How do volunteer and private organizations integrate themselves into the process when plans are missing (or highly inadequate or incomplete) for many of the components of the disaster phases?

INFORMATION OVERLOAD IN EMERGENCY PREPAREDNESS

In 2001, before the creation of the Department of Homeland Security (DHS), the major U.S. federal agencies involved in any disaster were:

- National Coordinator for Terrorism (Executive Office)
- Federal Emergency Management Agency (FEMA)
- Department of Commerce
- Department of Transportation
- Department of the Treasury
- Department of State
- Department of Health and Human Services
- U.S. Agency for International Development
- Environmental Protection Agency

- Nuclear Regulatory Commission
- Department of Justice
- Department of Agriculture
- General Services Administration
- Department of the Interior
- Department of Energy
- Department of Defense
- Department of Central Intelligence
- American Red Cross (given congressional authority for supplying shelters)

For a complete summary of all the subagencies and components, totaling about 160, see Figure 16.1, the organizational chart for emergency management in the U.S. government in 2001.

This was the situation before a major change occurred with the creation of the DHS. However, the only real change was that FEMA (6 boxes out of about 160) was taken out and placed in the DHS. Many of these agencies such as the Department of Health and Human Services (e.g., Centers for Disease Control), Department of Agriculture, and the Department of Defense had and still have very major responsibilities.

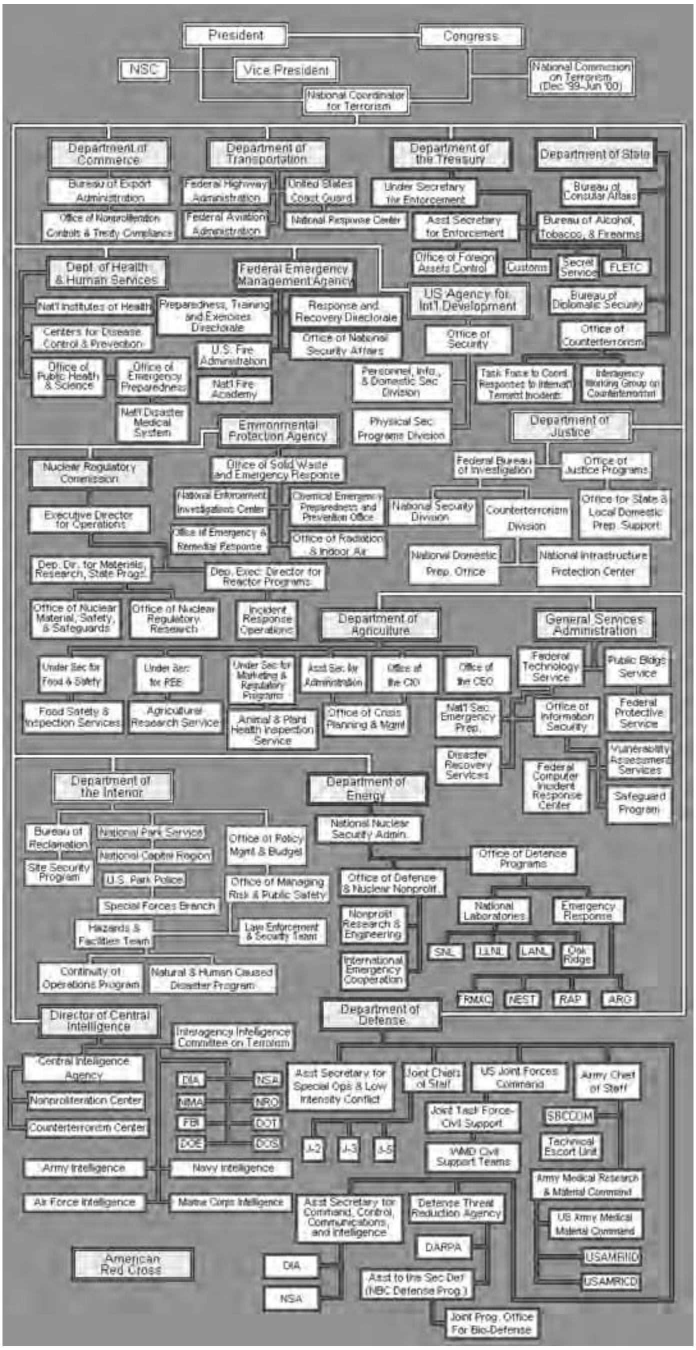
In the OEP days, the Department of Defense was the major agency for resources that were crucial to quickly provide transportation, communications, rescue, medical, and logistics for any major disaster where the local infrastructure could no longer support these functions. Anytime a federal emergency was declared in an executive order, OEP had immediate command and control authority over any federal resources and could draft any federal employee as a temporary OEP employee for the duration of the emergency. As a result, there was never any problem in coordinating the federal agencies and OEP itself was always in the range of only 300–500 employees. There was no need to place all federal resources into a single agency and, in fact, FEMA, when it was created, had only budget authority for Federal Disaster Aid programs and was never given a command and control authority such as OEP had. Any organizational memory seemed to be nonexistent in that formation process.

