Chapter 12

Mobile GIServices Applied to Disaster Management

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12.1 Introduction

Disaster management (or emergency management) is unique among GIS applications because it deals directly with loss of human life and property damage. In September 2005, the tragic event of Hurricane Katrina in the US demonstrated how important disaster management is. While the comprehensive implementation of disaster management systems can save thousands of people's lives, poorly implemented disaster *management* can of itself cause significant casualties, property damage and economic loss when the disaster happens.

On December 26, 2004, another example of poor disaster management was recognized after a massive 9.0 earthquake in the Indian Ocean. A horrifying tsunami destroyed coastline areas of 11 countries and caused an unbelievable number of deaths (over 150,000). People from around the world began to realize the power of Nature and how devastating hazards and loss can occur by underestimating her power. Some news reporters from the National Public Radio (NPR) in the US commented that if these countries around the Indian Ocean had had a tsunami early warning system (such as the Pacific Tsunami Warning System used by the US and Japan) hundreds of thousands of people would have been saved from the tsunami. However, the authors of this chapter disagree with this statement because a single tsunami warning system is not sufficient for the establishment of comprehensive disaster management. This chapter argues that what is really needed is an integrated mobile and distributed GIService, combined with the early warning systems, to support disaster management, response, prevention and recovery.

To create a comprehensive disaster management system, our society needs to rely on advanced geospatial technologies and services. Mobile GIS is one of the most vital technologies for the future development of disaster management systems. Mobile GIS and mobile Geographic Information Services (Mobile GIServices) extend the capability of traditional GIS to a higher level of portability, usability and flexibility. Mobile GIS are integrated software and hardware frameworks for the access of geospatial data and services through mobile devices via wireline or wireless networks (Tsou, 2004). The unique feature of mobile GIS is the ability to incorporate Global Positioning Systems (GPS) and ground-truth measurement within GIS applications.

This chapter introduces a new term, “Mobile GIServices”, which describes a framework to utilize Mobile GIS devices to access network-based geospatial information services (GIServices). Mobile GIServices can be adopted in various GIS applications and scenarios, including car navigation systems, utility management, environmental monitoring and habitat protection tasks. Disaster management and emergency response are one of the most popular domains in the recent development of Mobile GIServices.

For example, mobile GIServices can combine GPS and satellite images to assist the local government and emergency response teams in identifying potential threat areas. So critical “hot zones” can be immediately created. Near real-time spatial analysis models supported by GIS could be used to rapidly generate the most effective evacuation routes and emergency plans during natural hazard events, including wildfires, floods and tsunamis. Wireless Internet-based GIS could also assist public policy officials, firefighters and other first responders with identifying areas to which their forces and resources should be dispatched. To accomplish these goals, it is important to introduce these new mobile GIServices technologies to emergency management personnel and related organizations. Also, emergency managers and first responders need to realize both the advantages and the limitation of GIS technologies in disaster management.

In the US, the percentage of agencies that used computers as tools for emergency operations (such as 911 or emergency calls, ambulance dispatch, evacuation procedures or rescue services) was 54.2% in 2001. The percentage using emergency management software (such as GIS or Management Information Systems – MIS) was 26.6% (Green, 2001). Although software usage has increased in the last few years, some emergency managers and staff are still reluctant to adopt computers and GIS for their main tasks (based on the authors’ own experiences). One of the major obstacles is the concern for system portability and reliability. Traditional GIS are not considered portable by first responders (such as local police officers, fire fighters and emergency medical personnel who can arrive first and take actions to rescue people and protect property). Emergency managers also worried that loss of electrical power during a disaster might cause the whole computer system to breakdown.

The recent development of Mobile GIS and Mobile GIServices might solve these problems, as proposed in this chapter, by providing their own independent power supply systems (batteries and Uninterruptible Power Supply - UPS) and having a great portability (cellular phones, Pocket PCs, etc.). In addition, this chapter discusses how the new wireless communication technologies, such as 4th Generation (4G) cellular phone systems, Wi-Fi, and Wi-MAX techniques, might further improve the capability of Mobile GIServices and support comprehensive information services for disaster management.

This chapter will first introduce the disaster management framework for mobile GIServices (Section 12.2) and then recent advances in mobile GIService technology (Section 12.3). The discussion will focus on disaster management in three categories: emergency preparedness, emergency response and disaster recovery.

Next, the Taiwan Advanced Disaster Management Decision Support System (TADMDS) will be introduced as a showcase of the integration of Mobile GIServices with Web-based GIServices (Section 12.4). Finally, this chapter will conclude in Section 12.5 by highlighting the current limitations and possible future directions of Mobile GIServices technology.

12.2. The framework of disaster management

The term 'disaster' has various meanings and interpretations. To paraphrase Drabek and Hoetmer (1991) a disaster is defined as a large-scale event that can cause very significant loss and damage to people, property and communities. One important notion is that disasters are an outcome of risk and hazard (Cutter, 2003). Traditionally, there are two types of hazard: natural hazards (floods, typhoons, tornadoes, earthquakes, etc.) and technological hazards (chemical explosion, nuclear power plant meltdowns, terrorist attacks, etc.). In disaster management, we need to consider both potential hazards and potential community vulnerability (White, 1945). If an area or a local community has high-income level residents and very strong government support, the vulnerability of such a community will be low and will be more resistant to large-scale hazards. If a local community is poor and vulnerable, a small-scale earthquake or flood might cause significant human casualties and property damage. Human factors always play an important role in disaster management.

The development of GIS has occurred over three decades and there are many GIS applications focusing on disaster management and emergency response (Coppock, 1995). GIS can be used in real-time for monitoring natural disasters (Alexander, 1991) and remote sensing imagery can be applied to emergency management (Bruzewicz, 2003). GIS modeling helped the Chernobyl nuclear disaster relief (Battista, 1994), the management of wildfire (Chou, 1992) and the assessment of community vulnerability (Chakraborty and Armstrong, 1996; Rashed and Weeks, 2003). There has been also many research efforts combining GIS with natural hazard risk modeling and risk management decision support systems (Zerger and Smith, 2003).

On the other hand, mobile GIServices are a very new research domain and their focus is different from traditional GISystems. With the progress of wireless technology and GPS, Mobile GIServices for disaster management are likely to become very popular in the next few years. This chapter provides an overview of mobile GIS applications in disaster management. The chapter follows a conceptual framework developed by Drakek and Hoetmer in 1991, called "comprehensive emergency management" to highlight the potential of mobile GIS applications. This framework has four temporal phases of disaster management: mitigation, preparedness, response and recovery (see Box 12.1 and Figure 12.1).

