Evolving Technologies for Disaster Planning in U.S. Cities

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Abstract

The rapid development of modern technology has increased access to and reliance on sophisticated communication and real time technology. These technologies, which have become embedded within everyday life, have significant implications for government agencies - particularly within the field of disaster management. This paper draws on the evolution of disaster research, the history of disaster management in the US, literature on emerging uses of social media technology, and interviews from 24 emergency management offices in the US to examine three questions: 1) What types of technology are cities currently using in disaster management, 2) Which factors are most influential in determining how cities select emergency management technology, and 3) How can future technology development better address the needs of emergency managers? Several conclusions and observations emerged from analysis of the current literature and interview data.

First, technology is primarily used by city disaster management agencies in the preparedness and response phrases of the disaster cycle. These technologies can be grouped into communications, data management, and simulation technologies. Cities are already operating on web-based platforms and are, in many cases, tentatively experimenting with the use of social media as a one-way broadcasting system rather than a bi-directional platform to gather information from the general public.

Second, while various factors impact technology adoption, funding, the support of a political champion, and legal concerns stand out in particular. In addition to these adoption factors, cities are also currently facing a number of challenges including general interoperability, changing government-public relations, and increasingly mobile populations.

Future technology needs must \work to address these issues through the development and adoption of open standards, strengthening data integration capacities. Cities much also better leverage both existing and new forms of communication to build the level of trust needed to both reduce vulnerability and increase resilience.

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Abbreviations & Acronyms

CAP	Common Alerting Protocol
CMC	Computer-Mediated Communication
COP	Common Operational/Operating Picture
COTS	Commercial Off-the-Shelf
CIMS	Crisis Information Management System
DHS	Department of Homeland Security
DMA 2000	Disaster Mitigation Act of 2000
DOD	Department of Defense
DRR	Disaster Risk Reduction
EAS	Emergency Alert System
EMPG	Emergency Management Performance Grants
EOC	Emergency Operations Center
FCC	Federal Communications Commission
FCDA	Federal Civil Defense Administration
FEMA	Federal Emergency Management Agency
GIS	Geographic Information Systems
GPS	Global Positioning Systems
HGMP	Hazard Grant Mitigation Program
HSPD	Homeland Security Presidential Directive
ICS	Incident Command System
IT	Information Technology
IPAWS	Integrated Public Alert and Warning System
NFIP	National Flood Insurance Program
NIMS	National Incident Management System
NOAA	National Oceanic and Atmospheric Administration
NRF	National Response Framework
NRC	National Research Council
NRP	National Response Plan
OASIS	Organization for the Advancement of Structured Information Standards
OEM	Office of Emergency Management
RSS	Really Simple Syndication
UASI	Urban Areas Security Initiative
USGS	United States Geological Survey
VOIP	Voice Over Internet Protocol

1. Introduction

On December 26, 2010, a blizzard brought the New York City to a standstill, stranding thousands of residents and holiday travelers. City services, including emergency vehicles, struggled to respond to the deluge of service requests as hundreds of snowplows attempted to clear the roads. Nearly 48 hours following the initial snowfall, many were still stranded in Brooklyn, Queens, and Staten Island. The city's inability to handle the snow exacerbated the effects of the storm and prolonged the disruption of daily life. A preliminary review of the city's response listed six major problem areas, three of which involved communications or other forms of real time technology as components crucial to success (Weinstein and Funk 2011). Although snowplows had been dispatched to clear the roads, they often lacked radios and GPS systems, making it difficult to track progress or report obstacles across the city. This lack of real time information not only hindered the delivery of emergency medical services in the wintry conditions, but also prevented other city agencies from effectively responding to public inquiries and complaints.

Rapid technological advances, particularly in developed nations, have increased access to and reliance on sophisticated communication and real time technology. The mainstreaming of social media and networking through consumer technologies has enhanced the ability to capture and share data as well as changed the way in which technology plays a role in disaster management. In order to better understand how cities utilize technology throughout different phases of the disaster management cycle, this research aims to answer three questions: 1) What types of real time technology are cities using; 2) Which factors are most influential in determining how cities select emergency management technology; and 3) How can future technology development better address the needs of emergency managers? Understanding the choices and motivations behind city technology use as well as the drivers behind the adoption of new technology will allow policies to better address the needs and concerns of cities in relation to the goal of effective disaster management.

Technology plays a complex role throughout the different phases of the disaster management cycle, typically fulfilling operation and communication purposes. This is further complicated as the term "technology" encompasses a broad range of equipment, from weather monitoring and geographic information systems to crisis management software and social media, many of which are used for various phases of the disaster management cycle. This research focuses the use of real time technology within the disaster management cycle. In the context of this research, real time technology is broadly defined as technology with the ability to capture and provide situational information with little to no delay. As such, much of the technologies assessed in this thesis are aimed at communicating accurate, real time information to target audiences.

Although there are a wide variety of events that qualify as "disasters," this research focuses on the risks posed by natural hazards rather than man-made disasters such as chemical spills or terrorism. A natural disaster is an occurrence associated with a natural hazard that severely disrupts normal conditions and causes a level of loss and suffering that exceeds the resources and coping capacity of the affected community (World Health Organization, 2011). The term "natural disaster" often conveys the incorrect assumption that these events are "natural," rather than the result of human interactions in relation to the threats originating from natural hazards (World Health Organization, 2011). These interactions are crucial to the vulnerability of the community and, by extension, determine the impacts of such disasters.

In order to address this vulnerability in both developing and developed countries, it is necessary to take action in all phases of the disaster management cycle – mitigation, preparedness, response, and recovery. While all phases of the disaster management cycle are important, this research focuses on the use of real time technology, particularly for the *preparedness* and *response* phases. The primary reason for limiting the scope of this research to these areas is due to the fact that the majority of real time technology use has been focused around preparation and response to natural disasters, where emphasis lies on gathering as much reliable information as possible and disseminating it as quickly as possible to aid in decision-making.

Extensive urbanization and development have increased the number of people and communities at risk to natural disasters in both developing and developed countries. This increase in vulnerability is alarming in light of global trends that indicate natural disasters will continue to occur with greater frequency and intensity. These events disrupt social and economic development, infrastructure, and the delivery of emergency services, often disproportionately affecting poor and marginalized communities.

Addressing this rise in vulnerability is a challenging task, particularly since the impacts of disasters disproportionally affect the poorer classes of society and developing nations. To better accommodate potential gaps in knowledge and best practices, numerous countries and international organizations have created partnerships to facilitate the sharing of ideas and technology for the purpose of mitigation and risk reduction. Although state governments continue to maintain the responsibility for disaster management, collaboration through knowledge networks and public-private partnerships have created new ways to reduce vulnerability by focusing on mitigation and preparedness measures.

In light of the multidisciplinary nature of disaster management, this research draws upon a wide range of literature including urban risk, vulnerability, and technology diffusion. This literature provides grounding for the current state of disaster operations and emergency management practices within the specific context of the United States.

The following chapters explore the relationship between urban disaster management and technology. Chapter two, examines existing literature on the disaster research, the historical trends in US disaster management, and the development of technology for urban disaster management. Chapter three presents the research methodology, by discussing the city selection, an overview of the selected cities, data collection, and analysis methodologies. Chapter four presents the findings on the various types of technologies cities are currently using. Chapter five examines the findings on the sources of inspiration, adoption factors, and existing challenges. Chapter six, the conclusion, examines directions for future technology developments and suggests next steps.

This research will show that in response to current challenges of rapid development of technology and the rise of social media and crowdsourced information, cities are using a wide variety of communications and data management technology. The communication technology signifies that cities are working to better inform increasingly mobile and socially networked populations. Furthermore, while cities draw upon a number of disparate sources for inspiration, they consider five major adoption concerns: functionality, political support, funding, procurement, and legal issues. Many of the concerns cities currently face may be addressed by policies that promote the development and widespread adoption of open standards, and more clearly define procedures to allow emergency managers to collect and utilize social media for participatory information sharing.

2. Cities, Technology & Disaster Planning

2.1 The Evolution of Disaster Research

In order to understand why continued urbanization poses an increase in vulnerability, it is necessary to realize that disasters, particularly "natural disasters" are, in fact, the result of natural hazards acting upon human societies. A disaster occurs when a society is unable to successfully cope with the induced changes.

2.1.1 Understanding Risk, Vulnerability & Resilience

The field of disaster management is focused on the managing of risk in order to reduce the impact of disaster events by reducing vulnerability and increasing resilience and capacity. These concepts are crucial to both understanding the processes of disaster management as well as determining its overall effectiveness.

Within the discourse of disaster management, disaster risk is typically defined as a function of hazard impact, vulnerability, and in some instances, capacity. Perhaps the most common of these is the following conception equation:

$$\text{Risk} = \text{Hazard} * \text{Vulnerability}$$

As discussed by Wisner (2004), disaster risk can be conceptualized as the potential impact of a hazard, which is sometimes referred to as exposure, and the vulnerability of the community. The term "risk" can be defined in various ways, but is most often defined as the probability of a disaster occurrence (World Health Organization, 2011). Both the estimation and perception of risk are crucial to its management, as White (1945) notes – individual and societal risk perception are often directly correlated with overall disaster management capacity.

The term "vulnerability" refers to the degree to which a system is both susceptible to and unable to cope with the impact of natural hazards and other types of disaster events (World Health Organization, 2011), or more simply, the susceptibility to harm (Adger, 2006). A crucial component for the estimation of risk and identifying at-risk areas, communities or populations, the concept of vulnerability is comprised of both structural and non-structural components, which include hazard awareness and risk perception, structural condition and integrity, government administration, and overall disaster management ability.

Much of the social science literature has focused on exploring and identifying these various sources of vulnerability within the context of the disaster management cycle, as discussed below. As Paton and Johnston (2006) note, however, the broad definition of vulnerability and its characteristics has made it difficult to provide a "clear minimum standard to improve on," unlike the concept of poverty-associated vulnerability within the development literature. In addition to this, Paton and Johnston (2006) also note that certain characteristics, such as age, are "immutable" (Paton and Johnston, 2006).

While vulnerability represents the "weakness of 'at risk' areas, individuals or groups," resilience refers to the strengths and capacities through which a community can begin to mitigate its own hazards (Paton and Johnston, 2006). It is crucial to realize, however, that "vulnerability is not the opposite of resilience," and that simply reducing vulnerability does not necessarily increase resilience. Furthermore, both Paton and Johnston (2006) argue that while it is possible to create legislative measures and policies, resilience can be increased through capacity-building activities like education, prevention, and communication. Resilience, they explain, is a "characteristic that grows out of the people and their communities" (Paton and Johnston 2006).

As such, while the potential impact of an event on a community, or exposure, can be mitigated by resilience and capacity-building, the various structural and non-structural components not enhanced through these programs contribute to the vulnerability of the community. In addition to this, while it is possible to reduce vulnerability through better development or land use planning, for example, does not necessarily increase resilience – as such, it is possible for communities to be both resilient and vulnerable at the same time.

There are a number of additional models that begin to address the relationship between disaster risk, vulnerability, and resilience – many of which were developed within the social science literature. One of the more widely accepted of these models is the "pressure and release model" developed by Wisner (2004), as discussed in more detail in the following section.

2.1.2 Examining the Multidisciplinary Approach to Disaster Research

Disaster research spans across many disciplines, ranging from the social sciences to what Sylves (2008) terms "big science." Mileti (1999) traces this evolution from the early work of John Dewey and Gilbert White in the human ecology school and the concurrent development of Samuel Prince's disaster research school to the current interdisciplinary approach, which he argues, still operates on an expanded "hazards adjustment paradigm," in which individuals attempt to make decisions "based on limited information and constraints set by their social system" and a more general adjustment concept that is organized around a four stage process more commonly known as the "disaster management cycle" (Mileti, 1999).

Current disaster management strategies have centered around the four stages of the disaster management cycle: mitigation, preparedness, response, and recovery. Mitigation refers to activities, processes, or policies that are aimed at reducing physical and social vulnerability, and thereby preventing disasters or reducing potential losses from disaster events. Preparedness refers to all activities that focus on improving capacities for disaster response and recovery operations through increased readiness. The response phase, which "begins as a disaster occurs or is imminent" (Sylves, 2008), includes actions that prevent additional losses and the restoration of government services and operations. This phase is followed by the recovery phase, and includes all processes that are aimed at restoring affected governments and communities to pre-disaster conditions (Sylves, 2008).

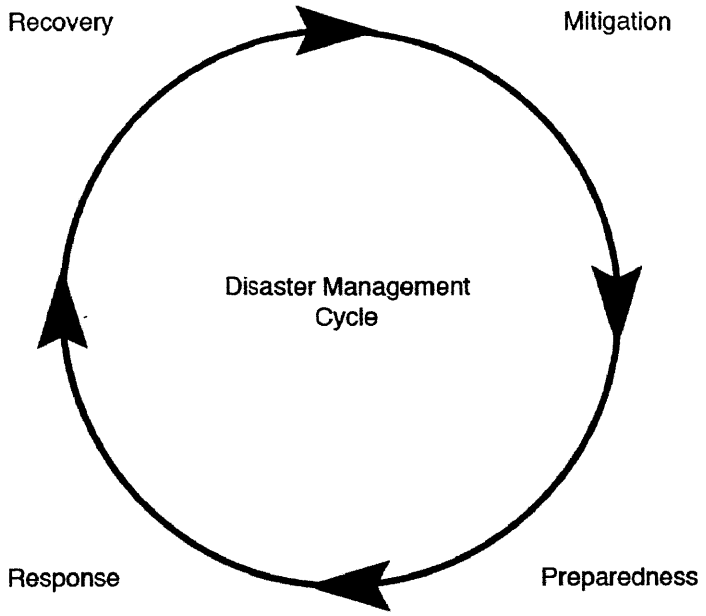

Figure 1: The Disaster Management Cycle

In an attempt to artificially divorce the study of social vulnerability from the complicated intersection of nature and the manmade environment, the social constructionist approach to disaster focuses on the importance of defining and labeling disasters as largely socially-produced concepts (Tierney et al., 2001). As Tierney et al. (2001) explain, the importance lies with understanding the "social processes through which groups promote claims about disasters and their consequences" rather than the potential or resulting impacts upon the physical world. As discussed by Tierney et al. (2001), numerous authors such as Stallings, Kreps and Drabek, emphasize the need to explore the activities of interest group and stakeholders as they work to address disaster-related problems within the broader social context as a way to better understand the "claims-making and definitional activity" for all seemingly objective properties of disaster events.