As a result of the creation of the Department of Homeland Security after 9/11, FEMA, which was the only agency to coordinate as an equal among the other federal agencies, was pulled out of the mix of the other agencies. For example, when the United States had the anthrax event, there was an internal policy conflict between the Centers for Disease Control (CDC) and the Federal Bureau of Investigation with respect to releasing public information (a CDC policy for infectious diseases) or withholding information (an FBI policy for not informing lawbreakers of what was known about such a crime) that was not really resolved internally in the government, but only by the press releasing information when they discovered what was occurring.

Note in Figure 16.1, the mention of the Red Cross, which is not federal but plays a major role in disaster response as do many other organizations that are not listed and not included within the formal coordination process among federal agencies. These participating nongovernmental organizations and community volunteer groups have never been truly integrated into the command and control systems used in disaster response, which leads to all sorts of shortcomings in the supporting information systems. For example, the release of someone from the emergency medical treatment process often occurs without any update to community support groups that might take over the recovery process for that individual.

The result of this history in the United States has been an unclear command and control structure at the federal level in a natural disaster or man-made infrastructure problem such as a commodity shortage. There is no single source of collaboration among all those involved, including the state

Figure 16.1 **Organizational Chart for Emergency Management in the U.S. Government in 2001**



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and local governments, and no single source for the collection and dissemination of plans and best practices for any or all of the many phases of the emergency-preparedness process. Instead, there are numerous fragmented sources in specific areas, where some organizations or agencies have many more resources than others. The results for the practitioners are a proliferation of diverse documents handled in the absence of any systematic approach, which has caused practitioners in all areas and phases of emergency preparedness and management to be overwhelmed with information that they cannot adequately find, filter, or utilize (Turoff and Hiltz, 2008a).

While there are significant efforts to overcome this problem in the medical emergency area, even there the primary current emphasis from an information science viewpoint is on classical information retrieval utilizing largely academic sources of literature. There are no systematic attempts to collect best practices, working plans, case studies, and other sources of what is commonly called the “gray literature.” A search on the Web for “emergency management” or “emergency preparedness” turns up about 9 million hits. The recent study of the behavior of practitioners in this area clearly identifies that they all feel the problem of information overload. Just joining a few of the relevant message lists produces hundreds of new documents every week. Many emergency practitioners feel these documents might contain something useful, but they have no time to skim such a large number of documents. They have a very real feeling that something there might improve their performance, but they have not seen it (Turoff and Hiltz, 2008a, 2008b). There is no library-type organization that takes the role of integrating all this material into an index relevant to all of the different concerns in the United States or internationally.

The resulting design for the emergency response community as an to attempt to solve their information overload problem involves interpreting their requirements to create a new type of information-recommender system controlled by the practitioners themselves. Such a system would have to allow vetted practitioners in emergency preparedness and management (EP&M) to:

1. Nominate documents to be included
2. Retrieve and skim or read these documents
3. Comment on the usefulness of a given document
4. Vote on the usefulness of a document if they are vetted professionals in a specific area
5. Be able to view very useful documents rated as such by others who are in the same specific areas of EP&M as themselves
6. Provide visualizations of document clusters on an interval scale such as provided by Thurstone’s law of comparative judgment utilizing comparative votes on the documents
7. Change their vote or viewpoint at any time based upon the discussion provided by the group
8. Do collaborative tagging to let the community keep the indexing tags for documents current and evolving with the latest changes in knowledge
9. Provide vote summaries broken down by the types of professionals who voted on any particular document (medical, fire, hazards, etc.)

This would represent a system supporting a “community of practice” to accumulate and acquire its own knowledge base of what it considers the most current and useful material for its field of endeavor (White et al., 2008a, 2008b, 2007a). But all of the above is somewhat foreign to the classical approach to information retrieval and would bypass the current journal industry. Essentially, a recommender system for a community of practice would take control of the literature out of the hands of journals, reviewers, and the publishing industry, significantly reduce costs, and allow total control of the process by the actual users themselves. It would be the ultimate “open access" system (Poynder, 2008). It would still require vetting the contributors to ensure that they are active and knowledgeable professionals in a particular aspect of EP&A. Also, editors would still be needed in specific areas to look for anomalies of strong disagreements among professionals that should be investigated. Even Wikis today now have roles for editors for given pages to assess changes and conflicts.