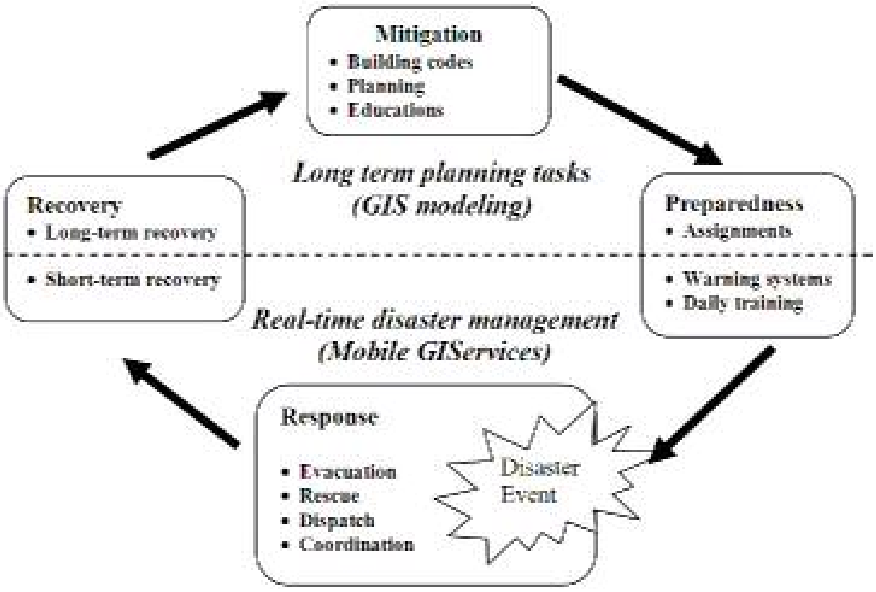

Figure 12.1. The role of Mobile GIServices in disaster management (modified from Cova, 1999 and Godschalk, 1991).

Box 12.1 – The four temporal phases of disaster management (Federal Emergency Management Agency (FEMA), 2004).

(1) **Mitigation** – Mitigation actions involve lasting, often permanent, reduction of exposure to, probability of, or potential loss from hazard events. They tend to focus on where and how to build. Examples include**:** zoning and building code requirements for rebuilding in high-hazard areas; flood plain buyouts; and analyses of flood plain and other hazard-related data to determine where it is safe to build in normal times, to open shelters in emergencies or to locate temporary housing in the aftermath of a disaster. Mitigation can also involve educating businesses and the public on simple measures they can take to reduce loss or injury, such as fastening bookshelves, water heaters and filing cabinets to walls to keep them from falling during earthquakes.

(2) **Preparedness** – While mitigation can make communities safer, it does not eliminate risk and vulnerability for all hazards. Therefore, jurisdictions must be ready to face emergency threats that have not been mitigated away. Since emergencies often evolve rapidly and become too complex for effective improvisation, a government can successfully discharge its emergency management responsibilities only by taking certain actions beforehand. This is preparedness. Preparedness involves establishing authorities and responsibilities for emergency actions and garnering the resources to support them. A

Box 12.1 (cont.)
jurisdiction must assign or recruit staff for emergency management duties and designate or procure facilities, equipment and other resources for carrying out assigned duties.

(3) **Response** – Response is the third phase of emergency management and covers the period during and immediately following a disaster. During this phase, public officials provide emergency assistance to victims and try to reduce the likelihood of further damage. Local fire department, police department, rescue squads and emergency medical service (EMS) units are primary responders.

(4) **Recovery** – Recovery is the fourth and final phase of the emergency management cycle. It continues until all systems return to normal or near-normal operation. Short-term recovery restores vital life-support systems to minimum operating conditions. Long-term recovery may go on for months - even years - until the entire disaster area returns to its previous condition or undergoes improvement with new features that are less disaster-prone. For example, a town can relocate portions of its flood-prone community and turn the area into open space or parkland. This illustrates how recovery can provide opportunities to mitigate future disasters.

In term of Mobile GIServices' tasks for each phase, there is a significant difference between real-time disaster management *needs* versus long-term disaster planning and mitigation *processes*. Mobile GIServices will be critical for real-time disaster management tasks rather than long-term planning processes. Many tasks in emergency response, recovery and preparedness will need critical geospatial information in real-time and updated geodata from the field personnel (fire fighters or police officers). Traditional GIS modeling and spatial analysis functions will be used mainly for long term planning tasks in the mitigation phase and some tasks in long-term recovery and emergency preparedness, such as estimating recovery cost and assigning responsible zones (see Figure 12.1).

Real-time disaster management has very specific requirements that are significantly different from long-term mitigation planning for disaster management. The differences between real-time systems and the long term planning process are summarized in Table 12.1. Most real-time disaster management will need to access the information immediately for warning systems, evacuation, or responder dispatch efforts. Therefore many emergency managers will only tolerate 5-10 seconds response time from sending a GIS function request to getting an answer from the system. On the other hand, long-term recovery and mitigation tasks are less time-sensitive and the GIS analysis runtime can be more flexible ranging from ten minutes to several hours.

Table 12.1. Differences between real-time systems and long term planning processes.

	Long-term planning tasks (GIS modelling)	**Real-time disaster management** (Mobile GIServices)
Response time	Flexible (1-10 days) (less sensitive to tasks)	Immediately (1-10 seconds) (sensitive to task operations)
Map types	Thematic maps (land use, census data, administration boundary, soil, etc.)	Pragmatic maps (roads and traffic updates, event locations, evacuation maps, GPS integration)
Numbers of users	Small number (1-10 people in administration level)	Large number (over hundreds – rescue teams, the first responders, and the general public)

Regarding map types, real-time emergency tasks will need “pragmatic maps” with GPS functions for navigation, evacuation routes and traffic updates. Transportation is the key theme in many related emergency response tasks. On the other hand, long-term mitigation plan will focus on thematic maps by using advanced GIS modeling and spatial analysis. There might be many layers used in this area, including land use, census data, administration boundary, soil, terrain, vegetation, etc. Regarding the number of users, in real-time emergency responses these will be much larger than in the long-term mitigation plan. Depending on the level of the disaster, the size of in-field agents in real-time emergency tasks could range from a dozen of people to hundreds of responders and staffs. In contrast, long-term mitigation tasks use GIS modeling for the planning processes that might only involved a few decision-makers or GIS professionals (ranging from one to ten people).