This perspective differs from the European critiques of modernity and industrial society, where authors such as Beck and Luhmann focus on how the circumstances of modern society have increased risks and overall social vulnerability (Tierney et al., 2001). Beck (1992) argues that the 'reflexive modernization' of industrial society have led to the rise of "risk societies," or societies in which the presence of new threats and the transformation of existing risks extend beyond current institutional management capacity. Beck(1992) further states that the risks of modernization, which are embedded within social order, are also reflexive in what he terms the "boomerang effect," where those who produce or profit from risks are eventually affected by the results due to an increasingly trend towards globalization. As described by Tierney et al. (2001), Luhmann's work further supports this notion as risk as "an inherent feature of modern social systems," which is further complicated by the obfuscation of causal links in an increasingly interconnected world.

The conflict-based, political-economy perspective continues to examine the trends of disasters arising from within the social system. Authors such as Tierney, Hewitt, Bogard, and Bolin, however, move beyond the focus of simply modernity and industrialization, adopting the view that disasters are the result of imbalances in political power and the "dynamics of the capitalist world system" (Tierney et al., 2001). As with the social constructionist perspective, this theory places importance on the influence of underlying political systems and power relationships in shaping development and vulnerability, rather than physical impacts.

The political-ecology perspective, which also explores the economic, political, and social sources of what Tierney et al. (2001) term disaster "victimization" and loss, concentrate on the disproportionate impacts on socially marginalized groups. Rather than focusing on the broader issues of claims-oriented conceptualization and modernity, the ecology-vulnerability view considers community networks and resources in relation to broader societal structure, emphasizing the how the influence of social relationships and access to political power, in combination with additional social inequalities result in uneven levels of vulnerability (Tierney et al., 2001).

It is clear from these numerous social science perspectives that there are a multitude of social characteristics that contribute to the overall vulnerability of a community. The "pressure and release" model developed by Wisner (2004) encompasses many of these characteristics within a progression of vulnerability that creates pressure that is then added to the simultaneous pressure of hazards as a part of the natural environment.

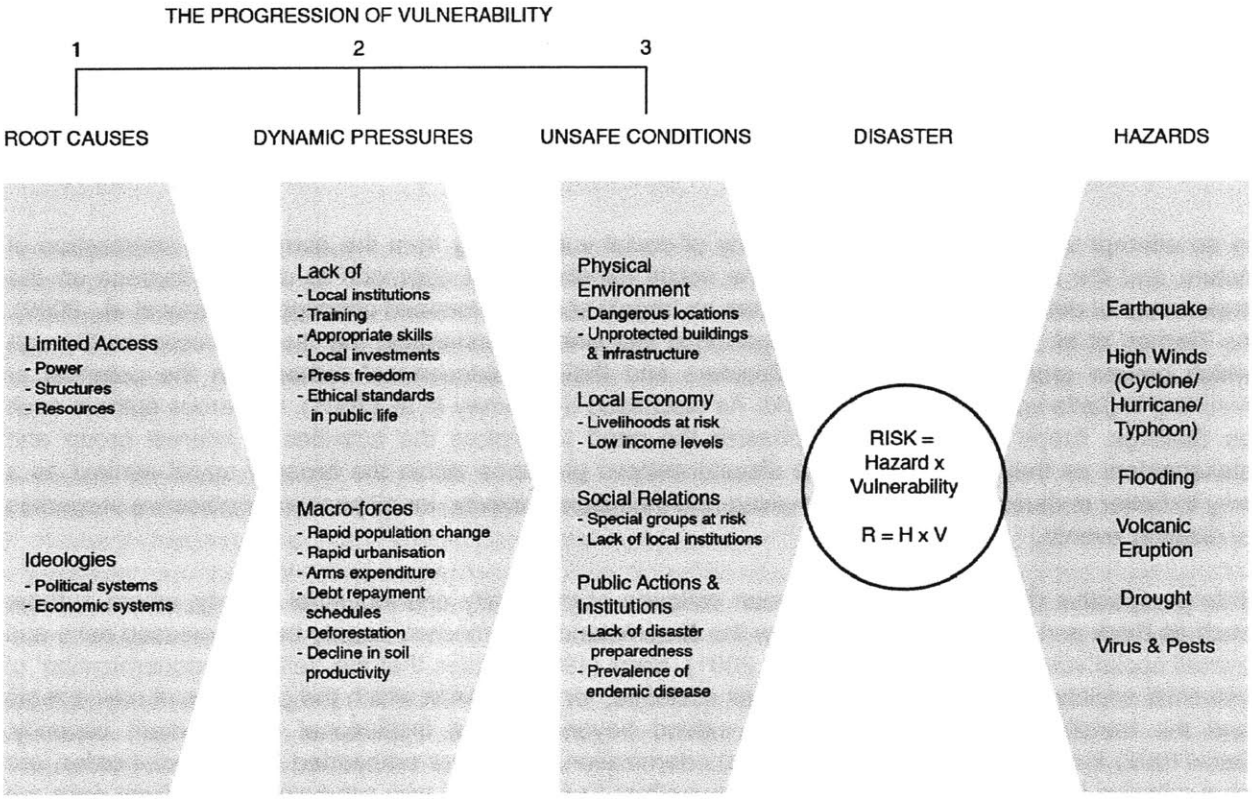

Figure 2: The Pressure & Release Model (Based on Wisner, 2004)

While the social science notions of disasters, vulnerability, and risk have centered on an acceptance that social processes play a role in the creation of disasters, many of the natural science fields have studied hazard research and the changing of the physical world (Tierney et al., 2001). Much of the natural science approach has focused on the assessment and characterization of risks within the context of the natural environment (US Environmental Protection Agency, 2011). Although these impacts are also considered in relation to human society, however, hazard research has focused more on the study of the occurrence of natural hazard events rather on the numerous social characteristics of vulnerability.

As Tierney et al. (2001) point out, both the social and natural science approaches developed along different trajectories, with hazards research focusing on pre-event hazard adjustment as opposed to the broader scope encompassed by the social science theories. It is important, however, to explore how disaster research and hazard research continue to develop and inform each other to create a more comprehensive approach to disaster management - as Beck (1992) writes, "scientific rationality without social rationality remains empty, but social rationality without scientific rationality remains blind."

It is important to note that despite the extensive exploration of social vulnerabilities, there are both social and natural components to disaster management. Furthermore, the social science literature, despite its extensive development, creates a broad and generalized picture of the social vulnerability that does not fully integrate the impacts of societal risk perception and, degree to which planning measures, such as land use codes and development, can mitigate many of the social pressures associated with the urban environment.

In the face of rapid urbanization without adequate consideration for vulnerability reduction and increased resilience, such a comprehensive approach to disaster management is necessary. In many instances, the complex environment of cities magnifies many of the social inequalities and vulnerabilities discussed by the social science literature, which are in turn exacerbated by disaster events that disproportionately affect poorer and more marginalized communities. Even with the knowledge of these underlying causes, addressing many of these issues remains difficult, due largely to their entrenchment within the social fabric. Other concerns, such as retrofitting or strengthening the built environment are costly, both in terms of finance and time. Understanding how these factors contribute to the physical and social vulnerability of a community, however, provide a crucial first step towards reducing risks and disaster mitigation (National Research Council, 2006).

2.2 Historic Trends In US Disaster Management

As the current focal point of most mainstream research, the four phases of mitigation, preparedness, response, and recovery are mutually related as "components of a highly complex but comprehendible response structure" (National Research Council, 2006). Applicable to both "natural" and "willful" hazards, the disaster management cycle is accepted and applied at all levels of the US government. The extent to which various activities are funded, however, differs between the national, state, and local levels of government.

Disaster management has a long history within the US. Evolving from World War II preparations and postwar concerns over the threat of nuclear war, the Federal Civil Defense Act of 1950 was passed as Cold War civil security policy (National Research Council, 2006). While the act placed the majority of the civil defense burden on the states in a decentralized "self-help" fashion, the measure also created the Federal Civil Defense Administration (FCDA) to formulate national policy to guide state efforts (Sylves, 2008). That same year, the Federal Disaster Relief Act of 1950 was passed in response to flooding in the Midwest, creating a framework and process establishing the use and provision of Federal assistance to state and local governments for the purpose of disaster management (Sylves, 2008). As Sylves (2008) writes, the Disaster Relief Act of 1950 created a general, national-level disaster policy model that identified national governmental responsibility in disasters and established policy for the provision of emergency relief.

As the National Research Council report notes, the 1960s were a "period of substantial social change, " with the Great Society programs of the Johnson administration aimed at revitalizing cities, reducing poverty, and the provision of disaster relief, particularly in response to earthquakes, floods, and hurricanes. The creation of the National Flood Insurance Act of 1968, which calculated rates and provided insurance for communities with minimal floodplain management through the National Flood Insurance Program (NFIP), was an example of such government policies (Haddow and Bullock, 2003). As Sylves

(2008) notes, during the late 60s the concept of preparedness programs shifted to encompass as "dual-use approach," linking civil defense and security with natural disaster management, with an all-inclusive "multi-hazard" approach aimed at reducing duplication and increasing adaptability being implemented in the Federal Disaster Relief Act of 1974. Although relegated to its origin as a nuclear attack preparedness program in the mid 1970s in response to Cold War tensions and public skepticism in the wake of the Nixon Watergate Scandal (Sylves, 2008).

Although the Civil Defense Act of 1950 was updated to include the dual-use framework for preparedness against attacks and natural disaster in 1978, fluctuations in defense spending for the Cold War and Vietnam resulted in multiple agencies with overlapping disaster management responsibilities (National Research Council, 2006). The creation of the Federal Emergency Management Agency (FEMA) in 1979, was aimed at addressing the overlap, and, upon its creation, reflected the concerns of its political administration - the civil defense and preparations necessary for full-scale nuclear war (National Research Council, 2006).

As the Cold War came to an end, the political view turned away from wartime preparation toward natural disasters. The creation of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (the Stafford Act) in 1988 foreshadowed this shift, amending the Federal Disaster Relief Act of 1974, which authorized presidential disaster and emergency declarations, created a broader range of eligibility criteria, and specified the types of assistance available to states (Sylves, 2008). The Stafford Act was primarily aimed at increasing hazard mitigation at the state level through the creation of a Hazard Mitigation Grant Program (HMGP), which would only provide assistance to states that had prepared a mitigation plan (National Research Council, 2006).

Despite promoting the idea of pre-disaster mitigation, the Stafford Act remained a relief-based, post-disaster program that did little to change investment at the state and local levels. Furthermore, FEMA was widely criticized in the following years, as the agency was unable to effectively respond to a number of serious disasters, including the Loma Prieta earthquake and Hurricane Hugo, both in 1989, and Hurricane Andrew in 1992 (National Research Council, 2006).

Hurricane Andrew was particularly devastating, as resulting losses became the highest in the US at the time, only to be later topped by Hurricane Katrina in 2005 (Blake et al., 2007). With an estimated impact of $16 billion in insured losses, Andrew also had a long-term impact on the insurance industry, with many smaller insurance firms going bankrupt or leaving the state (Hopper, 2005). In the wake of this, new policies, including a state-managed catastrophe fund and government flood insurance through NFIP, emerged to provide protection to residents living throughout Florida (Hopper, 2005).

Under the Clinton Administration and the leadership of then FEMA director, James Witt, national disaster management underwent further transformation with creation of the National Defense Authorization Act and the repeal of the Civil Defense Act of 1950, removing the heavy emphasis on security and cumbersome "dual-use" provisions. All remnants of civil defense authority were transferred to Title VI of the Stafford Act in a shift towards true all-hazards approach to disaster planning (Sylves, 2008). Witt also created three functional directorates, corresponding to the phases of the disaster management cycle: 1) Mitigation; 2) Preparedness, Training, and Exercises, and 3) Response and Recovery (Sylves, 2008).

This approach to all-hazards planning continued through out the 90s, which included a number of smaller natural disasters as well as rise in terrorist attacks. The post-disaster approach of the Stafford Act was addressed in the Disaster Mitigation Act of 2000 (DMA 2000) and the creation of the National Pre-disaster Mitigation Fund - the first "explicit pre-disaster all-hazard mitigation program" which was aimed at forming public-private partnerships, assessments on natural hazard vulnerabilities, and the creation of mitigation priorities (National Research Council, 2006).

The terrorist attacks on September 11, 2001 and the subsequent "War on Terrorism" created yet another drastic shift in disaster management, moving the focus back towards civil security and less on natural hazards. Political pressure resulted in an influx of financing with the establishment of a new department and late in 2002 the Homeland Security Act was signed into law - the Department of Homeland Security, of which FEMA was now part, became operational in 2003 (Sylves, 2008). With the overall goal of creating a comprehensive approach to manage domestic incidents, Homeland Security Presidential Directive - 5 (HSPD-5) was issued in February 2003 which called for the creation of a National Response Plan (NRP) and a National Incident Management System (NIMS), creating a standardized framework for disaster management operations at all levels of government (Sylves, 2008).