It is quite evident from the many message lists, blogs, and newsletters now offered in this area that many professionals are doing a lot of volunteer work to help filter and sort material for the benefit of other professionals in their community. What they need is a system that is really structured to make this process much more efficient than trying to use simple messaging, newsletters, and blogs. This type of system is based very much on the Delphi Concept for use by professional communities of practice and has been termed both as Social Decision Support Systems and/or Dynamic Delphis as well as being a collaborative recommender or marketplace system (Linstone and Turoff, 1975; White et al., 2007a, 2007b).

COOPERATION, COORDINATION, AND/OR COLLABORATION

Too much of the literature confuses collaboration with terms like *coordination* and *cooperation*. What we need for emergencies and disasters is true collaboration among members of the group that forms to solve a given problem as defined in the following scale of group communication commitment:

Degree of group communication commitment scale

1. Competitive—no trust in passed information
2. Informative—honest information exchanged on what is being done by each party
3. Coordinative—mutual scheduling of what tasks each party is doing and when
4. Cooperative—mutual agreement on what tasks each party is going to do
5. Collaborative—mutual agreement to work together on the same tasks

Many problems are unpredictable, and it is also highly uncertain who needs to be involved in a given problem at a given moment. These problem-solving groups are self-determined, and a given individual may be involved in other such groups at the same time. Supporting information systems must allow individuals to perceive the problems that they might be able to contribute to resolving as they occur. This is one reason why such collaborative systems must provide transparency of what is going on to all the participants and must include very dynamic updating (Turoff et al., 2008).

In his book, *The Intelligence of Democracy,* Lindblom (1965, p. 3) put it in very clear terms: "that people can coordinate with each other without anyone's coordinating them." In disaster planning and response, full-scale collaboration is needed, and we would extend the above quote to encompass coordination, cooperation, and collaboration. This view flies in the face of classical views of management that do not recognize the potential capabilities of fully distributed collaborative networks of individuals and the potential for "collective intelligence" (Hiltz and Turoff, 1978/1993). This can occur only if some degree of true collaboration is undertaken.

Many of the proposed automated approaches to handling events in disasters are a waste of time. What we need are creative and dedicated individuals trained and motivated to deal with the unexpected. This view is shared by others as well (Carver and Turoff, 2007; French and Turoff, 2007). Where we need automation is in helping to reduce information overload in the emergency management field, which is growing a lot faster in its volume of documents than in the wisdom we are seeking. Too much that obviously has to be done is not being done, for example, because of our increasingly aging infrastructure and a lack of emphasis on mitigation in emergency preparedness. Perhaps the one effort that might turn this around is the creation of an emergency preparedness and business continuity audit that would create a comparative measure for a given type of organization or facility of how well prepared it is for an emergency event (Turoff et al., 2006).

Often emergency teams are partially distributed virtual teams, and disasters that cross political boundaries are more representative of the situation that needs true virtual team collaboration. Historically, this area has seen a great deal of prior work at NJIT (New Jersey Institute of Technology) on such topics as software development teams and project management teams (Hiltz et al., 2006). A partially distributed virtual team is a hybrid team whereby some individuals are collocated in subgroups, and the subgroups are distributed from one another (Huang and Ocker, 2006). In an emergency, people from each organization involved in the response may form such distributed collocated subgroups. The challenge is for the subgroups to form an effective team. A system must enable the teams to overcome the inherent difficulties of working in such teams. For example, collocated members may tend to have “collocation blindness” (Bos et al., 2006) whereby they resist reaching out to distributed members even when the best expertise lies outside of the collocated group. Deferring to expertise (high reliability theory, Weick and Sutcliffe, 2001) is too often lacking in behavior during extreme events.

Real-time, effective decisions are required of experts collaborating on management and response. Without effective response, outcomes can be catastrophic, with more dire consequences than expected or experienced previously. Errors in management and decision making can exacerbate the situation and result in greater injury, loss of life, or a disastrous financial toll. Lessons learned from past experiences include the need for a feedback mechanism in a support system so that the processes of an event can be critiqued and further utilized to promote learning from failures. Characteristics or values of success need to be identified and integrated into the information system. Expecting the unexpected and managing disasters effectively calls for a system with dynamic features conducive to supporting group collaboration on a large scale.