Therefore, to implement a comprehensive Mobile GIServices, we need to consider the technological challenges of large numbers of users, the response time and the nature of the GIS functions. Real-time emergency response tasks will need robust and user friendly mobile devices. The devices must be robust (they may drop to the ground), easy to read (even under direct sunlight or in snow conditions), and have a long battery life and runtime.

The next section will start to focus on the mobile GIServices framework and how to adopt mobile GIServices into three disaster management phases: preparedness, response, and recovery. Since most tasks at the mitigation phase are more related to GIS modelling and spatial analysis (see Figure 12.1), this chapter will not focus on the disaster mitigation tasks.

12.3. Mobile GIServices framework

The architecture of mobile GIServices utilizes a client/server computing framework. Client-side mobile GIServices components are the end-user hardware devices, which display maps or provide the analytical results of GIS operations. Server-side components provide comprehensive geospatial data and perform GIS operations based on a request from the client-side components. Between client and server, there are various types of communication networks (such as hard wired network connections or wireless communications) to facilitate the exchanges of geodata and services. Figure 12.2 illustrates the six basic components of mobile GIServices: 1) positioning systems; 2) mobile GIS receivers; 3) mobile GIS software; 4) data synchronization and wireless communication component; 5) geospatial data; and 6) GIS content servers (Tsou, 2004).

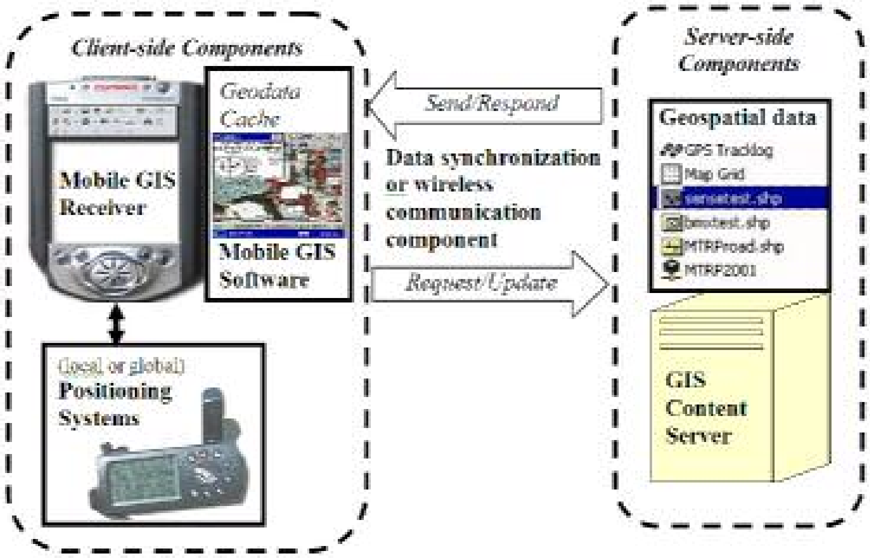

Figure 12.2. The architecture of mobile GIServices (Tsou, 2004).

Positioning Systems refer to the components that provide georeferenced coordinate information (X, Y, and Z-elevation) to mobile GIS receivers. There are two major types of systems, *local positioning systems* and *global positioning systems* (GPS). Local positioning systems rely on mechanical distance measurement or triangulation of the radio signals (or cellular phone signals) from multiple base stations in order to calculate the position of a device. GPS uses satellite signals to calculate the position of GPS units. Sometime, mobile GIS applications may require both types of positioning systems within urban areas to generate satisfactory results.

Mobile GIS receivers are small-sized computers or terminals that can display maps and locational information to end-users. The hardware components of mobile GIS receivers include CPU, memory, storage devices, input/output connections and display (screen) hardware. Pocket PCs, smart phones, tablet PCs and PDAs are the most popular mobile GIS receivers. Occasionally, notebook computers can be used as a mobile GIS receiver if connected to GPS and other mobile GIS components. However, most mobile GIS receivers require a very small size hardware device to achieve their portability. The major differences between small mobile GIS receivers and traditional personal computers are smaller screen resolutions (240x300), limited storage space and slower CPU speed (Wintges, 2003).

Mobile GIS software refers to the specialized GIS software applications employed by mobile GIS systems. Because of the limitations of mobile GIS receivers (smaller display units, limited storage, etc.), the design of mobile GIS software needs to focus on specific GIS operations (geocoding, address matching, spatial search, routing services, map display, etc.) rather than encompassing comprehensive GIS functions. For example, the functional design of LBS software is quite different from the functions provided in field-based GIS packages. Most mobile GIS software packages are lightweight, customizable, and are designed to function with positional systems (such as GPS tracking).

Geospatial data are specifically designed GIS layers or remotely sensed imagery used for mobile GIS applications. Because of the limited storage space in mobile GIS receivers, most GIS data needs to be compressed or subset from their original extents. Usually, the mobile GIS receivers store geospatial data in a *geodata cache*[1], located in a temporary GIS storage space or a flash memory card. Often customized datasets are downloaded and synchronized from GIS content servers. One alternative approach is to utilize wireless communications to access needed portions of large-sized GIS layers and/or remotely sensed imagery from the content server directly.

Data synchronization/wireless communication components support the linkages between mobile GIS receivers and GIS content servers. These linkages could be real-time wireless communications (via Wi-Fi or cellular phone signals) or cable-based data synchronization communications (via USB or serial ports). Both mechanisms provide two-way communications. For cable-based connections, the GIS content servers *send* geodata to the receivers (stored in geodata cache) and the receiver uploads *updated* geodata back to the content server. For wireless communication, the mobile GIS receivers *request* a specific service or map from the GIS content server, and the server *responds* to the request by sending the new map to the receiver. To facilitate two-way communications, several middleware or data synchronization software packages (such as Microsoft ActiveSync or Web Services) are required for mobile GIS applications. If both mobile receivers and GIS content servers have networking capabilities, Internet-based protocol, such as TCP/IP and HTTP can provide very effective communication channels for mobile GIS applications.