The National Incident Management System (NIMS), provides a core set of concepts, principles, terminology and technologies based in the following areas: Incident Command System (ICS), multi-agency coordination systems, unified command, training, identification and management of resources, situational awareness, qualifications and certification, collection, tracking and reporting of incident information, crisis action planning, and exercises (Sylves, 2008). The NIMS also administers additional programs such as Supporting Technology Evaluation Program (STEP), to support NIMS implementation and the overall goals of the National Response Framework (NRF), the successor to the NRP (US Department of Homeland Security 2009).

While the language of this risk-based framework stress preparedness for all hazards, however, the focus has remained firmly anchored around terrorism-related events. Sylves (2008) points out that the inclusion within the DHS should have worked to the advantage of FEMA, a "legacy agency" with connections to state and local leadership. Instead, from 2003 to 2005, FEMA lost much of its jurisdiction over mitigation and recovery disaster management functions in "bureaucratic turf wars" with larger organizations within DHS (Sylves, 2008).

This changed in the wake of Hurricane Katrina in 2005, when the Post-Katrina Emergency Reform Act of 2006 reconstituted FEMA as a full-service emergency management agency, though still within the Department of Homeland Security (Federal Emergency Management Agency, 2010). This change was one of many made in response to national outrage over the way response and recovery efforts were coordinated.

As of the writing of this thesis, Hurricane Katrina is the costliest hurricane to strike the US – it is also one of the top five deadliest (Knabb, 2005). It is also an example of the ways in which structural and societal vulnerabilities and inequities are exacerbated through a chaotic, fragmented disaster management process. As Shane (2005) and other journalists noted, jurisdictional battles, logistical confusion, and a general lack of information, coordination, and communication led to delays and the inefficient deployment of resources.

In the aftermath of the disaster, there was much speculation on how potential differences race and class may have affected the speed and effectiveness of the response. As Sandalow (2005) writes, the storm "thrust the nation's enormous economic disparities into plain view," emphasizing the fact that prior to the hurricane, New Orleans had already been ranked among the nation's poorest cities. Although not all who were affected were poor and/or African American, many felt that the Bush administration would have "responded with more urgency" had the affected community been located in "white suburbs rather than predominantly black inner city" (Sandalow, 2005).

Currently, FEMA continues to operate within the DHS and the National Response Framework (NRF), providing support to both state and local governments. Although the balance between terrorism and natural disasters continues to shift based on political environment and the occurrence of events, there are benefits such as numerous disaster preparedness grants, including state level Emergency Management Performance Grants (EMPGs), State Homeland Security Grant Program, as well as the Urban Areas Security Initiative (UASI), all of which assist in providing funds for emergency management (Sylves, 2008).

2.3 Urban Disaster Management & Resilient Cities

Although disaster planning can occur at all levels of government, cities often represent the inherent tension between development and vulnerability. With over half of the world's population located within urban areas, it is crucial towards view the factors within an urban context (Population Reference Bureau, 2007). As Tierney et al. (2001) note, new planning methodologies have served to encourage urban development, which is aimed at providing benefits specific to increased density. Within specific contexts, this type of development can create unique challenges, particularly around the areas of service provision, structural robustness, and social justice. These challenges are only exacerbated by disaster events, which often disproportionately affect the more marginalized and resource-poor communities (Wisner et al., 2004).

It is crucial to understand that cities face different challenges in relation to the context of their contemporary and historical development. Pelling's (2003) work centers more on obstacles such as unplanned expansion and legislation within the international context, particularly for mega-cities in the Global South, arguing that larger and more industrially developed cities face additional sources of technological risk, but temper their vulnerability through increased regulation. Paton and Johnston (2006) also take a more varied approach, focusing on communities in both first and third world countries, while Godschalk (2003) and Tierney et al. (2001) examine disasters in industrialized cities, or more specifically the urban context within the US, which include both technological risks and threats of terrorism. While cities in the developed world, however, still suffer from "inappropriate" planning and shifting development trends (Pelling, 2003), many industrialized cities are still discovering the extent to which these problems have exacerbated their vulnerability over time - as Tierney et al. (2001) point out, "for the foreseeable future, we will be living with the consequences of having steadily if not unintentionally created vulnerable communities."

Both Godschalk (2003) and Pelling (2003) also note this rise in vulnerability, arguing that increasingly interconnected infrastructure, sprawling development, and inequitable social relationships not only create risks, but raise the potential severity of losses. Pelling (2003), however, is quick to point out that these factors must be considered within the context of the larger system. The notion that issues such as population growth and urban sprawl can increase vulnerability, for example, stem from a neo-Malthusian framework in which population pressure increase resource depletion and environmental degradation, raising the likelihood for disaster (Pelling, 2003).

As such, it is necessary to study the ways in which cities are working to improve their disaster management capabilities. As Godschalk (2003) notes, despite FEMA's emphasis on hazard mitigation, hazard mitigation guidelines "have not focused on or identified the unique needs and characteristics of cities under stress, as opposed to more generic situations." He further argues for a concentration on "urban hazard mitigation" as a way to foster the development of resilient cities through research, policy prioritization, education, and collaboration (Godschalk, 2003). Godschalk's concept of resilient cities aims to "bridge natural hazard mitigation and counterterrorism practice," through the effective use of "apparent opposites," such as efficiency and redundancy, which would enable cities to develop the flexibility needed to deal with disaster events.

Pelling (2003) also advocates for the importance of creating resilient systems within in cities, arguing that they serve as "focal points" for complex socio-economic, political, and environmental linkages as well as "nodes" for the transformation of energy and information exchanges. Furthermore, he observes that particularly within the urban context, there has been much attention on large, catastrophic events, despite the fact that "everyday hazards" or "chronic disasters" can lower the overall resilience of the system and increase vulnerability through acceptance and complacency (Pelling, 2003). Programs that enhance communication, resource allocation, and local participation are crucial to building urban resilience (Pelling, 2003).

As discussed earlier, however, decreasing vulnerability does not necessarily increase resilience. Following the theory that vulnerability arises as an inherent outcome of the social order, Paton and Johnston (2006) argue that many vulnerability characteristics are "immutable" - as such, vulnerability analyses are most useful in determining "at risk" areas (Paton and Johnston, 2006). Resilience, is aimed at addressing the strengths and capabilities that allow communities to cope with and recover from crises (Paton and Johnston, 2006). As with Pelling (2003) and Godschalk (2003), Paton and Johnston (2006) call for improvements within community activities as a way to create local capacity, including education, communication, and unity of purpose.

2.4 Cities As Centers for Technological Innovation

Being both desirable and dangerous "nodes" of development (Pelling, 2003), it is necessary to study the ways in which cities are working to improve their disaster management capabilities in a complex environment of increasing mobility and interconnectedness. Differences in current conditions can affect the feasibility of various approaches, including the introduction or implementation of new technology - cities often operate at a scale conducive to the local adoption of new technologies and pilot programs without the necessarily encountering the delays of jurisdictional bureaucracy present at the other levels of government.

Furthermore, as evidenced in both the literature and more recent disaster reporting, the cities and communities in which disasters take place are the first responders. The additional complexity of coordinating response and recovery efforts between additional state and federal agencies likely provides and incentive for cities to engage proactively through various measures, which may include technological solutions.

As much of the disaster literature points out, technology has greatly enhanced the capabilities of both scientists and emergency managers. Concerns over technological risks and over-reliance, however, advocate for caution. Tierney et al. (2001) warn that a cultural acceptance of technological solutions should not prevent us from realizing that the increased use and reliance on technology may also have negative or unforeseen effects on disaster management. These risks stem from a lack of information regarding both the capability and readiness of emergency agencies to adopt and implement new and possible untested technology (Tierney et al., 2001).

Understanding the impact of technology within the broader context is particularly challenging, given the complexity of disaster management in general. National Research Council (2007) suggested a framework for considering the use of information technology in the broader social context. This framework consists of a four-part "stack" model, made up of the following layers: 1. Organizational and social context; 2. Human behavioral context, 3. Procedural and policy framework; and 4. Technology (Rao et al., 2007).

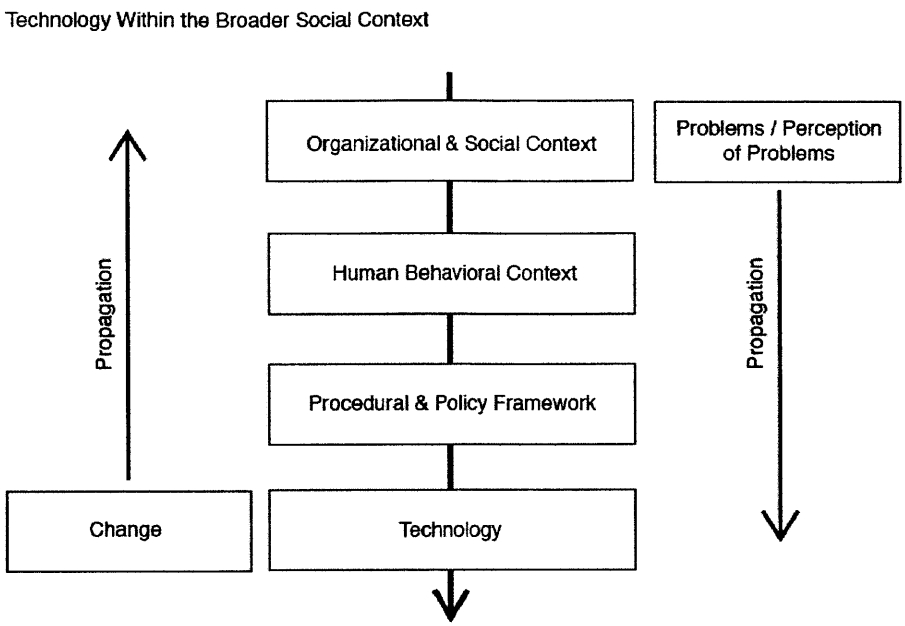

Figure 3: 4-Tier Framework (Based on Rao, Eisenberg & Schmitt, 2007)

As described by the Rao et al. of the National Research Council (2007), the organizational and social context component of the model refers to the "goals, metrics, priorities, and beliefs of each organization involved, as well as those of "meta-organizations" such as an incident command structure (ICS) or emergency operations center (EOC) that involves multiple organizations." This portion of the framework includes cultural and organizational constraints as well as informal social networks.

The human behavior context layer refers to the various skill sets, experience, training, and personal factors that can be attributed to an individual's performance (Rao et al., 2007). This portion of the framework explores the importance of the human variability, which the report describes as an "only partially controlled variable" within carefully planned systems.

Predictable and structured behaviors and responses are included within the procedural and policy framework layer. The report notes that many of these types of behaviors are typically based on extensive knowledge about the current system, which can lead to confusion in situations where there are profound shocks or changes to the existing system (Rao et al., 2007).

The technology phase of the framework includes the "physical layer of communications," and the "medium through which communications and infrastructure needs are met" (Rao et al., 2007). According to the report, this layer also includes the capital infrastructure investment for both communications and information technology as well as issues with technical failure, interoperability and data compatibility.

This framework provides a well-organized structure for the categorization of various issues and impacts of both operations and technology within the broader social context at various scales - from the individual to the organization level. The report points out three insights that result from this model: 1. Problems, or the perception of problems, tend to propagate downwards through the structure; 2. Changes tend to propagate upwards through the structure; and 3. Many of the interoperability and data-sharing challenges tend not to be technical in nature (Rao et al., 2007). Perhaps most importantly, these insights suggest that while many issues and complications are often "mistakenly" attributed to technology (Rao et al., 2007), when in fact changes in technology, result in changes at the policy, individual, and organizational levels.

The effective use of new technology requires new policies and procedures, which lead to the learning of new skills at the individual level as well as new organizational challenges which require adaptation and adjustment over time (Rao et al., 2007). In light of the concrete nature and consequences of new technology, as opposed to more abstract impacts of the other tiers, it becomes easier to see how multi-level change often originates with changes in, or the adoption of new technologies.

2.5 Technologies and Disaster Management

The notion of technology as a catalyst of change within the disaster management framework is particularly crucial in light of advanced computing and increasingly sophisticated products that have not only exponentially improved the range and speed of communication and information exchange, but also changed the types of information that are gathered and the ways in which it can be displayed. The rise of social media and other forms of real time information sharing technology are not only changing social relationships, but professional relationships as well. Both government agencies and private sector organizations have begun integrating social media software and platforms into their operations.

2.5.1 Understanding the Various Subtleties of "Real Time" Technology

There are a number of definitions for the term "real time". The term of "real time," according to Merriam-Webster Online Dictionary and Dictionary.com, originates in the early 1950s. The current meaning, which is simply "the actual time during which something takes place" (Merriam Webster, 2011), is commonly used in reference to computing and other forms of data analysis. Many of the consumer technologies currently available allow for near instantaneous delivery of information to a multitude of mobile devices.

Within the context of computer animation and 3D graphics, however, the concept of "real time" is much more nuanced. As Hadwiger (1998) writes, real time 3D graphics consistently demand renderings and animation of 30 frames per second or greater – an operational speed at which there is no perceivable delay to the viewer. The speed of frame rate perception is critical to providing a smoother animation and, ultimately a more realistic virtual environment (Hadwiger 1998).

A second definition of "real time" can also be found within the computing environment, but refers to the loading and task performance times experienced by the user. According to the Apple iOS Human Interface Guidelines (2011), this time should not exceed two to three seconds before requiring a progress bar to indicate the amount of time needed to complete the task.