MUDDLING THROUGH

Too many people seem to feel that dealing with an emergency can be a very well-planned process, where the results of the emergency are very predictable and what can be done about it can be very well planned, and that anyone can be trained to act properly when the emergency occurs. There is often too much emphasis on treating the emergency problem as some sort of scientific process that is completely understood, and the assumption that intelligent agents can be used to take over many functions such as recommending actions and executing them. The real nature of any emergency, and especially one that becomes extreme or extends over a wide area, is the need to deal with the unexpected and with situations that were not predicted ahead of time. Even in the same type of disaster in the same area, whether a tornado, hurricane, flood, or bomb threat, the circumstances may result in different challenges. For example, one hurricane may present different challenges because of which areas are flooded, how much rainfall has occurred, what collateral damage has occurred (such as release of toxic materials), and so on. What is critical about making an emergency plan is not what specific decisions are made but what the process for making decisions is and who needs to be involved to deal with a specific problem. Disasters recognize no geographical, political, or other man-made boundaries. The wider the scope of the disaster the more that many different organizations not only have to coordinate but also may have to fully collaborate in dealing with a single specific problem.

In 1959 Lindblom wrote a classic paper about the concept of making decisions by “the science of muddling through" rather than by a "scientific" process of setting goals and deducing logical resulting actions. Though this was mentioned briefly in the chapter on the threat-rigidity syndrome, it is worth revisiting this concept in more detail. The following summarizes and contrasts the two views of decision making discussed:

1. Scientific deductive decision making with complete knowledge of all relevant variables and values from which an optimization can be made by use of resulting obvious criteria for the decisions.
2. The subjective comparison of a limited number of alternatives relying heavily on experts and their past experience and expertise, where they are focusing on a judgment based upon a few of the most important values ("muddling through").

This might be an oversimplification of a superb paper proposing a different form of decision making for governmental decisions at all levels. However, it strikes us that in the context of the unexpected such as occurs in disasters and emergencies, "The Science of Muddling Through" should be required reading for practitioners, designers, and researchers concerned with emergency preparedness and management.

In 1979 Lindblom published a follow-up paper restating the concepts of muddling through in a comparative analysis of different types of "incrementalism." In that paper he listed the stratagems for muddling through that could also be termed as "disjointed incrementalism." What is relevant for our purposes is how similar they are to the concepts underlying high reliability organizations and concepts of "sense making," which are increasingly popular in emergency management operations (Van de Walle and Turoff, 2008). Quoting Lindblom from the 1979 paper (p. 517):

1. A greater analytical preoccupation with ills to be remedied than positive goals to be sought;
2. A sequence of trials, errors, and revised trials;
3. Analysis that explores only some, not all, of the important possible consequences of a considered alternative;
4. Fragmentation of analytical work to many (partisan) participants in policy making (e.g., stakeholder analysis and community participation).

We must also include one other passage (Lindblom, 1979):

> A fast-moving sequence of small changes can more speedily accomplish a drastic alteration of the status quo than can an only infrequent major policy change. (p. 520)

The above seems to be the way practitioners have to actually plan and execute responses and recovery in this field. It is also the way significant change can be brought about in the other phases of emergency preparedness.

What Lindblom wrote sounds a lot like the theory of a High Reliability Organization (HRO), which seeks to turn a large-scale team of professionals and the organizations they belong to into an instant HRO (Weick and Sutcliffe, 2001), even when they have never worked together before. However, the concept of HRO is always talked about in terms of the focus on a physical system such as a nuclear power plant or an aircraft carrier. No such constraint is present in Lindblom's "muddling through" theory and in fact the major problem in emergency management is that the team often does not exist formally until the emergency occurs. This fact leads to other problems such as trust and lack of openness when the teams that form represent many different agencies and include people who have not had previous experience with the other members.

SOCIAL COMPUTING, COMMUNITY INVOLVEMENT, AND CITIZEN PARTICIPATION

Many social computing applications are already being used by citizens (interested members of the public who have no official role) to prepare for, respond to, and find information about emergencies, and this use will only grow in the future (Palen et al., 2007). In this section, we review what social computing and citizen participation mean today and could mean in the future. This is an area that has yet to receive the attention it deserves within the formal emergency preparedness and management community.

Many of the technology components of social computing and the nickname "Web 2.0" have existed since the early days of the Web in various group-oriented systems (Hiltz and Turoff, 1978/1993), but the scale and diversity of applications and participation are "new." One current definition is:

> . . . the philosophy of mutually maximizing collective intelligence and added value for each participant by formalized and dynamic information sharing and creation." (Högg et al., 2006, page 23)

In the opening talk of the first Web 2.0 conference held in October 2004 in San Francisco, Tim O'Reilly and John Battelle summarized what they saw as the themes of Web 2.0, in particular an architecture of participation that encourages user-generated Web site content. These applications derive their effectiveness from interhuman connections and grow in effectiveness in proportion to the number of people making active use of them. Examples include eBay, Craigslist, Wikipedia, del.icio.us, Skype, dodgeball, Flickr, and YouTube. Technologies such as Web logs (blogs), wikis, podcasts, RSS feeds, and other forms of many-to-many publishing, social software, and Web application programming interfaces (APIs) provide enhancements over read-only Web sites (Wikipedia, 2008). Besides user-generated content, other characteristics of social computing sites include "folksonomies" or user tagging (putting shared labels on things to aid search and retrieval), incorporation of some sort of user feedback or recommendations about the quality or importance of the material (e.g., the "favorites" and "most viewed" ratings on YouTube), and a tendency toward use of multimedia rather than just text. All of this contrasts with "traditional" or "Web 1.0" Web sites, which tended to limit visitors to viewing rather than participating.