GIS content servers are stand-alone GIS workstations or web-based servers providing geospatial data or map services to mobile GIS receivers. Most cable-based mobile GIS receivers use stand-alone GIS workstations as content servers. Wireless-based mobile GIS receivers may require advanced web servers or wireless Internet map servers for accessing geospatial data. In some instances, one mobile GIS receiver may be used to access multiple web-based servers at the same time in order to integrate multiple GIS layers. A single GIS content server can also provide data and services to multiple mobile GIS receivers simultaneously.

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[1] Geodata cache is the temporary local memory storage for saving geospatial data downloaded from the GIS content server. Therefore, if the connection between the client and content server is not available, mobile GIS units can still use the local geodata cache to perform parts of GIS tasks.

Mobile GIServices can provide geospatial information and GPS coordinates for field-based personnel conducting remote field (*in situ)* GIS tasks. For example, landscape architects may use mobile GIS devices to display a remotely sensed image as a background in a remote field location and then draw a preliminary design for a tree line based on GPS locations. To enable comprehensive mobile GIServices, wireless communication is essential for connecting mobile GIS devices and GIS content servers. Box 12.2 introduces recent progress in broadband wireless technology, Wi-Fi and WiMAX, which can provide a comprehensive communication channels for Mobile GIServices.

Box 12.2 – Recent progress in broadband wireless technology, Wi-Fi and WiMAX, which can provide comprehensive communication channels for Mobile GIServices.

Wi-Fi/WiMAX data network systems are a promising category for broadband wireless mobile GIS communication. Both Wi-Fi and WiMAX are wireless network standards defined by the IEEE 802 LAN/MAN Standards Committee (IEEE 802 LAN/MAN Standards Committee, 2004). The IEEE 802 committee forms multiple working groups in developing Local Area Network (LAN) standards and Metropolitan Area Network (MAN) standards, such as 802.3 (Ethernet), 802.11 (Wireless LAN), 802.15 (Wireless Personal Area Network - WPAN), and 802.16 (Broadband Wireless Access – WiMAX). Currently, the most common wireless LAN infrastructures is the IEEE 802.11 (or Wi-Fi) technology. IEEE 802.11 specifies the physical and Media Access Control (MAC) layers for operation of Wireless Local Area Networks (WLAN). The 802.11 standard provides for data rates from 11Mb/s to 54Mb/s (Pandya, 2000). The term, Wi-Fi (wireless fidelity), is the global brand name across all markets for any 802.11-based wireless LAN products. Many computers, PDAs, printers, etc. have begun to adopt Wi-Fi - or IEEE 802.11 as their major communication channels.

There are four extensions in the 802.11 technology as follows:

- 802.11.**a** provides up to a 54Mbps transfer rate in the 5GHz band (referred to as Wi-Fi5).
- 802.11.**b** is the most popular extension and can provide up to 11Mbps data transfer rate in the 2.4GHz band. Because of the different radio frequency, 802.11b devices are not compatible (accessible) to 802.11a signals.
- 802.11.**g** provides up to a 20+ Mbps data transfer rate in the 2.4GHz band. Since the 802.11g and 802.11b standards are using the same radio frequency, 802.11g devices are backward compatible to 802.11b signals.
- 802.11.**n** is a new technology (available in late 2005) to upgrade the 802.11a and 802.11g. 802.11.n adopts MIMO (multiple input multiple output) technology to provide faster communication speed up to 200 Mbps. The 802.11n can be integrated with 2.4 GHz 802.11g or 5 GHz 802.11.a together (Janowski, 2005).

Box 12.2 (cont.)

WiMAX is an emerging IEEE 802.16 standard for broadband wireless wide area network (WWAN) or Metropolitan area network (MAN) applications. WiMAX can provide a larger coverage of service area than Wi-Fi. Its communication signals can cover 4-6 miles range (or up to 20 miles for the long distance setting). With such range and high throughput, WiMAX is capable of delivering backhaul[2] for carrier infrastructure, enterprise campuses and Wi-Fi hotspots (Intel, 2004).

WiMAX can provide broadband to areas that do not have cable or DSL services. Presently, WiMAX includes two steps of the IEEE 802.16 technology. The IEEE 802.16**d** is the first step, which will be used to specify large area wireless communication via outdoor antennae in a fixed location. A fixed WiMAX service can provide up to 75 Mbps speed with Sub 11Ghz radio frequency. The IEEE 802.16**e** will be the next step (under development), used to specify portable wireless hardware for mobile WiMAX services. The new mobile WiMAX can provide roaming capability and enable more persistent connectivity within a service area (Intel, 2004). Mobile WiMAX use 2-6 GHz frequency with 30 Mbps communication speed.

The progress of wireless communication, mobile devices and GPS devices has significant impact for the development of mobile GIServices. Recently, more and more mobile GIS applications have been encountered in data gathering, vehicle navigation and emergency response situations. The next sections highlight the potential of mobile GIServices for various tasks in disaster management. Section 12.3.1 describes how Mobile GIServices can be used for emergency preparedness, Section 12.3.2 evaluates how Mobile GIServices can be used for emergency response, and Section 12.3.3 discusses the use of Mobile GIServices for disaster recovery.

12.3.1. Mobile GIServices for emergency preparedness

As discussed in section 12.1, many essential tasks in emergency preparedness will benefit from real-time mobile GIServices, such as emergency warning systems and daily personnel training activities. Mobile GIS can be used to create various early warning systems by combining wireless remote sensors with GPS and mobile devices. For example, in 2002 the Department of Transportation in California (Caltran) collaborated with the University of California at San Diego to install GPS enabled sensors in all major bridges in California. In preparedness for earthquakes, flooding events or any physical damage occurring to bridges, the remote sensors automatically send out warning signals to the control and command centers giving

[2] This means that the WiMAX can become a network backbone (with huge bandwidth) for mobile communication needs (data transmission from hundreds of mobile clients to a centralized access point). Backhaul is similar to the meaning of backbone, but ‘backhaul’ is used more often for mobile communication channels, c.f. ‘backbone’ used for wired networks, like Ethernets or the Internet.

the new GPS positions via wireless networks. By comparing the old GPS position with the new one, transportation managers can immediately detect any potential damage on the bridges and make quick responses (see High Performance Wireless Research and Education Network (HPWREN), 2005). Mobile GIServices combining wireless remote sensors with GPS can also be applied in other disaster warning systems, such as earthquake prediction, tsunami warning and wildfire management.