While both of these definitions draw upon the literature of human-computer interaction and visual perception, it is clear that the definition of "real time" is changing. As Laplante (2006) writes, the evolving use of "real time" can create confusion and frustration about the speed with which interactions take place. It is clear from the three definitions listed above, however, that despite a lack of specificity, the use of "real time" signifies "deadlines satisfaction" (Laplante, 2006).

When considered within the context of emergency management, the use of "real time" remains ambiguous, particularly with regard to the description of real time interactions with real time data, as opposed to real time interactions with static, or archival data. As this subtle difference, a product of increasingly sophisticated data gathering technology, is not very clearly defined throughout the literature, discussion of "real time" technology can be difficult.

Although there exists an extensive literature on the "real-time" technology and disaster management, many of these technologies are also categorized under the broader category of information technology (IT). According to a 2007 report published by the National Research Council, the first applications of information technology to disasters were in the form of voice communications. Since then, the rapid technological development, through research and spillover from both military and consumer sectors has led to the use of increasingly sophisticated technology, including advanced computing, geospatial data and imagery, models, and simulations (National Research Council, 2006).

2.5.2 Technology Use

Of the various technology categories being used within the field of emergency management, one of the newest is the use social media and mobile communications. A subset of computer-mediated communication (CMC), social media should be considered within the various applications and services referred to as Web 2.0 (Starbird et al., 2010). Web 2.0 refers to internet applications that facilitate participatory information sharing, collaboration, and user-centered designs (TechPluto, 2009). While this categorization can be extended to include many of the current and developing information technologies referenced more generally in this research, Web 2.0 represents the two-way exchange of information-usually on high bandwidth wireless internet. It is important to note that there are lower tiers of technology, such as Web 1.0, which facilitates one-way internet reporting, and basic voice communications (Strickland 2011). Many of the more commonly used mobile communications refer to the use of cell phone capabilities, which include the ability to send and receive text alerts, and, in many cases, provide access to the internet.

A new body of literature, led by authors such as Starbird and Palen explain, the real time nature of these platforms as well as their ability to engage with communities can and should be leveraged by emergency management as a way to support citizen reporting. According to Starbird and Palen (2010), the use of microblogging services such as Twitter can serve as "mechanisms for information production, distribution and organization." The increased popularity of participatory information sharing, or crowdsourcing, has led to the development and use of specialized web platforms that aggregate user-provided information such as Ushahidi and Sahana (Goodspeed, 2010).

The term "crowdsourcing" was coined by Jeff Howe (*Wired* Magazine) in 2006. Howe used the term to refer to the idea of a web-based system that would companies to leverage the knowledge of the general public for problem-solving, content creation, and in some cases, even research and development (Howe, 2006). Much like the various definitions associate with "real time," the crowdsourcing has taken on a much broader definition: "the practice of obtaining needed services, ideas, or content by soliciting contributions from a large group of people and especially from the online community rather than from traditional employees or suppliers" (Merriam Webster, 2011).

Within the context of disaster management, this term maintains much of this broader definition, drawing on the notion of participatory information sharing through various technology platforms, including crisis management crowdsourcing platforms such as Ushahidi and Sahana, which integrate publicly reported information into web-based interactive maps and visualizations.

Ushahidi, Swahili for "testimony," is a non-profit tech company that specializes in developing free and open source software for information collection, visualization and interactive mapping (Ushahidi, 2008). Originally developed to map report of violence following the Kenyan elections in 2008, the Ushahidi platform has become a way to map and visualize citizen-reported information through the web and the use of mobile phones (Ushahidi, 2008).

Sahana, a crowdsourcing information platform similar to Ushahidi, is currently being used to manage landslides in the Philippines. Sahana provides more coordinated information sharing as well as specific modules aimed at fulfilling specific crisis concerns such as organizational registries, volunteer organizations, and situational awareness (Goodspeed, 2010).

More recent disaster events such as the earthquake in Haiti and both the earthquake and tsunami in Japan resulted in extensive use of crowdsourcing and the building of non-official informational sites, including an Ushahidi crisis map where people can text and tweet for people who need assistance (Sinsai, 2011), and a Person Finder site powered by Google (Google, 2011). These sites, while unofficial by governmental standards, fulfill the need for a space that allows users to both respond and contribute information during and after crisis events.

These technologies represent many of the new developments that can affect disaster management both formally and informally. Cities, while concentrating on the maintenance and development of their own systems can potentially capitalize on these informal, non-official systems as a way to support their own operations.

The adoption of new technology and innovation is difficult to predict – as Rogers's *Diffusion of Innovations* (2003) suggests, there a number of factors that affect the successful adoption of innovation, regardless of its benefits. One of the most influential factors for adoption, according to Rogers (2003), is the presence of a "champion" or an influential figure that pushes for the adoption and subsequent implementation of new innovations within the organization.

Many cities do maintain internal capacity to create in-house technological solutions that are often more customized than external solutions. While the scale of such innovations may depend on the size and availability of organizational resources, such internal development remains a viable method for new technological solutions (Rao et al., 2007).

With regards to new, externally developed technologies, however, Rao et al. (2007) note that the adoption process is particularly difficult for disaster management. Concerns over failure and uncertainty, as discussed by Tierney et al. (2001), make the process of selecting, testing, acquiring, and implementing new technologies tedious and slow. Disaster management agencies have historically acquired new technology through "waterfall acquisition" (Rao et al., 2007). This type of acquisition, as Rao et al. (2007) note, is characterized by a linear process that results in a long series of major deployments that can occur over years. These long acquisition cycles can be particularly damaging and costly given the fast past of technological improvement.

While Rao et al. (2007) suggest various solutions, such as shorter-cycle iterative development, evaluative metrics for cost-benefit analysis, and metrics-driven investments, perhaps the one of the most effective suggestions lies in "building capacity at the intersection of IT and disaster management" through closer relationships with developers and using open, practitioner-driven processes and platforms. These solutions not only provide cities with increased capacity, but also work to build a more comprehensive understanding between developers and disaster managers.

In working towards building a more resilient city, disaster managers will consider using a variety of measures, including technological solutions. As relatively independent centers of innovation, these cities can build their technological capacities through a variety of systems, models, and interactive technologies as discussed extensively by Rao et al. (2007). In light of this, however, there are still gaps in our understanding of what cities currently use, how they find and select new technologies, and the challenges that affect their overall capacity. Understanding these underlying and motivational factors can lead to a better understanding of how cities are using technology for disaster management and how the future of such technologies can be improved to better suit their needs.

3. Research Methodology

While technology has long been a crucial component for large-scale disaster planning, the availability and use of real time technology has examined the use of real time technology for urban areas. This research focuses specifically on the development and use of real time technology for major urban areas across the United States. In order to understand how future technology development can assist in improving the efficacy of disaster management, it is necessary to examine the role such technology currently occupies in large cities and throughout the various phases of the disaster management cycle.

3.1 City Selection

A total of thirty cities[i] were originally selected for participation in this research. The primary factors for initial selection of cities were population size, cost of living, median household income, and potential exposure to a variety of natural hazards. These factors, in combination with general perceptions on cities as innovators, were used as a general approximation for technology-wealthy areas of relatively large populations throughout the US. The sample of cities interviewed represented a moderately diverse range of geographic and social criteria.

Population size was one of the most important factors in selecting cities. The majority of the selected cities fall within larger metropolitan areas with populations well over a million people. These cities were then evaluated on a cost of living index, as well as in relation to median household income, salary growth, and overall employment growth[ii]. These criteria were used to select larger, more expensive cities based on the assumption that such cities would likely have more resources and operational capacity. Additionally, it was assumed that cities with wealthier constituents would, in response to potential lobbying and public accountability, more heavily invest in technology – particularly technology that emphasizes public interface.

Beyond these primary selection criteria, cities were chosen based on context-specific criteria, including perceived vulnerability, the presence of academic institutions, and the potential for comparison within the state context. In limiting the number of selected cities to thirty, certain cities were selected over others. The list of selected cities is as follows:

Table 1: Participating Cities

Los Angeles, CA	Atlanta, GA	Kansas City, MO	Philadelphia, PA
San Diego, CA	Honolulu, HI	Raleigh, NC	Pittsburgh, PA
San Francisco, CA	Chicago, IL	Charlotte, NC *	Houston, TX
New Haven, CT *	New Orleans, LA	Las Vegas, NV	Dallas, TX
Washington, DC *	Boston, MA	New York, NY	Seattle, WA
Miami, FL	Baltimore, MD	Cleveland, OH	
Orlando, FL	Detroit, MI *	Oklahoma City, OK	
Tampa, FL *	Minneapolis, MN	Portland, OR	

* Denotes cities that were contacted but did participate in the research

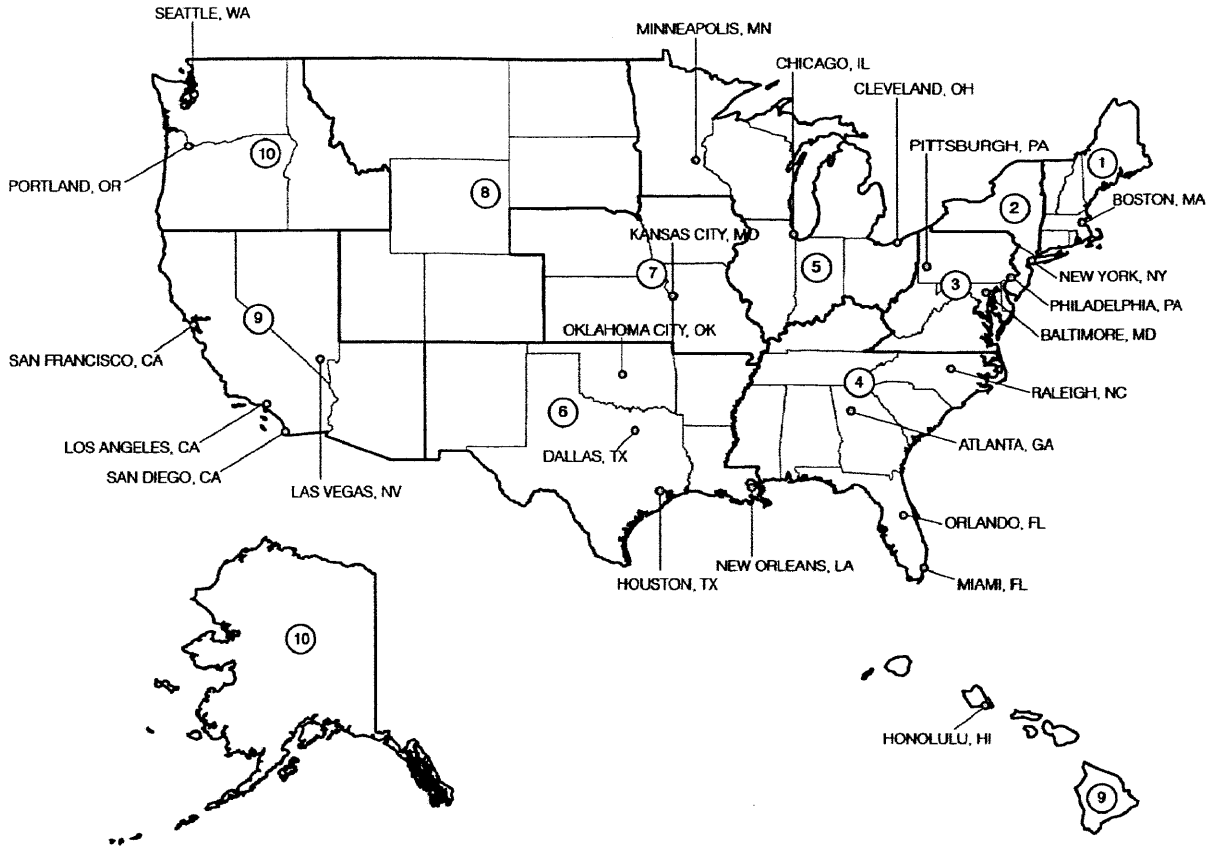

Figure 4: Map of Participating Cities & FEMA Regions

3.2 City Background

3.4.1 Regional Distribution

While differences in regional divisions make generalization more difficult, the selected cities were located broadly throughout the US, with the majority of cities being located on the eastern half of the country. Many of these cities are located in states with close proximity to large water bodies, including the Pacific Ocean, the Atlantic Ocean, the Great Lakes, and the Gulf of Mexico. Understanding the geographic and regional context is crucial to understanding common hazards as well as regional operations concerning evacuation and resource provisions through programs such as the Emergency Management Assistance Compact (EMAC).

The Emergency Management Assistance Compact (EMAC) is administered by National Emergency Management Agency (NEMA), a national non-profit professional organization of and for emergency management directors throughout the US. EMAC is a congressionally ratified interstate mutual aid agreement that provides a standardized process through which states can share resources during times of disaster. (National Emergency Managers Association, 1995). As such, geographic proximity to other states can provide increased response capacity – an option that may not be available for more isolated states such as Alaska and Hawaii.

The map above illustrates the ten FEMA regions, which focus on providing support for the states located within that region. As is visible from this map and from earlier discussion on the city selection criteria, this

research does not include any cities from FEMA region 8. With the exception of this region of relatively lower population, the selected cities included at least one representative FEMA region, with higher representation in regions 4, 6, and 9 and the selection of cities for in-state comparison.