Use as a Platform for Citizen Participation

The British Broadcasting Corporation set up a user-generated content team as a pilot in April 2005, with three supporting staff. In the wake of the July 7, 2005, London bombings and an oil fire in Buncefield, when the BBC received 5,000 photos from viewers, the team was made permanent and was expanded, reflecting the arrival in the mainstream of the "citizen journalist." Likewise, in 2006, CNN launched CNN iReport, a project designed to bring user-generated news content to CNN, and Fox News Channel launched "uReport." Increasingly, citizens will be able to upload "eyewitness" data, including photos and text, to describe disasters (as well as other newsworthy or not so newsworthy events) in real time. One challenge is for official government response agencies to make use of these sources as information to help guide decisions about the scope, nature, and location of needed responses.

A number of urban police departments have set up Web sites for citizens to contribute photos, videos, and reports on crimes and accidents as a new type of 911 or hotline. The extension of this is the ability of citizens to contribute potential pre-disaster threat items, localized disaster events, and recovery needs during all phases of a disaster situation.

Under the leadership of Leysia Palen, a “Crisis Informatics Group” at the University of Colorado, Boulder, has been studying the use of social computing systems in emergency response in the United States. As they point out, “citizen-side information generation and dissemination activities are increasingly playing a critical role in disaster preparation, warning response and recovery” (Liu et al., 2008). Citizens have always been the real “first responders,” reaching out to help those around them who are in danger or suffering, and then self-organizing to provide food, shelter, transportation, and other aid to those in their communities. Now, with the increasingly accessible Internet, online forums have allowed people to transcend geographical distances that normally constrain the reach of helping efforts, to share information and coordinate citizen-led efforts, in addition to any official government and nongovernmental Web sites. Hundreds of sites sprang up during Hurricane Katrina, for instance, some of which used maps as the basis for annotating current conditions. Some of these sites (e.g., www.fluwiki.com) are concerned with citizen preparation for disasters, rather than aid after the crisis occurs (Palen et al., 2007). A series of recent papers from the Crisis Informatics Group describes how specific systems were used in given emergency situations.

Photo Sharing

In their article on “the emergent role of on-line photo sharing in times of disaster,” Liu and colleagues (2008) describe how online photo sharing through Flickr has been used in six notable disasters in the United States, including Hurricane Katrina, the Minneapolis Bridge Collapse, the Virginia Tech shooting incident, and the Southern California wildfires of 2007. Flickr allows its members to store, sort, search, tag, and share photos and images via the Internet. Social organization around photos and topics of interest occurs through the creation of Flickr groups that focus on a specific subject matter. The authors conducted a longitudinal qualitative study to investigate whether and how disaster-related Flickr activity evolved for twenty-nine groups related to these six disasters between December 2004 and October 2007. They describe attempts to create shared “tagging nomenclatures,” to document not only the disaster in progress but also social convergence activities around the disaster. Both photos and other visuals are posted, for instance, a screenshot of a Google map mashup of the locations of the wildfires as they were spreading and screenshots of a Second Life memorial “wall” for the victims of the Virginia Tech shootings.

Backchannel Information Sharing

The 2007 Southern California wildfires (which lasted for 19 days, destroyed about 1,500 homes, burned over 500,000 acres, and caused massive evacuations) were studied by the Crisis Informatics Group in terms of the use of social media to provide “backchannel” communication (Sutton et al., 2008). California, like many areas, has an official and hierarchical command and control system (Incident Command System or ICS), which is supposed to oversee the one-directional communication of disaster information from the formal government agencies to the media, and thence to the public.

The data for this study come mainly from a broadly distributed online questionnaire that asked respondents to answer questions about information and communication technology (ICT) use and information gathering, a sharing activity related to the fires. In addition, the research team collected data using observation and interviews.