Another example of emergency preparedness is the development of comprehensive intelligent vehicle transportation systems at the California Institute of Telecommunication and Information Technology, or Cal(IT)2 (see CAL(IT)2, 2005). Cal(IT)2 collaborated with US National Science Foundation and Caltra to develop pervasive computing and communications systems for intelligent transportation, called ‘Autonet’. This project utilizes mobile networks among cars with GPS to estimate and predict travel conditions and optimize traffic management. For example, a traffic light can automatically adjust its change frequency based on the numbers of vehicles nearby the traffic light. When an emergency vehicle approaches the traffic light, it will change its lights to allow the emergency vehicle to pass first. Therefore, all vehicles become cooperating partners in the traffic management system. By tapping into the information storage and processing power available within each vehicle, the traffic management authority can approach system-optimal control.

Mobile GIS equipment can also be adopted in the daily training activities of firefighters, police officers and emergency responders (such as the ‘911’ or ‘999’ services). At the preparedness phase, there are great potentials and many future applications for mobile GIServices. However, there are still some challenges for Mobile GIServices installation, including how to update GIS databases and road conditions, how to provide secure wireless communication channels, and how to balance performance and portability. The most challenging part is to improve the usability of the software and hardware and to create a quick learning curve for the first responders. Current user interface design in mobile GIS software and hardware is still too complicated and difficult to use (Tsou, 2004). For example, one popular Mobile GIS software package, ESRI ArcPAD, only has tiny fix-sized buttons (Figure 12.3) for general map viewing functions (Zoom-In, Zoom-out or Pan).

12.3.2. Mobile GIServices for emergency response

Emergency response is the most critical phase in disaster management. Mobile GIServices can play a very important role in evacuation, dispatch and vehicle tracking. To activate an evacuation plan, emergency managers have to gather the most updated geospatial information from the field as quickly as possible. By combining mobile GIS software, wireless communications and GPS, *in situ* agents (firefighters, police officers) can report the ground truth immediately via Wi-MAX or cellular networks. For example, if police officers found a possible terrorist attack target, they can immediately submit the hot zone and publish the information to every police officer in the nearby area. The Mobile GIServices will update the critical information more effectively and efficiently than traditional radio signal conversions and report mechanisms (Figure 12.3).

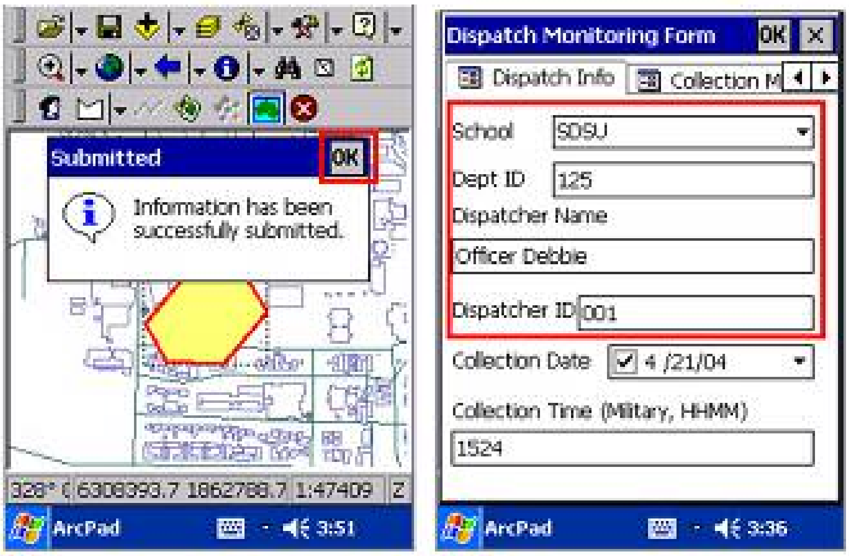

Figure 12.3 A police officer can submit a hot zone by using Mobile GIServices.

Mobile GIServices can also be applied for the first responder dispatch monitoring systems (Figure 12.4.). A Web-based mapping interface can gather everyone's field report and updates together and display these changes immediately for emergency managers. The dispatch monitoring system will be used to integrate the field-based information for facilitating better emergency responses.

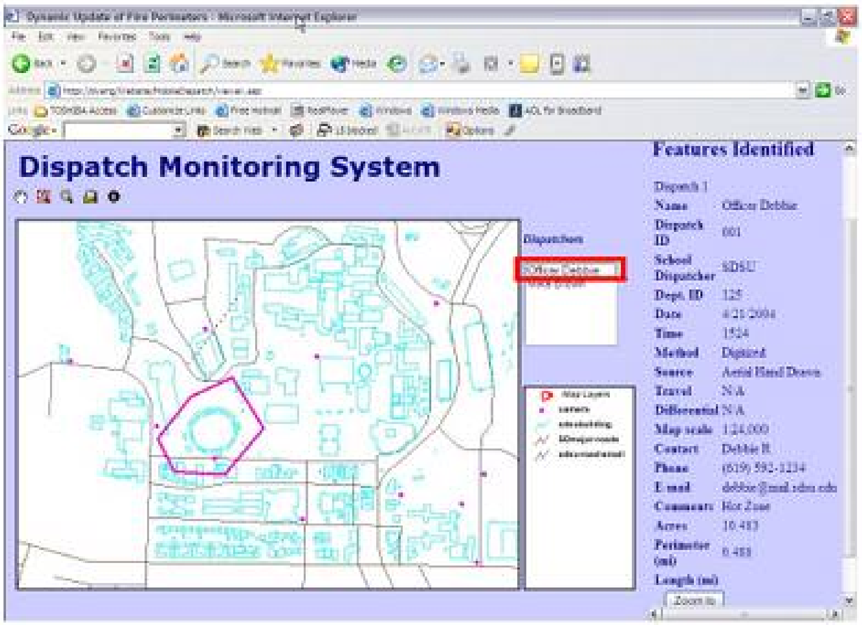

Figure 12.4 A Web-based emergency dispatch monitoring system.

In addition to real time GIS updates and dispatches, another important task in emergency response is to use GPS tracking of all in-field agents. Figure 12.5 shows a Web-based GPS tracking map browser, which illustrates a simulated security officer carrying a Pocket-PC with GPS functionality across the campus of San Diego State University. In the Web browser, the red dot can dynamically move according to the GPS signals received from the security officer's Pocket PC. This prototype testing was created by using ESRI's Tracking Server (beta-version) with customized ArcPAD GPS functions. Due to the lack of WiMAX wireless channels on the campus, the system relied on a GPS simulator to create the real-time GPS signals feeding to the Internet Map Server via TCP/IP.