Table 2: Participating Cities by FEMA Region

Region1	Region 2	Region 3	Region 4	Region 5
Boston, MA	New York, NY	Baltimore, MD Philadelphia, PA Pittsburgh, PA	Miami, FL Orlando, FL Atlanta, GA Raleigh, NC	Chicago, IL Minneapolis, MN Cleveland, OH
Region 6	**Region 7**	**Region 8**	**Region 9**	**Region 10**
New Orleans, LA Oklahoma City, OK Dallas, TX Houston, TX	Kansas City, MO		Los Angeles, CA San Diego, CA San Francisco, CA Honolulu, HI Las Vegas, NV	Portland, OR Seattle, WA

4.1.2 Jurisdictional Differences

As discussed within the research methodology, it is important to acknowledge various jurisdictional differences between the selected cities. While these differences were not heavily discussed during the interviews, it was presumed that differences in jurisdiction might affect various aspects of the disaster management process including funding and access to resources. These differences were also thought to potentially affect the organizational location and capacity of the disaster management office, as well as determine the extent of its responsibilities in relation to other city agencies. Of the selected cities, there are 3 consolidated city-counties, one independent city, and several unique governance structures.

A consolidated city-county is the merging of a city, a municipal corporation, and a county, an administrative division of the state into one unified jurisdiction (US Census Bureau, 2011). The city of San Francisco is a consolidated city-county, as is the city of Honolulu and New Orleans, which is combined with Orleans Parish. A consolidated city-county is not the same as an independent city, despite the fact that an independent city may also result from the consolidation of a city and county (US Census Bureau, 2011).

An independent city is a city that is not part of any county, and therefore operates independently of any county organizations (US Census Bureau, 2011). According to the US Bureau of the Census, the city of Baltimore, in Maryland, is the largest independent city in the US.

In addition to consolidated city-counties and independent cities, there are several other cities that have unique government structures such as New York. New York is slightly different from consolidated city-county in the sense that the city is an amalgamation of 5 counties, which are more commonly referred to as boroughs (US Census Bureau, 2011).

4.1.3 Population Distribution

In general I attempted to select cities that were associated with larger metro areas, selections which were aimed at exploring the potential capacity to focus on more extensive and robust disaster management. While this is strongly correlated with population size, the combination of selection criteria resulted in a wide range of population values as indicated in the chart below. The city with the largest population count was New York with approximately 8.4 million people, while the city with the smallest population was Orlando, FL, with approximately 236 thousand residents. The average population size across all participating cities was approximately 1.23 million people. As the following table indicates, the average

population count is affected by large outliers, (such as Los Angeles (3.8M), Chicago (2.9M)), as well as smaller outliers including Pittsburgh (312K) and Orlando (236K) (US Census Bureau American Factfinder, 2011).

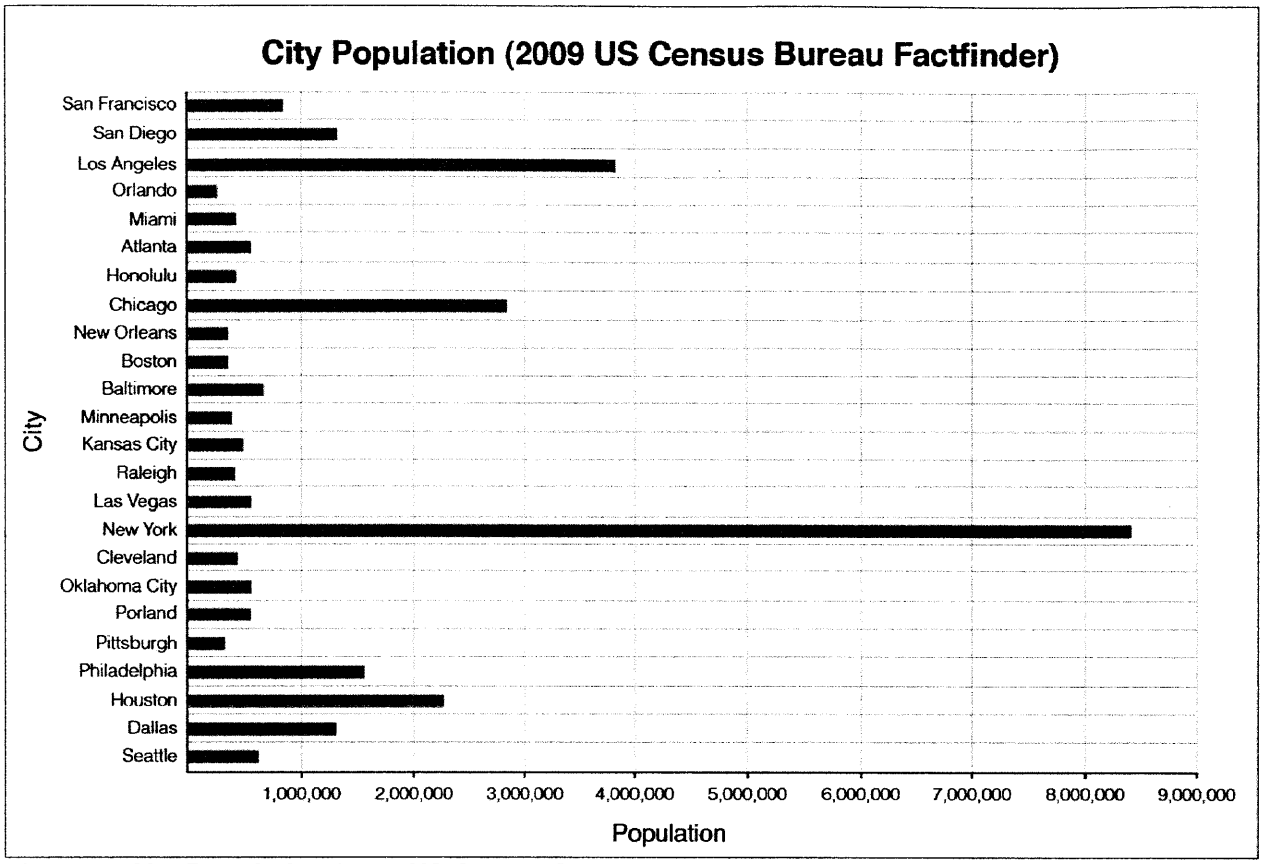

Figure 5: City Population (2009 US Census Bureau Factfinder)

4.1.3 Common Hazards

As mentioned in earlier discussions, geographic location provides a strong indication of the various natural hazards that a city faces. Cities within the same geographic region are likely to share common hazards that may occur with greater frequency. The following chart illustrates frequency of common natural hazards by city, with the most common hazards being flooding, severe thunderstorms, and extreme heat events, closely followed by hurricanes and severe cold and winter storms.

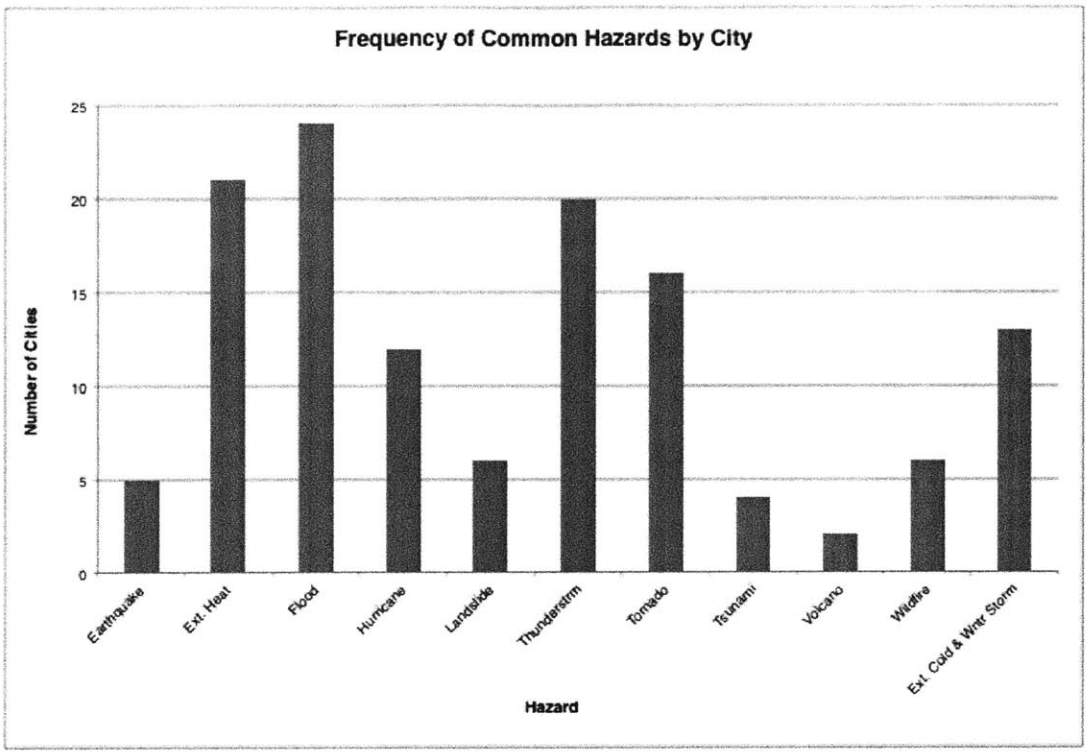

Figure 6: Frequency of Common Hazards by City

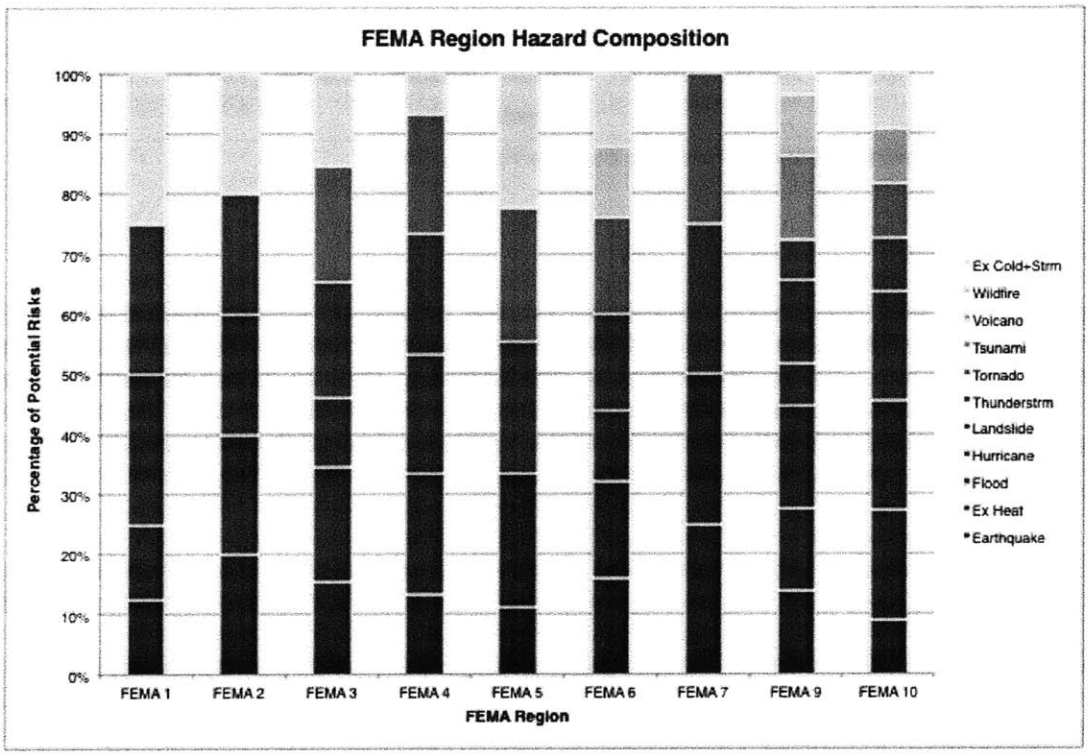

Figure 7: FEMA Region Hazard Composition by Participating City Location

4.1.4 City Summary

The cities selected for this research represent a broad geographic distribution of larger metropolitan areas that are generally wealthier and perceived as technologically progressive. These cities face a wide variety of natural hazards and operate in diverse jurisdictional contexts, all of which can affect the technologies they currently use for emergency management, their ability to identify and adopt new technologies, as well as the needs and challenges they presently face.

3.3 Data Gathering

Of the 29 cities contacted, 24 cities agreed to participate in the research, a participation yield of 82.76%. While five cities chose not to participate, their attrition does not appear to introduce any further systemic bias into the analysis based on the participation of other cities with similar selection criteria. The data were collected through semi-structured telephone interviews with personnel from 24 emergency management offices. Participants for these interviews were selected based on their expertise and experience with their agency's disaster management and emergency response practices. The majority of interviewees were senior operations/communications specialists or managing directors who were familiar with their office's technology use and procurement procedures. Interviewees were identified through press releases, websites, telephone inquiries, and the assistance of personal contacts.

The interview itself was comprised of 8 questions covering the areas of current technology use, adoption factors, past technology use, and future technology development. There were eight main questions with subparts that enabled interviewees to expand on the specifics of their answers (See Appendix A). Interview times ranged from 30 minutes to 70 minutes, with an average interview lasting approximate 40 minutes. Interviews were conducted by telephone without any electronic recording. Notes were taken during the conversation. These were then transcribed for analysis.

These data were supplemented with interviews with Paul Hewitt (Argonne National Laboratory), Craig Hosang (New York Mayor's Office of Operations), and Laurie Van Leuven (DHA/FEMA). Additional information was gathered from social media sites, reports, press releases, and presentations. These sources provided further information on interoperability standards, funding structures, and market size for crisis information management software (CIMS).

3.4 Limitations of Study

There are a number of limitations that must be acknowledged within the research design of this thesis. These biases include the choice of city selection criteria, self-representation by agencies, a lack of national perspective, and differences in scalar perspectives.