The authors report on emerging features of a rapidly changing information arena, showing illustrations of emergent, ICT-supported “backchannel” (unofficial) response activity, and instances of incorporation of such backchannel activity into more recognized, traditional information outlets. They found that the majority of the 279 respondents who completed the questionnaire reported seeking information via mobile phones to contact friends or family (54 percent), through Internet searches for news and discussions (40 percent), by accessing information portals advertised in traditional media (76 percent), and through discussions on various Web forums (16 percent). In providing information to others, 10 percent used the text messaging system Twitter; 10 percent used photo-sharing sites such as Flickr; and 36 percent reported posting information or participating in online discussion groups. Many respondents reported that they considered the information coming through the traditional mass media to be insufficient because it lacked specificity, was too slow in being updated, or was just plain wrong. A particularly striking quote is,

> What we learned . . . is that there is no “they.” “They” won’t tell us if there is danger, “they” aren’t coming to help, and “they” won’t correct bad information. We (regular folks) have to do that amongst ourselves. (Sutton et al., 2008, p. 627)

The authors conclude that the reasons for and descriptions of respondents’ information-seeking behaviors illustrate the mounting need for changes in emergency response management policy that take into account the changing, ICT-extended information arena of disaster and recognize its advantages. In sum:

> Previously backchannel activities are becoming increasingly more visible and legitimate as a means of retrieving reliable information. In fact, they are being adopted as useful, viable sources of information not only by at-risk populations, but also by traditional media and some emergency management personnel—actors that traditionally comprise the “front channel.” In this disaster, we saw evidence that community forums were increasingly seen as reliable, authoritative sources of information both by community insiders and by outsiders. (Sutton et al., 2008, p. 629)

Creating Collective Intelligence

Perhaps the most interesting of all the recent work by members of the Crisis Informatics Group is their paper on “collective intelligence” or “collective sense-making” in the aftermath of the 2007 Virginia Tech shootings. Vieweg and colleagues (2008) report on the results of an investigation into the “informal,” public-side communications that occurred online immediately after the shootings, focusing on examples of online social interaction organized around the goal of collective problem solving. They show how a loosely connected group of people worked together in Facebook groups on a grave topic to provide accurate results.

The tragedy at Virginia Tech began when two people were killed during a first shooting (by a mentally unstable student) at approximately 07:00 EDT, and an additional thirty were killed during a second shooting that occurred between 09:30 and 09:50. VT officials held a press conference at noon to announce that at least twenty-one people were confirmed dead and twenty-eight were injured; this was the stimulus for the beginning of a large-scale, collective problem-solving effort to find out who the victims were. Facebook users reported personal information they had access to or had seen posted elsewhere in a display of collective problem solving, providing an example of collective intelligence (Hiltz and Turoff, 1978/1993). The Facebook groups produced a correct list of victims before it was announced publicly, and there were no “false positives,” nobody confirmed killed who in fact was not (Vieweg et al., 2008).

The study gives examples of how participants in the list-building activities at Virginia Tech paid attention to the nature of sources and to verification of names that were entered. When participants were unsure of reports, they requested corroboration by others. For instance, one entry that listed a source was:

> I just finished speaking with his girlfriend, and it appears JH [initials are used here rather than full names as in the original] is a fatality as well.

QUALITY OF INFORMATION ISSUES

Certainly, explicit attention to citizens-as-participants must be concerned about managing incorrect information that could jeopardize public safety, cause distress unnecessarily, or in other ways hinder the preparation or recovery effort. In creating a greater role for online citizen participation, we need to be concerned about problematic rumors; privacy protection of information and its source; difficulty of coordination with official civic agencies; and potential failure of Internet access. Information generated from the “bottom up” without validation cannot be guaranteed accurate or timely or appropriate for an unfolding event. However, what are needed are efforts to include public participation in the organizational management of disasters. The current political trend in the United States favors command-and-control-style crisis management and neglects to appreciate the roles of the public as “first responders” and ongoing participants, and thus fails to incorporate citizen activity and citizen-generated information in formal warning, response, and relief efforts.

Information systems designers need to provide structures and features for collecting, validating, and transmitting such citizen-generated information (Palen et al., 2007). Continued failure to recognize that widely available ICT challenges conventional models and demands new informational relationships between official organizations and the public portends a future where crises are managed much less well than they could be if “collective intelligence” were able to go to work on solving problems related to disasters.

As in the earlier discussion of information overload there are opportunities to utilize vetted contributors who have established backgrounds on the topic that is the objective of the collective intelligence system (Hiltz and Turoff, 1978/1993). An example is the idea that in a local area those citizens who have lived through prior local disasters and work with community organizations such as volunteer fire departments, the Red Cross, and Community Emergency Response Team (CERT)–trained responders, and so on, have unique experience and knowledge that could contribute to long-term organizational or “community” memory. For example, estimates of the monetary value of damage are useless for real operational purposes. Local people are best able to estimate the potential damage from an approaching storm or flood and are able to use experience to estimate what might occur and/or to report what is occurring. An effort to investigate the important dimensions of a disaster scale and how important each one was arrived at 13 such dimensions on an interval scale of importance for estimating the threat and responding to it (Plotnick et al., 2007).