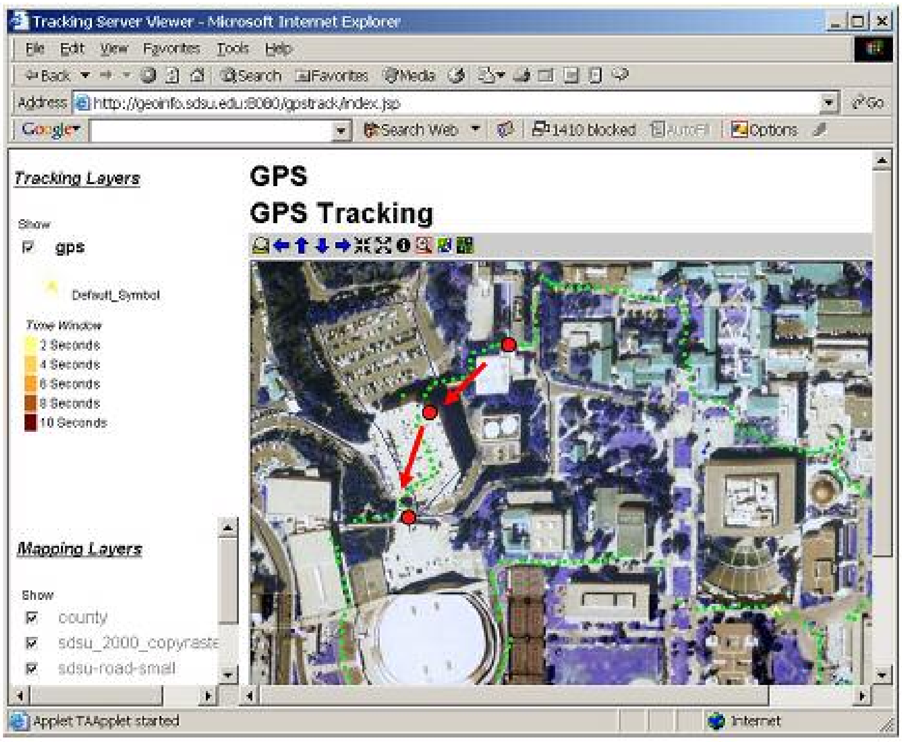

Figure 12.5. Web-based real time GPS tracking services (the moving red dot indicates a person with the Mobile GIS device sending GPS location back to an Internet map server in real time).

These examples illustrate the potential of Mobile GIServices in emergency response. There are other possible response tasks for Mobile GIServices, such as rescue team coordination, choosing appropriate shelter locations for disaster victims, creating the best evacuation routes for the residents, etc. Some tasks might need to combine both spatial analysis functions and the real-time Mobile GIServices.

12.3.3. Mobile GIServices for disaster recovery

Mobile GIServices can be applied in both long-term recovery tasks and short-term recovery tasks. Long-term recovery tasks, such as re-building damaged houses, ecological conservation and restoration and community reconstruction, require years of efforts to recover the damages caused by disasters. Mobile GIServices might be able to help in some tasks, such as the detection of land use change in environmental remediation. Figure 12.6 shows an example of using remote sensing imagery and GPS to compare the land cover changes for different vegetation types after a wildfire event.

Figure 12.6 shows different colours indicating different types of land cover change (Tsou, 2004). For example, the green colour indicates areas of increasing leaf cover within the study area. Test participants used the GPS to locate their positions on the colour-coded land use map during assessments of land cover changes around the event area.

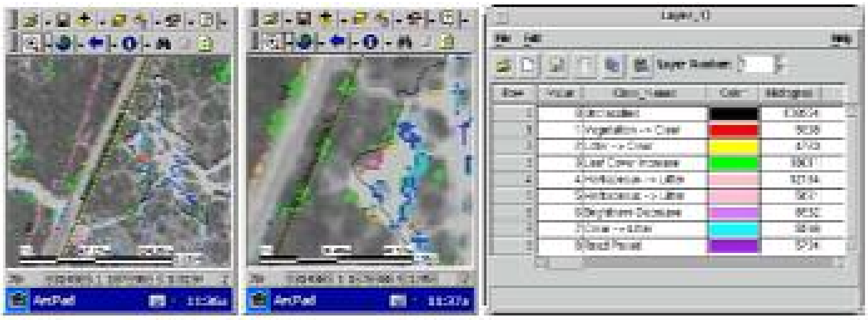

Figure 12.6. Land cover changes detection by Mobile GIServices (Tsou, 2004). (The different coloured polygons indicate the different types of landcover changes.)

For short-term recovery tasks, the major focus is to restore vital life-support systems to minimum operating conditions. Repairing damaged roads and bridges, providing clean water and electricity are the major tasks involved with these short-term recovery tasks. Mobile GIServices can help the emergency managers to accomplish these tasks by using utility mapping combined with GPS to identify the scale of damages in specific areas.

In a large-scale disaster, the most challenge part of short-term recovery is the coordination between different rescue teams. For example, hundreds of different rescue teams participated in the 2004 Tsunami disaster recovery and rescue work. Their experiences indicate that it is extremely difficult to coordinate these rescue teams in order to cover all damaged areas. Mobile GIS and GPS mapping will be an excellent tool to help the coordination of such tasks in the future. Another example is the rescue effort after the September 11, 2001 terrorist attacks in New York, US. The Fire Department of New York (FDNY) joined City, State and Federal Agencies to recover the ground zero site. Fire fighters used a ruggedized GPS receiver [3] manufactured by a company, called “LinksPoint and Symbol” with handheld data terminals to collect geospatial information from the debris of the buildings (see Forbes, 2002). The FDNY was tasked with the responsibility of documenting the items recovered from the rubble of the disaster zone and recording information regarding location, time and type of item found - information critical to both the ongoing investigation and analysis of the event. This information was also being used by other agencies involved in the investigation. This example demonstrates a great potential for adopting mobile GIServices for post-disaster investigation and recovery works.

[3] When an equipment or device has been modified or enhanced its shield and reliability to become weather-resistant, and shock-resistant, it is called ‘ruggedized’, i.e. ‘tough’ design for devices for any types of environment or usages.