3.4.1 Selection Bias

As discussed earlier, the selection factors prioritized population size, cost of living, median household income, and growth as a way to select larger, wealthier cities. Additional criteria were then used to tailor the distribution of cities to address specific criteria to create a list of thirty cities. The result is an uneven distribution, weighting the eastern half of the country. As is evident from both maps, there were no cities selected within the region Montana, Wyoming, Utah, Colorado, North Dakota, and South Dakota. In light of these heavy selection biases, it is necessary to realize that the results of this research do not reveal a complete picture of disaster management across major, technology-wealthy cities in the United States.

3.4.2 Self-Representation

For this research, local emergency management offices were interviewed about their own experiences, needs, and abilities as a way to limit the scope of possible analysis. While these offices occasionally referenced the capabilities of other cities, the analysis only reflects these cities' perceptions of their own

capacities and goals. As such, it is necessary to realize that there may exist implicit biases on individual performance and/or capabilities that may not necessarily be apparent from an external perspective.

3.4.3 Variations in Perspective

This research relies heavily on the response of individuals at the local level of emergency management. As such, the analysis focuses on technology use at the city level and does not expand on state or national perspectives on disaster management. Additionally, some of the selected cities are unique government entities such as consolidated city-counties (e.g. San Francisco, Honolulu) or independent cities (e.g. Baltimore), while certain cities consolidate emergency management operations for both the city and county (Atlanta-Fulton County). While this variation limits the potential for uniform comparisons at the city level, the research is still aimed at examining technology use and adoption from an urban perspective.

4. Findings: Technology to Improve Disaster Management Functionality

In order to better understand how and why cities are using various forms of technology, the interviews were focused on examining technology used for internal government functions as well as interactions with the general public. While this research examined a wide variety of technology, the interviews revealed that emergency managers view technology primarily through potential function and utility rather than for use within a specific phase of the disaster management cycle. These functions were most easily split into the following categories: communication, data management, and simulation & modeling.

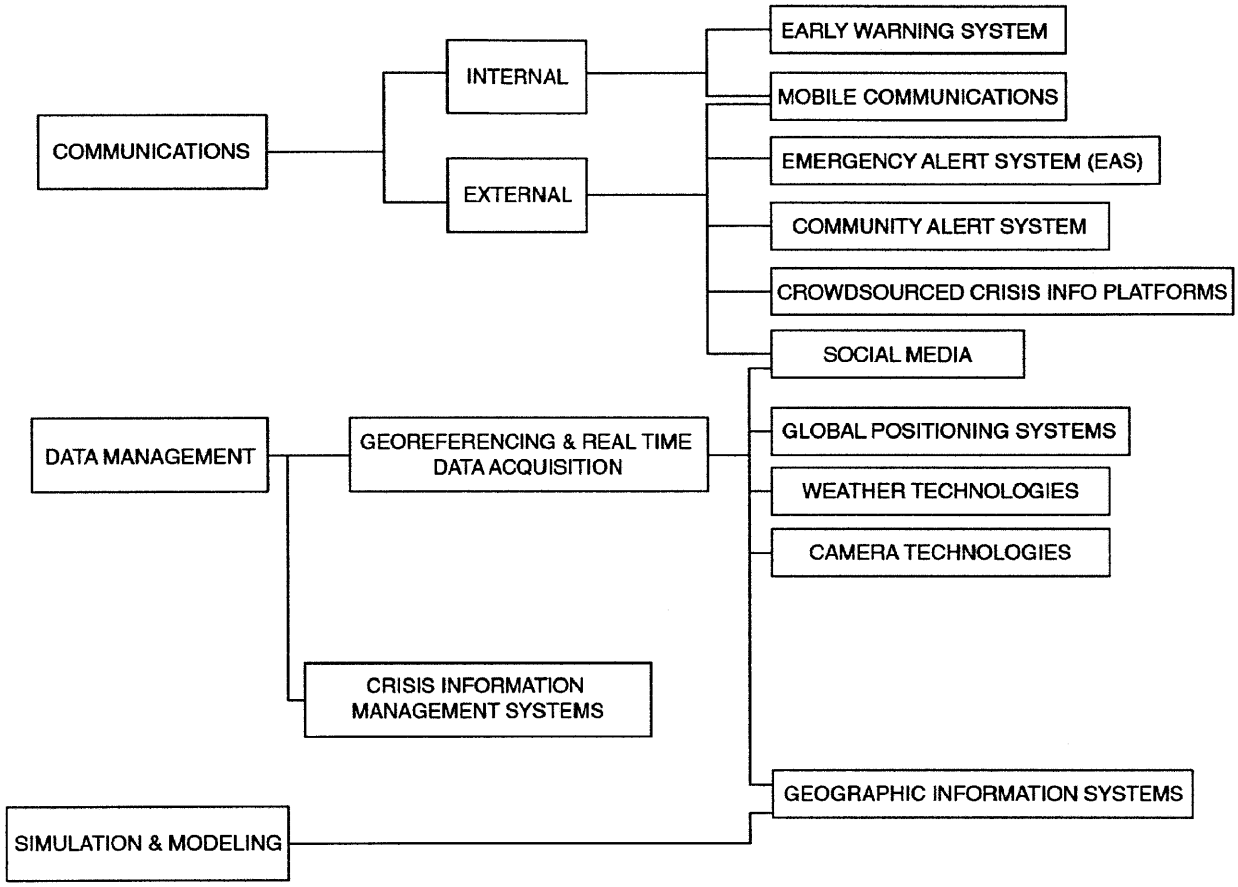

Figure 8: Technology Flow Chart

The technologies in these categories serve to enhance what emergency managers refer to as "situational awareness" and a "common operational picture" (COP). Both of these terms, while used extensively within emergency management, originate within the language used by the military within a command and control structure. "Situational awareness," according to the US Army Operations manual (2008), can be simply defined as participants knowing what is currently happening around them. A "common operational picture," can similarly be defined as "a single display of relevant information within a commander's area of interest tailored to the user's requirements and based on common data and information shared by more than one command" (Army, 2001), or more simply as the visualization of operations that enable headquarter monitoring and control (Lindsay, 2011).

Both situational awareness and COP are referenced during the response phase of the disaster management cycle. While all three categories offer different capabilities, communications and data

management technologies, with more extensive real time technology options, experiences the heaviest use during the preparedness and response phases.

In working towards a more easily shared and informed situational understanding, the technologies discussed in the following sections often serve multiple functions, creating overlaps between the following categories. While the groups are aimed at simplifying the analysis, it is not uncommon for specific technologies to provide multiple functions such as monitoring and communications. As such, the following categories are based on what was perceived to be the primary function of the listed technology based on the answers provided by the participating cities.

4.1 Communications

The majority of the technologies examined in this research function within a communicative capacity. While many of the technologies discussed in the other sections of these research could easily be placed within this category, the technology discussed in this section function primarily to improve the communication between government agencies as well as with the general public.

External Communications

Effectively communicating with the public during hazard events can reduce or prevent increased damage or injury. Early warning systems can alert people to evacuate using specific routes or to take shelter indoors. Informational updates can apprise both those affected and neighboring communities of the situation as well as when the danger is over. Recent developments in technology, particularly within the consumer marketplace, have increased the speed and the extent to which people can both send and receive electronic forms of communication, which has in turn changed the rate at which emergency operations take place.

4.1.1 Alert and Early Warning Systems

Much of the more recent disaster literature has focused on the use of technology to develop early alert and warning systems, including a particular focus on mobile cell phone technologies. Every single participating city utilizes an emergency alert system (EAS), which are often supplemented by voluntary messaging services, Reverse 911 systems, sirens, and social media.

The EAS draws on partnerships with more traditional news media outlets, including television and radio stations. These news agencies assist with the widespread broadcasting of alerts and warning information to the general public. In certain circumstances cities, such as Las Vegas, are able to utilize a government-owned and operated station, though respondents indicated that cities typically work with privately owned media companies, such as when television stations run emergency information banners to inform viewers of alerts (City of Las Vegas Office of Management, 2011).

Many cities supplement the EAS with additional community alert systems that message users through various forms of communication, including recorded voice messages, emails, text messages, and calls to landline and/or mobile phones. These alert systems are voluntary in the sense neither residents or visitors are automatically connected to the alert service - they must call independently and/or register online and provide contact information. Registered users receive updates before, during, and sometimes after disaster events, enabling people to stay connected and informed even without access to television and/or radios.

Nine cities also utilize a Reverse 911 call system, which automatically dials specific numbers (usually landline numbers) with associated addresses as provided by telephone service providers (Eastside Fire & Rescue, 2011). Often used by 911 call operators, the system can dial (or redial in certain instances) landline telephone numbers with corresponding addresses – a traditional method of identifying

households and members of the community. This service does not, however, dial cell phones, as mobile providers are not currently compelled to release cell phone information.

A more context-specific early warning system is use of out door sirens. Located throughout the community these speakers sound various tones, sound patterns, and messages to the community as a way to alert the general public to specific disasters. Cities such as Honolulu and San Francisco, for example, use sirens to convey evacuation in response coastal tsunami warnings, while Kansas City and Dallas use sirens to broadcast tornado warnings.

Despite being related to specific hazards, however, the use of sirens was also management-specific, as cities such as San Diego and Houston choose not to use sirens despite facing similar hazards. As both Miami (2011) and Houston (2011) noted, the use of outdoor sirens, rather than informing residents to evacuate or take shelter, would most likely cause mass panic as residents would not know how to respond.

In addition to the systems discussed above, a number of cities also utilize various social media platforms to disseminate information and alerts to the general public. While these platforms can provide extensive outreach, however, every city stated that the use of social media systems would not, at least for the time being, replace the more traditional early warning systems, which include those technologies mentioned above, as well as utilizing the news media outlets over television and radio. The following section discusses the most commonly used social media platforms in greater detail.

The vast majority of cities did not discuss the use of specific vendors with regards to their alert systems. As discussed earlier, however, a number of cities supplement their Reverse 911 systems with additional notification services. Of these multi-platform notification systems, Nixle was used by several cities, specifically Los Angeles, Honolulu, Chicago, and Minneapolis. A company that creates multiple products for secure mobile communications, Nixle provides a free, secure notification service that government agencies can use to reach the public.

Several cities also mentioned the use of the Public Information Emergency Response (PIER) system, which also provides a web-based mass communication and notification service similar to that of Nixle, which several participants felt was very law enforcement-centric.

Table 3: City Alert & Early Warning Systems (Based on Interviews & Website Information)

City	PIER	Nixle	Rev 911	Siren	Community Alert System	City/ County	Alert System Capabilities			
							Email	VOIP	Cell	Pager
Los Angeles	Y	Y	Y		Alert LA (County)	County	Y	Y	Y	
San Diego			Y	N	Alert San Diego	County	Y	Y	Y	
San Francisco				Y	Alert SF	County	Y		Y	Y
Miami			Y	N						
Orlando					Orlando Alert	City	Y		Y	Y
Atlanta			Y							
Honolulu		Y		Y	(Nixle)	County				
Chicago		Y	Y	Y	Notify Chicago & Nixle (Police)	City	Y		Y	Y
New Orleans					NOLAReady	City	Y		Y	Y
Boston					Alert Boston	City	Y		Y	
Baltimore					Baltimore City Services	City	Y		Y	
Minneapolis		Y			SWIFT911	City	Y		Y	Y
Kansas City			N							
Raleigh										
Las Vegas			Y			City				
New York				Y	Notify NYC	City	Y		Y	
Cleveland			Y							
Oklahoma City										
Portland				Y	Public Alerts	County	Y	Y	Y	
Philadelphia					Ready Notify PA	City	Y		Y	Y
Pittsburgh					Public Safety Alerts		Y			
Dallas			Y	Y	Reverse 911 Community Signup			Y	Y	
Houston	Y			N	Alert Houston		Y		Y	
Seattle			Y							
Total (24)	**2**	**4**	**9**	**6**	**16**	**5 County 9 City**	**14**	**4**	**14**	**6**

Note: Blank values indicate no information

4.1.2 Social Media

As examined earlier, the rise of social media has changed the way people communicate with each other, including within the context of disaster communications technology with general public. Social networking sites, blogs, video sharing, and photo sharing websites have greatly improved our ability to share information with large audiences via online communities.

While included as part of the initial selection criteria, all of the selected cities had an operational web page, which usually provided contact information as well as links to various social media platforms. Of these

services, the most commonly used were Facebook and Twitter. Aside from additional video-, photo-sharing and blogging platforms such as YouTube and Flickr, several cities mentioned the potential for open source crowdsourcing and aggregation platforms such as Ushahidi and Sahana.

Facebook

As the most widely used social networking service and website in the world, Facebook allows users to create customized profiles where they can share information with other users (Kazeniac, 2009). A highly versatile platform, registered users are able to view and share photos, list interests and personal information, and communicate with other users through an instant messaging chat feature. Users are also able to join groups, create and invite others to events, and view consolidated newsfeeds on what friends are doing and sharing.

Within the disaster management context, Facebook provides a platform for emergency management departments to pass information to the general public. Depending on both the phase of the disaster management cycle and the degree of departmental engagement, the posted information can range from general tips on preparedness and community education events to weather alerts and warnings as discussed above.

While the majority of participating cities discussed use of Facebook, only thirteen cities had clear links to Facebook pages from their department homepage. The majority of these cities, such as New York, San Francisco, Chicago, and Boston, have extensive department Facebook sites with frequent postings, and based on interviewees, extensive monitoring. Several cities, such as Honolulu and Dallas, discussed the current, but limited use of the website, as well as plans for future development over time.