Clearly if such a set of dimensions were utilized as a measuring instrument for an anticipated threat and as a measure of what is actually occurring, local citizens and professionals who had been vetted to input estimates of what they expect would result in a dynamic measuring instrument of both the threat and its actual impact upon occurrence. This would be a type of public, online dynamic poll

Table 16.1

A Thurstone Scale for the Relative Importance of Measures of Disaster Impact

Scale	Value	Disaster Damage Dimensions
20	20.00	Casualties and fatalities
19		
18	18.00	Utilities impact
17		
16	16.60	Potential to spread
	15.90	Ability of local response adequacy
15	15.43	Loss of command and control
	15.40	Infrastructure damage
	15.40	Resources for aid or containment
	15.38	Time needed for response
14	14.82	Duration of disaster
13	13.09	Public reaction
12	12.96	Geographic impact
11		
10	10.07	Time to return to normal
9		
8	8.61	Chance of imminent reoccurrence
7		
6		
5		
4	4.70	Financial loss
3		
2		
1		
0	0.01	Financial recovery costs

Source: Plotnick et al. (2007).

collecting estimations on the damage that would take place locally (Plotnick et al., 2007). This scale was arrived at by a Delphi process among graduate students in an emergency information systems class. Note that the lowest values for informative purposes were the two that are most often reported (financial loss and recovery costs). What citizens want to know are the other variables in following Thurstone's scale (see Table 16.1). Many of these variables are better estimated by local citizens with experience in prior similar disasters or local experts familiar with things such as local building codes and practices. Using national estimates does not give informative estimates when the threat is on the way. One needs local estimates of each variable on this scale.

Each of the dimensions shown in Table 16.1 can have a local scale of the degree of damage estimated by the local community "experts" on a continuous basis, from the earliest detection of the current threat right up to its actual occurrence, and then afterward as actual damage assessment occurs.

RISK ANALYSIS, STAKEHOLDER ANALYSIS, AND COMMUNITY SYSTEMS

The concept of "risk analysis" as it is applied in classical management studies emphasizes reducing all risks to potential dollar loss and using that to determine what should be done. This is not the concept of risk analysis that is needed in emergency preparedness and management. In this case we are concerned with determining the details of actual risks, for example, whether one bridge is more prone to being taken out in a flood than another, which buildings are more likely to collapse in an earthquake of a given size, what hillsides are likely to block which roads with mudslides in a given heavy rainstorm, or what mistakes led to inadequate response and recovery efforts in prior disasters in the same or similar localities. This interpretation comes right out of such concepts as high reliability theory, mindfulness, Delphi exercises, policy analysis, scenario planning, technological forecasting and planning, and muddling through (Lindblom, 1959, 1965, 1979; Linstone and Turoff, 1975; Rittel and Webber, 1973; Van de Walle and Turoff, 2008; Weick and Sutcliffe, 2001; Wenger et al., 2002).

Even in classical management we have seen the evolution of concepts such as stakeholder analysis to overcome the shortcomings of the typical monetary approach to risk analysis. A formal approach to stakeholder analysis might be more useful for integrating the large spectrum of concerned planners, responders, and decision makers, since disasters do not obey political and geopolitical boundaries. This would mix the key people at different levels of government (federal, state, local) with other national or even world organizations concerned with any of the disaster phases. Various communities have severe communications problems because nongovernmental groups are not regular members of the command and control system used during disasters. For example, many urban areas have no active linkage between community organizations providing services and the general medical system in that community (Turoff and Hiltz, 2008b). As a result someone coming out of a hospital care situation after a disaster is not listed in any database that would interface to the community organizations that might be of further help with such basic problems as shelter, food, and other forms of help.

In any case, what is clear is the following needs for emergency preparedness-based risk analysis (Hendela et al., 2006; Turoff et al., 2002, 2004a, 2004b, 2008; White et al., 2007a, 2007b, 2008a; Yao and Turoff, 2007):

1. Determination of what has worked and what has not worked in past experience.
2. The collaborative participation of a large multidisciplinary community of practice with members who are familiar with the local area and its vulnerabilities.
3. An information-based knowledge structure able to accept, organize, and provide a community and organizational memory for experiences, plans, resources, and other critical items for emergency preparedness and response.
4. The ability for a community's citizens and professionals to continually and dynamically contribute their knowledge and wisdom and be able to evaluate and expose problems and disagreements for discussion and resolution.

This would be in essence a community-recommender system for the community decision makers in local government, private companies, nonprofits, and other community organizations.