The following section will now use a case-study from Taiwan to demonstrate the actual implementation of disaster management systems by combining Mobile GIServices and Web-based GIS.

12.4 Case-Study: Taiwan advanced disaster management decision support system in Taiwan.

The National Science and Technology Program for Hazards Mitigation (NAPHM) is an integrated and inter-disciplinary program, which is sponsored by the National Science Council (NSC) of Taiwan and is operated by the National Taiwan University (NTU), for hazards mitigation related research and technology development. The overall goal of this program, which started in 1997, is to implement hazard mitigation research to effectively reduce the risk of and loss to the general public and society arising from natural hazards. The main objectives of this program are as follows (Yen et al., 1997):

- To provide a comprehensive technological framework for practical hazards mitigation efforts.
- To consolidate the efforts of the government agencies and disaster management communities involved in order to promote, systematically, hazard mitigation research.
- To integrate hazard-related research results and transfer them to feasible procedures so that they can be implemented effectively.
- To develop appropriate methodologies for the potential analysis, risk assessment and scenario simulation of natural hazards. The methodologies will be fine-tuned before they can be used to develop a hazard mitigation plan within the jurisdictions of various government agencies.

One unique feature in the design of NAPHM is to adopt Mobile GIServices within the disaster management system. Disaster managers and other decision-makers can utilize an Integrated Disaster Information Network (IDIN), which adopts a distributed architecture via wireless mobile networks and Mobile GIS devices (Figure 12.7).

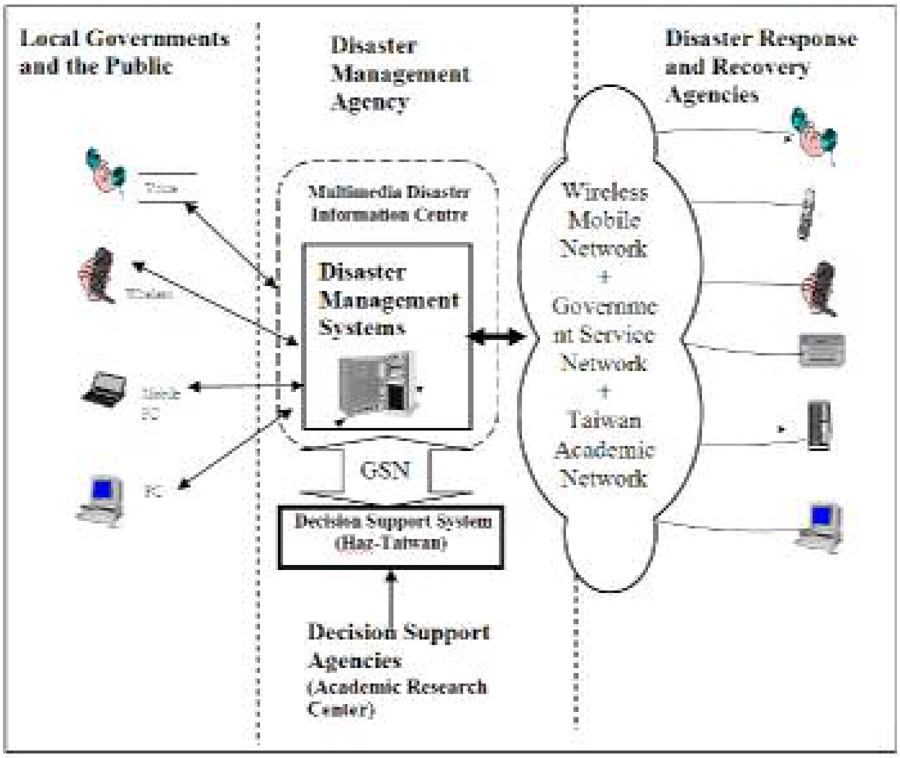

Figure 12.7. An Integrated Disaster Information Network (IDIN).

There are some considerations to be made in the designing of a comprehensive IDIN. The first issue is the Network Connectivity. A robust and reliable network connectivity lies at the heart of any successful disaster management application. However, in reality there is a wide-range of network types with different bandwidths for transmitting data and information. Successful prototypes should have enough network bandwidth to disseminate information across various connection types.

The second issue is to create a wireless mobile communication environment. Wireless computing (e.g. notebook computers, slim-notebooks, Pocket PCs, PDA's and ever-increasing hand-held mobile phones, pagers and other electronic devices) is essential for the communication among first responders, emergency managers and decision makers. Mobile computing and wireless communication will become the key technology for disaster management because the mobile computing platform can be widely used in real-time emergency response, ground-truth measurements and disaster management networks.

Figure 12.8 illustrate a Typhoon Information Display System. The system can display current and predicted typhoon routes (the top box on the left side), satellite image of typhoon (the middle box), radar information (the bottom box on the left side) together. Users can choose one of the maps to switch to full-size display (the right side window) and some animation functions. Therefore, one can track the past, current, and future predicted status of typhoon in this system (Figure 12.8).

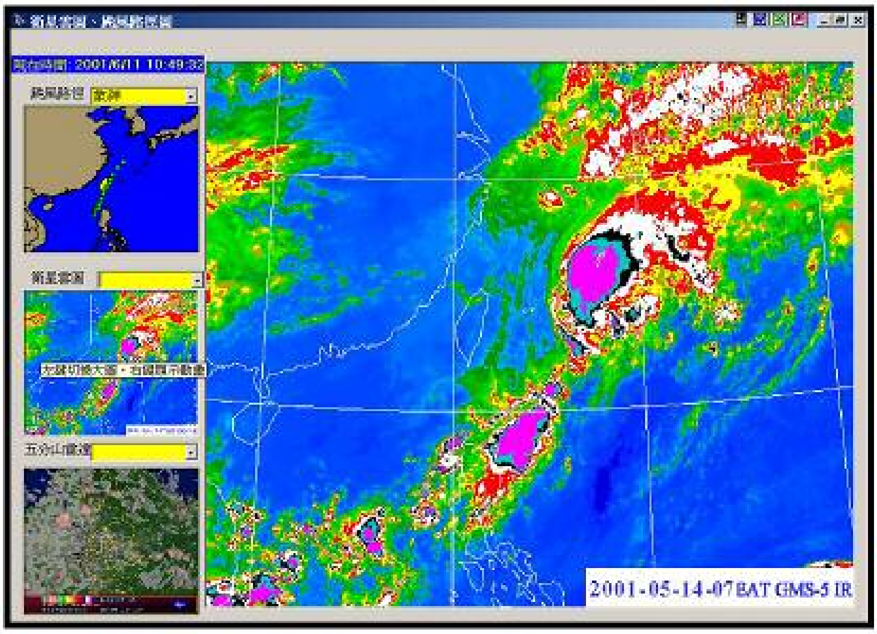

Figure 12.8. Typhoon Information Display System for Taiwan. (Top box on the left side shows the predicted path of typhoons, middle box shows the satellite image, and bottom box shows local radar information. Users can click on the left-mouse button for a full-size display or click on the right button to display animation.)