Twitter

Twitter is a website that offers a social networking and microblogging service which enables users to exchange information through short 140 character messages called "tweets" (Twitter, Inc., 2011). The term "microblogging" refers to a new medium of blogging that allows users to exchange snippets of information that are much smaller than typical blog entries, allowing users to use platforms such as Twitter to provide real time updates to broad audiences.

Within the context of this research, Twitter, as another of the most widely used social networking sites, was another commonly used platform (Kazeniac, 2009). Much like the Facebook pages, department Twitter pages are also aimed at disseminating general information, status updates, and warnings. Community users can follow the department feed, or, in many cases, also sign up for really simple syndication (RSS) feeds, which compile the Tweets for digest reading.

Although similar to the updates posted on Facebook pages, the character limitations and the real time nature of microblogging result in shorter messages and more timely updates. As discussed by Starbird et al. (2009), Coyle (2009) this ability to both quickly push information out as well as gather information from observers is crucial, particularly within the response phase of the disaster management cycle.
Sixteen of the participating cities had clear links to department Twitter pages. Although many of the cities with Facebook pages also had Twitter feeds, a number of cities, such as San Diego, Oklahoma City, and Portland, had Twitter feeds but no Facebook page. In several cities such as New York, San Francisco, Minneapolis, and Boston, various first responder agencies have begun to using Twitter not only for public notification, but for gathering real time citizen reported information.

In general, while many cities are currently using Twitter as socially-based real time notification system for pushing information to the public, the majority of participants noted that its potential use for crowdsourced information would likely play a crucial role in both future technology development and disaster management in general.

YouTube, Flickr & Other Media Platforms

In addition to Facebook and Twitter, there were a number of additional media sharing platforms that cities occasionally linked to, including video sharing and photo sharing sites such as YouTube and Flickr. Both sites allow departments to continue to expand their public outreach through different forms of media.

YouTube is a video-sharing website that allows users to create a channel, upload, share, and view new videos. Users are able to subscribe to other channels, tag favorite videos, as well as embed videos in other social networking sites such as Facebook (YouTube, LLC, 2011). As such, users can comment on the video within the context of the YouTube website or comment on or reference the video in Facebook or Twitter.

Within the context of disaster management, the YouTube channels provide disaster managers with additional forms of media to communicate with the public. As emergency management from Orlando (2011) noted, having the ability to post videos on general disaster preparedness not only increases the potential for public exposure and education, but provides a new way to communicate information that may not be quite as clear in other contexts.

While only six participating cities linked directly to department YouTube pages, and only Seattle linked directly to Flickr (a photo sharing site) a number of cities, including Baltimore, Raleigh, and Philadelphia, subscribed to a sharing service that provided links to over 20 additional social media sites such as Digg, Delicious, MySpace. In general participants referred to social media platforms in terms of Facebook, Twitter, and YouTube, with little discussion of other sites that are aimed at the same type of information sharing.

Open Source Aggregators & Crowdsourcing Platforms

Amidst the rise of both Facebook and Twitter as social media tools for crisis management, there has also been an increased use of open source platforms for managing crowdsourced information during crises events (Coyle et al., 2009). These systems such as Ushahidi and Sahana aggregate information from disparate sources of information, display findings, statistics, and updates on digital maps that reflect changes in information.

Although more commonly used abroad, as discussed earlier, both Ushahidi and Sahana are open source platforms aimed at improving collaboration and information management (Goodspeed, 2010). The results are then integrated into a central website that allows users to monitor situational changes both during the response and recovery phases.

While not currently being used by US cities, discussions in cities such as San Francisco and Boston have shifted to include the notion of open source platforms, cities appear more focused on both capturing and using the crowdsourcing capabilities with both Facebook and Twitter.

Table 4: City Use of Social Media (Links from Homepage)

City	FB	Twitter	YouTube	RSS	Flickr	Blog	Other Platforms
Los Angeles	Y	Y	Y				
San Diego		Y					
San Francisco	Y	Y					
Miami							
Orlando	Y	Y					
Atlanta							
Honolulu							
Chicago	Y	Y					
New Orleans	Y	Y	Y	Y			
Boston	Y	Y	Y	Y			
Baltimore	Y	Y					Y
Minneapolis							
Kansas City							
Raleigh	Y	Y					Y
Las Vegas				Y			
New York	Y	Y	Y				
Cleveland							
Oklahoma City		Y					
Portland		Y					
Philadelphia	Y	Y	Y			Y	Y
Pittsburgh	Y	Y					
Dallas							
Houston	Y *	Y *	Y *				
Seattle	Y	Y		Y	Y	Y	Y
Total (24)	**13**	**16**	**6**	**4**	**1**	**2**	**4**

* Indicates social media on a related webpage (e.g. Fire, City Manager), but not the emergency management homepage

Notes: Other Platforms refers to additional social media services such as Digg, LinkedIn, Delicious, etc.

Internal Communications

During disaster events, emergency managers use information technology systems to facilitate communications between numerous government agencies at different levels, ranging from regional FEMA offices to local public safety agencies. These technologies range from mobile communications through blackberries, emails, and text messaging to messages from larger, more formalized information management systems.

Every city used mobile communications systems that included handheld mobile devices such as Blackberries, pagers, and cell phones with text messaging capabilities. Several cities, including Miami, Atlanta, and Philadelphia, used internal early warning and alert systems to contact first responder organizations and key personnel. Similar to the notion of the voluntary community alert systems, these

systems contact specific individuals based on provided contact information at the very beginning of the response phase of the disaster management cycle.

In addition to this internal alert system, first responder agencies such as fire and police departments often use radios and voice over internet protocol (VOIP) systems to communicate while on the ground. Additionally, during disaster events and the activation of the Emergency Operations Center (EOC), comprehensive data management systems often provide secure communications forms specific to the configuration of the system. These are examined in further detail within the data management section of this chapter.

4.3 Data Management

Although effective communication is crucial to disaster management, the practice of emergency management involves assimilating a multitude of information flows from first responders, public safety agencies at all levels of government, as well as from the public. Many of technologies cities are currently using allow for the use of georeferencing and real time data acquisition technologies to support crucial time-sensitive decisions.

Cities are also using web-based information management systems in order to better aggregate event information from disparate sources, as well as resource availability and distribution. In addition these functions, these crisis information management platforms also assist emergency management agencies in documenting any and all decisions and resources used during an event for both legal reasons as well as for reimbursement from FEMA.

4.3.1 Georeferencing & Real Time Data Acquisition Technologies

There are a variety of technologies that cities currently use for the purpose of acquiring and integrating information from various situations. While these range from satellite-based imagery to local traffic cameras, cities utilize these systems to improve situation awareness during, before, and after a disaster event. The vast majority of the participating cities use some form or combination of forms of these technologies, with the most abundant being the use of traffic cameras and geographic information systems (GIS).

Here the concept of *georeferencing* refers to the ability to locate and position information at various scales and using various types of media, including satellite imagery and aerial photography. More specifically, georeferencing defines the spatial location of data through geographic coordinates, usually through the use of global positioning systems, geographic information systems, and specialized weather tracking technology.

Real time data acquisition technologies provide the ability to obtain real time information, including various forms of imaging, audio, and video data. While the notion of "real time" information is somewhat unclear within the disaster management context, real time information is being used here to refer to information with little to no delay in both capture and transmission. These types of technologies typically include continuous live feeds or a quick series of messages through various forms of social media as discussed earlier.

Geographic Information Systems

A tool for cartography, spatial analysis, and database technology, GIS is a particularly powerful tool for analyzing the spatial environment, running user-designed queries, as well as modeling and simulation (which is discussed in a later section). GIS provides the underlying mapping software onto which new information can be georeferenced and analyzed.

Every participating city used GIS, with cities such as Philadelphia, Seattle, and Las Vegas noting that their offices' ability with such technology was particularly strong. Within the context of the disaster management cycle, the various imaging and analysis capabilities of GIS make it particularly useful for all phases of the disaster management cycle.

Global Positioning Systems

Global positioning systems provide the spatial coordinates needed to place new information within the context of the existing environment. Technologies with GPS abilities allow information to be more thoroughly integrated into the context of the spatial environment as displayed through digital maps and visualizations.

Global positioning systems (GPS) were also used by a number of cities, such as Kansas City, Orlando, and Chicago. Kansas City (2011) noted that GPS was excellent for tracking resources such as snowplows as well as outdoor tornado sirens, which would improve situational awareness and equipment maintenance, respectively.

Weather Technology

Although several cities mentioned constant improvements in advanced weather and geological monitoring technology by national groups such as the National Oceanic and Atmospheric Administration (NOAA) and the US Geological Survey (USGS) which use GPS coordinates to integrate real time weather updates, the majority of participants focused on the use of other technology, including live video feeds from government cameras and social media sharing sites.

Streaming Video Feed & Social Media

Fifteen of the selected cities discussed the current and increased use of live streaming video within the context of disaster management. The use of government cameras for traffic and public safety not only increase situational awareness, but also provide real time information needed for rapid decision-making.

As discussed earlier, various social media sharing sites, such as YouTube, allow users to post videos that can then be viewed through the site directly or shared via other social networking sites such as Facebook or Twitter. While not necessarily providing information at the same speed as the real time, live streaming videos provided by government equipment and networks, users from the general public would be able to take short videos, upload them, and pass on information that could also further improve situational awareness during the response and recovery phases of the disaster management cycle.

This type of technology, however, while facilitating real time data acquisition, does not necessarily facilitate integration through georeferencing. For example, a video taken on a flooded street corner does not necessarily contain the information necessary to map that event, unless the video contains street names, zip codes, or GPS coordinates that would allow it to be placed with the context of the larger community. This inability to effectively integrate information can limit the degree to which real time data is effective.

Of the various technology vendors that were mentioned, the most common GIS system vendor was ESRI. The largest provider of proprietary GIS-based software, ESRI not only works with local, state, and federal agencies, but also partners with other software providers to provide industry-specific software solutions. While these partnerships not only serve to provide a more comprehensive range of services and potentially reduce interoperability problems between software platforms and data types, it is still possible that interoperability issues between system updates may create other unique challenges.

4.3.2 Crisis Information Management Systems

With the exception of Cleveland, all of the participating cities use web-based crisis information management systems (CIMS). These CIMS provide a wide range of functionality, including messaging and mapping capabilities, providing a dashboard on which it is possible to aggregate and organize information from disparate sources. These systems also assist with the logging of information, much of which is needed for FEMA reimbursements and for audit purposes within the recovery phase of the disaster management cycle.

These programs enable various agencies to share information and real time status updates with other agencies through secure channels of communication using web-based systems. As indicated by their promotional materials, these systems enable users to track multiple incidents and events of various scales, assign and track tasks, create situation reports, and streamline resource management (ESi, 2010). These capabilities, while useful for emergency management needs, also encompass the needs of the private sector. As such, many of these systems are also being used and developed by large companies in the private sector.

Although discussed further in the following chapter, in certain cities these systems are only used during disaster events when the Emergency Operations Center (EOC) is activated. In order to help staff remain familiar and comfortable with these systems, cities often engage in exercises and drills to increase preparedness and improve operations in preparation for real disaster events. This specific activation sequence also places the use of CIMS within the response phase of the disaster management cycle, with some overlap into the recovery phase for document and resource tracking.

There are a number of CIMS vendors that are widely used, namely WebEOC by ESi, E Team by NC4, and Knowledge Center (See Appendix B). While they provide similar services, participating cities had differing opinions on ease of use, integration into workflow, and customizability.

While these CIMS emphasize interoperability and comprehensive capabilities, however, cities mentioned difficulty sharing operational information across these platforms, particularly in situations where local systems to not match county or state systems. This issue of interoperability at various levels of government is discussed more extensively in chapter 5.

4.4 Modeling & Simulation

Although technology has become more adept at predicting shifting weather patterns and simulating potential events, it is clear from both the literature and the continued impacts of various disaster events, that current technology still lacks a great deal of predictive power. While this is certainly an area for continued future development, several cities discussed the use of software for modeling and simulation purposes, with the vast majority of these technologies being GIS-based programs.

These models were not extensively discussed, though there are a variety of simulations that model predicted impacts and losses. The FEMA HAZUS-MH model, which combines science, engineering, mathematical models and GIS technology to predict potential losses from a wide variety of disasters, is one such tool (Federal Emergency Management Agency, 2008).

As discussed earlier, the various spatial analysis and visualization properties of GIS make it useful for all phases of the disaster management cycle – within the specific context of modeling and simulating impacts from historical or hypothetical events, GIS is particularly useful for identifying vulnerable areas within the mitigation phase of the disaster management cycle.

4.5 Conclusions

4.5.1 External & Internal Communications

Based on the findings of this research, cities are using a wide variety of communication tools. The direction of information flow is crucial in determining why cities choose specific technologies over others. Communications with the general public have traditionally been one-way – through alert notification systems built around the rigid constraints of telephone landlines. The changing nature of technology has in turn begun to change the way people socialize and communicate, creating more mobile and proactive behavior. This shift is visible in not only the technologies that cities are currently using, but also the ways in which they are being used.

Despite many of the context-specific criteria that is visible within the use of outdoor siren technology and seemingly in response to increased mobility, more cities are choosing to supplement the traditional EAS with voluntary community alert systems that begin to place the burden of notification on individuals. The vast majority of participating cities are also currently using at least one form of social media to interface with the public for educational purposes as well as community building and awareness.

At the same time however, the mixed degree to which participants were engaged with the notion of multi-directional information exchange signifies that despite an awareness and understanding around the potential for crowdsourced information and citizen reporting, the vast majority of these cities are still adjusting to the shifting dynamic of social media.