The community as a whole should provide the opportunity for participation in building and maintaining a community disaster plan. Today most plans come down as templates from the federal government and are not highly tailored to the local community. The usual government members are not made up of the professionals who have the background knowledge to be able to assess details such as engineering vulnerabilities in the infrastructure. The CERTs (Community Emergency Response Team) are a positive concept but really limited to civilian training for only the response phase and do not encourage contributors to any of the other critical phases such as planning and mitigation. Also, there is no easy way for leadership in the community to be actively involved except for an occasional tabletop exercise, which might happen once every six months, never get to a professional level of detail, and be face-to-face only. Furthermore, there is usually no detailed result except for some top-level insights by the leadership who may rarely come back to a second exercise in the same year.

Local severity and probability of risk assessment could well serve as a first motivational tool. This should be generated and compiled on an asynchronous basis much as in an online dynamic Delphi, allowing continuous input and discussion by members of the community as well as collective ratings of risks. The results of such an approach could serve as a collaborative process for the community and leadership to determine important planning details and preparing for the necessary resources and equipment.

A new variant of Wikipedia (www.wikimapia.org) allows people to link information to specific points or areas on a world map, which can utilize detailed maps of a given area as the knowledge structure. This means that a lot of community information and viewpoints can be linked to the potential location of a risk, problem, resource, and so on.

The Wikimapia system is available online and is accessible anywhere there is Internet connectivity and a browser. There have been other recent calls for the use of modern Web technology to create a 911 system that would integrate all community activities in emergency management at the local, regional, state, and federal levels. It would cut across all the different physical devices available to community members (Shneiderman and Preece, 2007). The suggested name in the United States is “911.gov.” It would provide a variety of applications tied to any phase of emergency preparedness, with open access to all citizens.

CONCLUSION

We still face major problems in bringing about integrated systems to facilitate all phases of emergency preparedness and management:

- Organizations that do not divulge or exchange information on mistakes
- Planning actions rather than process
- Top-down rather than bottom-up planning
- Reductionist problem solving rather than collaboration and integration
- Lack of deference to expertise in the political process
- Lack of community involvement
- Lack of a transparent ethic on response and recovery goals at the federal, state, and local levels
- Lack of a formal integrated response team until a disaster actually occurs
- Localized solutions that lead to long-term disasters (paradox of the commons: e.g., relying on levees and ignoring the destruction of the barrier islands for New Orleans)
- Goal-formulation, problem definition, and equity/ethical issues should all come together in emergency management planning (Rittel and Webber, 1973)
- Emphasis on efficiency and the principle of least-means, which creates major problems in having adequate resources for emergencies
- Classical planning model insufficient for wicked problems
- Attempts to divide problems and responses for assignment to different unique organizations
- A few high-level exercises once or twice a year for sensitizing the leadership but never getting into real challenging details
- A situation where planners are usually different from the ones that must execute the plans
- A planning focus on the decisions to be made rather than the more critical concern of the process for making the decisions

- Exercises are so well planned that everyone knows exactly what to expect and what to do beforehand, which does not facilitate learning from the exercise by encountering surprises
- Participants may change and do not know one another
- Very little community and few nongovernment agencies involved in pre-disaster activities
- Lack of transparency among emergency response team members when they feel they are representatives of the interests of their organizations rather than the teams they become part of

Major efforts are needed to rebuild emergency preparedness and management and its information system infrastructure in many places throughout the world from the bottom up rather than the top down. This requires cooperation among many different levels of government and organizations as well as more emphasis on systems that are oriented to local and lateral collaboration and command and control structures based upon virtual organizations (e.g., Mowshowitz, 2002).

We need teams that exist as virtual communities for functions such as planning, training, and preparedness on a continuous basis as well as systems that can support asynchronous operation of these teams, which will come from many different organizations and must be able to contribute and collaborate at any hour of the day or night when they can spare the time to do so. Planning must blend with the testing of planning concepts in multiplayer games that can be based upon the characteristics of the actual areas where the disaster can strike. The resulting effort must produce a growing database of threat and response scenarios that are increasingly realistic and improved by the efforts of those engaged in continuous and dynamic exercises being conducted both for the improvement of the plans by the professionals and the training of those who want to learn the plans and how to become involved. Ultimately, the only way to bring about the best possible state of emergency preparedness in any country is the complete involvement of the local populace and their willingness to cooperate and collaborate within the community.

There is a very dedicated community of professionals in emergency management in the United States and elsewhere in the world. They have often faced terrible examples of mismanagement and lack of influence in the processes associated with many recent historical disasters. They need to be better integrated with those who are developing and implementing the systems needed to address the problems they face. There is a significant element of truth in the motto expressed on the message list of the International Association of Emergency Managers in recent years:

> We, the willing, led by the incompetent to do the impossible for the ungrateful, have done so much for so long with so little, we are now capable of doing practically anything with nothing.

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