In order to efficiently manage the response to a disaster, the damage events report templates were designed to be used by the first responders (which are also the Mobile GIS users) to submit their findings into a GIS (Figure 12.9). The location or zone of each damage event can be submitted by Mobile GIS devices and then displayed on the system with information on the classification, magnitude and handling of the situation. The interface of the system can also display videos or photos to aid emergency responses.

Figure 12.9. Damage Condition Display System in Taiwan that can track multiple disaster recovery and rescue tasks. (Top table on the left side shows the ID of each disaster and their symbols – red icon for fire, blue icon for flood. Second table describes the disaster location and street names, third table describes the disaster situation and the damage level, fourth table shows the rescue and recovery actions taken by local government. Additional functions provide video and photos of the disaster taken at different locations. This screen shot shows that there are two major disaster events: one processed and one still awaiting action.)

In general, the Taiwan's disaster management system illustrates the need for geospatial information during various disaster events, such as typhoons, earthquakes and floods. The Typhoon Information Display System has been successfully implemented by the Central Weather Bureau in Taiwan. The system has been used for five years (since 2001) to help the general public and the media tracking the path of typhoons and their impacts.

This section introduced an Integrated Disaster Information Network (IDIN) for supporting multiple decision support systems in disaster management by using the Internet, Mobile GIServices, and wireless communications. The integrated spatial decision support systems can provide decision-makers with critical and real-time information for hazards mitigation and emergency response, including potential hazard areas, hazard loss estimation, and scenario simulation of various hazard mitigation options. The next section discusses the future development and limitation of Mobile GIServices.

12.5 Conclusion and future developments

Disaster management is a complex domain of human activity involving multiple agencies and stakeholders, a collaborative approach utilizing state-of-the-art Mobile GIServices can facilitate a comprehensive and functional disaster management plan. This chapter introduced the basic components of Mobile GIServices and their potential disaster management role in three main phases: preparedness, response and recovery. The GIS industry has started focusing on Mobile GIS applications and the development of mobile hardware/software (Peng and Tsou, 2003), such as ESRI's ArcPAD, Mapinfo's MapXtend, and mobile Google map (Google Inc., 2005). However, there are still some major impediments in the development of Mobile GIServices.

The first impediment is the lack of comprehensive user interface designed specifically for Mobile GIServices. Most current mobile GIS software still follows the legacy concepts of desktop GIS interfaces. The tiny, sensitive stylus pen and the small on-screen keyboard input method are not the right choice for Mobile GIServices in the emergency context. Direct voice commands and an easy, touchable screen simply used by human fingers (that may be wearing gloves) are more appropriate for emergency responders and in-field workers (see Figure 12.10).

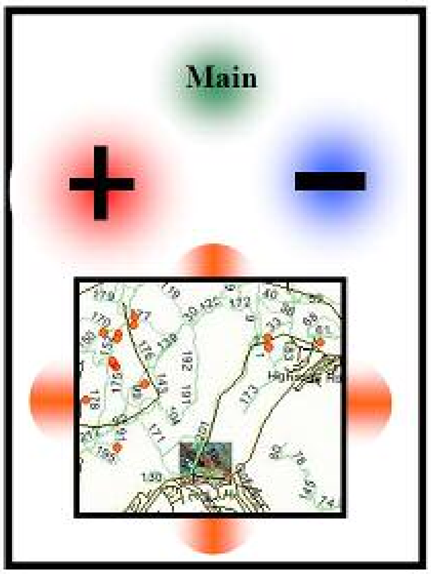

Figure 12.10. A simplified user interface design for displaying maps in a touch-screen Mobile GIS device.

The second limitation of current Mobile GIServices is the lack of real-time data collection and distribution mechanisms. It was difficult to verify the accuracy of submitted geospatial data from fieldwork. Currently, a GIS professional has to manually convert the data submitted from field workers to the Web-based GIService framework. Some predicted advances in Web Services technologies and improvement in distributed database functions might solve these technical problems in the future. However, it is always dangerous to rely on automatic data conversion without verifying the data accuracy and data quality.

The third impediment is the integration of spatial analysis and GIS modeling into Mobile GIServices. Many emergency tasks and disaster management works will need advanced GIS analysis functions that required significant computing power and computer memory. Most mobile GIS devices are tiny and only have very limited computing capability. The pre-processing and post-processing time for spatial analysis and remote sensing images might prevent the adoption of Mobile GIServices for real-time response tasks due to the hardware limitations. One possible solution is to send the complicated GIS model and spatial functions via the Internet to remote GIS engine services. Then, the analysis results will be sent back to the Mobile GIS devices via the network.

The final issue is the lack of alternative display methods for Mobile GIServices. Since most mobile GIS devices are small and fragile, emergency responders and managers might be reluctant to use small screens on Pocket PC or cellular phones to share their maps with others. One possible alternative is to print out paper maps directly from Mobile GIS devices since paper maps are easy to carry and there will then be no need for batteries in the field. It would be useful if users could print paper maps directly from their Mobile GIS devices via wirelessly portable printers or from built-in printer inside a Pocket PC or a notebook computer.

In summary, this chapter introduced an integrated Mobile GIServices framework that can provide comprehensive services for disaster management tasks. The chapter has argued that Mobile GIServices are a very promising field with very high demands from both field-based workers and the GIS vendors. With the progress of new wireless communication technology and GPS techniques, Mobile GIServices can help to monitor the dynamic changes in the real world and provide vital information to prepare and prevent natural hazards or human-made disasters. Hopefully, with the efforts from GIS professionals and GIS developers, the advancement of dynamic and mobile GIS research will protect people from various hazards in the future and improve their quality of life.

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