With regard to internal communications, cities appear to be using a variety of consumer market products as well as improved radio systems. Although the three cities of Miami, Philadelphia, and Atlanta appear to be more proactive within their internal notification systems, the majority of most cities appear comfortable with their own internal methods of information exchange.

Within the context of the disaster management cycle, the use of early warning and notification systems (both external and internal), is particularly suited to the very end of the preparedness phase as well as beginning of the response phase, while other forms of communication, including the use of social media as well as internal radio systems, is better suited to the preparedness and recovery phases.

4.5.2 Georeferencing & Real Time Data Systems

The findings indicate that cites are using GIS, GPS, enhanced weather tracking, and live video feeds to enhance their disaster management capabilities. Although the use of GIS within the disaster management community has occurred for some time now, cities are beginning to use GPS to better track resources as well as georeference information to improve overall situational awareness.

Although cities are both using and benefitting from improved weather technologies, these improvements appear to take change at a national level, with less development and more implementation on the part of cities. The increased use of live video feed is also likely to continue over time, not only due to improved technology, but to the shifting flow of information attributed to the increasing use of social media. In this context, the role of GPS and georeferencing technologies will continue to increase as well, improving the data integration in general.

The aggregation and management of the products from these technologies is currently being handled by web-based crisis information management systems. Twenty-three out of twenty-four cities use a CIMS to organize and aggregate event information for improved situational awareness, common operational picture, and auditing purposes. The strict use sequence, however, which typically requires the activation of the EOC, limits the use of CIMS to primarily the response and the beginning of the recovery phase of the disaster management cycle.

4.5.3 Simulation & Modeling

Although the technologies discussed in relation to modeling and simulation were somewhat limited, the majority of cities are currently using GIS for a variety of spatial analysis and visualization purposes. Cities that did discuss the increased use of simulation and scenario modeling, namely Boston and Chicago, noted that this was an area for significant future development.

Despite the lack of emphasis on this particular technology use, however, it appears as though simulation and modeling are more commonly utilized during the recovery and mitigation phases, was ways to not only reduce vulnerability to natural hazards, but also assist in creating resilient cities.

5. Inspiration, Adoption & Challenges

As evident from both existing literature as well as the information gathered from the interviews, local emergency mangers are using a wide range of advanced communication and information management technologies. While it is clear that many of these technologies fulfill multiple roles, understanding the factors that affect both why and how cities choose to adopt technologies can both what emergency managers value as well as what is necessary for robust and flexible emergency management.

5.1 Inspiration

All of the cities that participated in this research named a combination of sources for new, innovative technologies. These included industry conferences and publications, vendor relationships, in-house solutions, and by simply examining both consumer products and private industry solutions.

In light of these different sources, however, every participating city identified a specific need that could be met through the use of a new technology supplied by or developed with either vendors or in house IT specialists. As such, while many of the more external factors serve to shape and adjust potential solutions, the day-to-day operations and challenges often serve as the true source of inspiration for new technological solutions.

5.2 Adoption

While the following categories attempt to determine the primary and secondary factors most crucial to a city's decision to adopt and implement new technology, a large number of cities identified a combination of factors rather than simply a primary adoption factor. As such, it is necessary to point out that while the breakdown of participating cities by adoption factor tries to prioritize factors, it may be most appropriate to consider all of these factors in relation to one another.

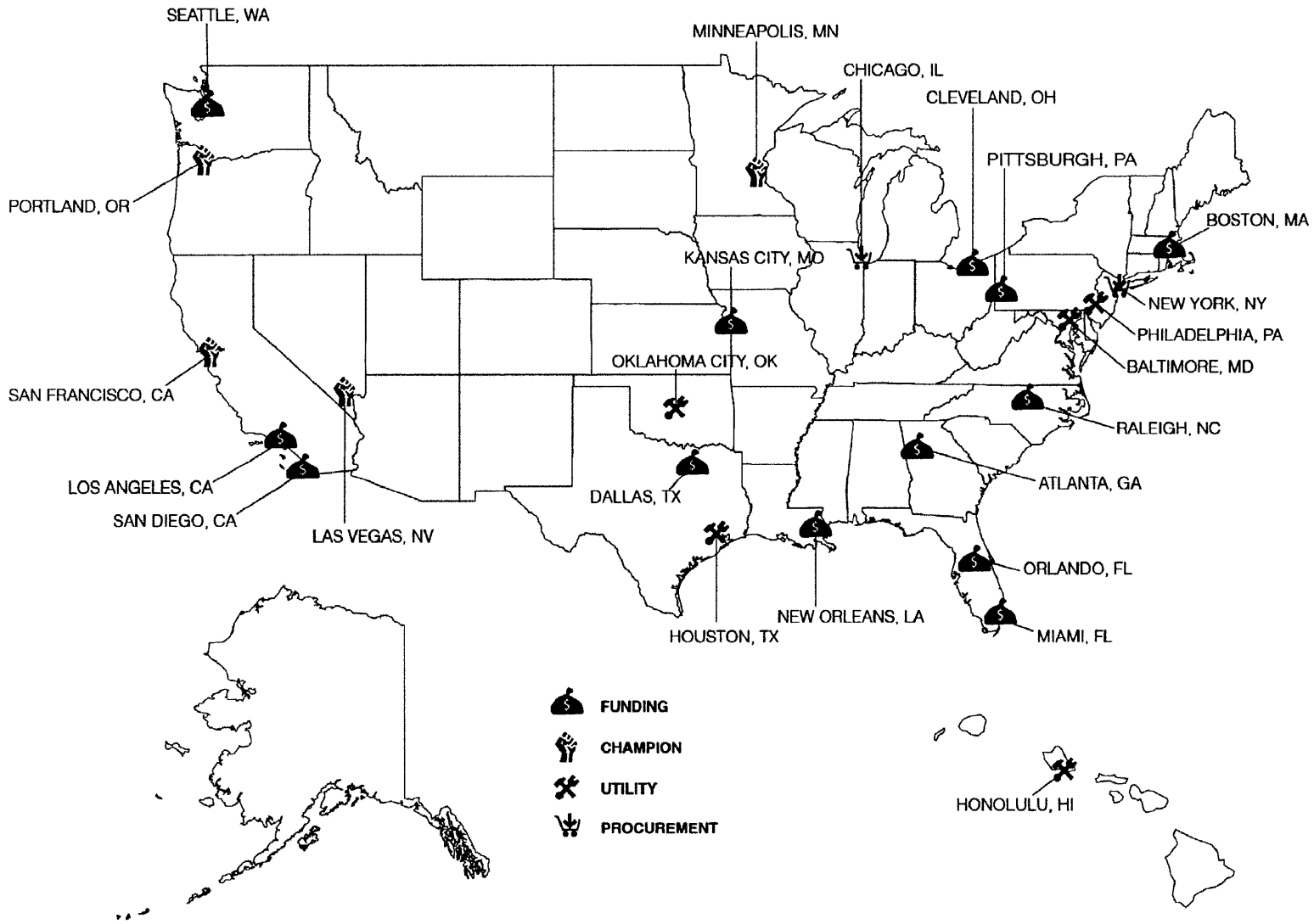

Figure 9: Map of Primary Adoption Factors by City

Table 5: Primary & Secondary Factors by City

City	Primary Factor	Secondary Factor
Las Vegas	Champion	Funding
Portland	Champion	Funding
San Francisco	Champion	Utility
Minneapolis	Champion	
Orlando	Funding	Champion
Los Angeles	Funding	Champion
Boston	Funding	Champion
Cleveland	Funding	Champion
Pittsburgh	Funding	Utility
Miami	Funding	Utility
Atlanta	Funding	Utility
New Orleans	Funding	Utility
Dallas	Funding	Utility
San Diego	Funding	Utility
Raleigh	Funding	
Kansas City	Funding	
Seattle	Funding	
New York	Procurement	Legal
Chicago	Procurement	Legal
Baltimore	Utility	Funding
Philadelphia	Utility	Funding
Oklahoma City	Utility	Funding
Honolulu	Utility	Funding
Houston	Utility	

5.1.1 Utility

Despite differences in regional divisions making generalization more difficult, the selected cities were located broadly throughout the US, five of the participating cities listed utility concerns as the most important factor for adoption.

While the notion of "utility" generally refers to the selection of technology for the purpose of fulfilling a specific need, the term, as defined here, also includes concepts related to overall utility such as interoperability with existing systems, ease of use, and integration with existing emergency management practices.

5.1.2 Political Champion

A number of cities also listed strong political support as crucial to the successful adoption and implementation of new technologies. While not all cities listed this factor as being the most important, however, every single city agreed their respective OEM leadership was progressive and very supportive of new technological solutions. This usually extended to the city-management level, with mayoral support as well.

The importance of having a political champion extends from their ability to not only prioritize the piloting, procurement, and implementation the use of new technology and software, processes that are both time-consuming and resource-intensive. Political champions not only ensure that projects make budget cuts, but may also be able to smooth the potential obstacles with procurement and implementation.

It should also be noted that here the conception of a political champion also encompasses the notion of departmental support in addition to the support provided by progressive leadership. Cities such as Boston and Cleveland, for example, mentioned departmental support for new technology explaining the importance of departmental feedback through a collaborative adoption process.

5.1.3 Funding

Of the various adoption factors listed by cities, the most commonly mentioned was funding. Almost every city was quick to point out that the testing, selection, adoption, and subsequent adoption of new technology was and continues to be a very costly process. In addition to the initial expenses with the procurement and implementation of new systems, technologies often require continuous updates and maintenance, which can make a system prohibitively costly in the long term. As such, cities must not only consider the initial costs, but the potential compounding of maintenance and customization costs over time.

Kansas City gave two examples of high equipment costs: the purchase and maintenance of outdoor tornado sirens, which can cost up to $30,000 per siren, as well as the maintenance of alert notification systems, which can cost as much as $75,000 per year. As some emergency managers noted, having costly and often redundant programs and systems can be difficult to support on tight budgets, particularly when money that is going to the OEM for a potential event could potentially be going to other public safety agencies for more frequent and inevitable events.

Interestingly enough, while funding was one of the most commonly mentioned adoption factors, twenty-three of twenty-four participating cities fall within areas that qualify for special Federal funding through the Urban Areas Security Initiative (UASI) grant program. This program provides funds to large metropolitan areas that often extend beyond the boundaries of the city to include smaller surrounding areas. With the exception of Raleigh, NC, all other cities are included in such large, metro areas and therefore received some portion of funds from these grants.

Although such funding was likely tied to the purchase and maintenance of DHS approved technology and other disaster management needs, funding for equipment was not the only financial concern discussed. Many of the cities that listed funding as an adoption factor linked the shortage of funds to the shortage of staff. Although the interview did not ask about the number of staff within the OEM, participants in several cities, including Seattle, Oklahoma, and Raleigh mentioned potential constraints of capacity due to limited staffing.

These constraints were usually described in the sense that having a smaller staff meant more efficiency and responsibility per person, increased reliance on partnerships with other local public safety agencies, and, on occasion, the prioritization of crucial projects. Where staffing constraints were typically referred to was most often in relation to the monitoring and use of social media and the potential validation of information gathered from the public. Dallas, for example, mentioned that the extent to which staff engaged in Twitter and Facebook activity was often tied to their amount of available time.

5.1.4 Procurement

Several cities, Chicago, New York, and Philadelphia (secondary concern), focused on the issue of procurement. As discussed earlier, the process of not only testing, but also procuring and then implementing a new technology can be both time and resource-intensive. For both Chicago and New York, the procurement process was the greatest obstacle to adopting new technology.

Cities noted that securing the terms of contracts, determining how to best integrate the system into existing practices, and ensuring that all procurement procedures are adequate can take up to an additional year of time, further slowing the process of adoption. While neither city framed this delay as being detrimental to the overall adoption process, within the context of other cities where political support may change with election cycles, such delays may become fatal for new projects. Additionally, with the rapid pace of technology development, cumbersome procurement procedures simply exacerbate the rate at which current and older technologies become outdated.

5.1.5 Legal

While a secondary adoption factor for both Chicago and New York, the notion of legality was unique in the sense that it was linked very closely to the use of social media sites and the notion of crowdsourced information. Both cities briefly described potential issues with logging interactions with the public, gathering and distributing potentially personal information, and ensuring that information is not misused or misinterpreted.

As an interviewee from the New York Mayor's Office of Operations explained, there were a number of legal requirements that needed to be made clear before the city's OEM could open its Snow Update web page. The formulation of the page was part of a response concerning the city's performance during the blizzard of December 2010. The site contained a Community Forum, which allowed residents to interact with a map in order to report problems or issues with unplowed streets, delivery of city services, and/or dangerous conditions. This site allowed residents to comment, post pictures and/or videos, as well as map specific locations as a way of sharing information both with other residents and the city agencies. The page, however, does have a NYC Social Media Customer Use Policy which details the use, terms, and conditions for all of the material posted on the website.

5.2 Existing Challenges

The interviews revealed a number of existing challenges for not only the effective use of current technology, but also for the paradigm shift created through the increasing use of social media and crowdsourcing. The following categories represent the major obstacles mentioned by emergency managers.

5.2.1 Interoperability

Technology interoperability was one of the greatest concerns mentioned by participants. While interoperability has long been a concern between different platforms, however, it continues to create obstacles for technology within emergency management. The majority of the interoperability comments were centered on the use of CIMS and radio communications between first responder agencies.

Of the twenty-five city agencies for which information was available, fifteen used systems that were different from the state emergency management agency. Although the use of different systems does not necessarily result in the inability to transfer and share data, most cities agree that finding solutions through in-house fixes or external software platforms can be costly and time-consuming.

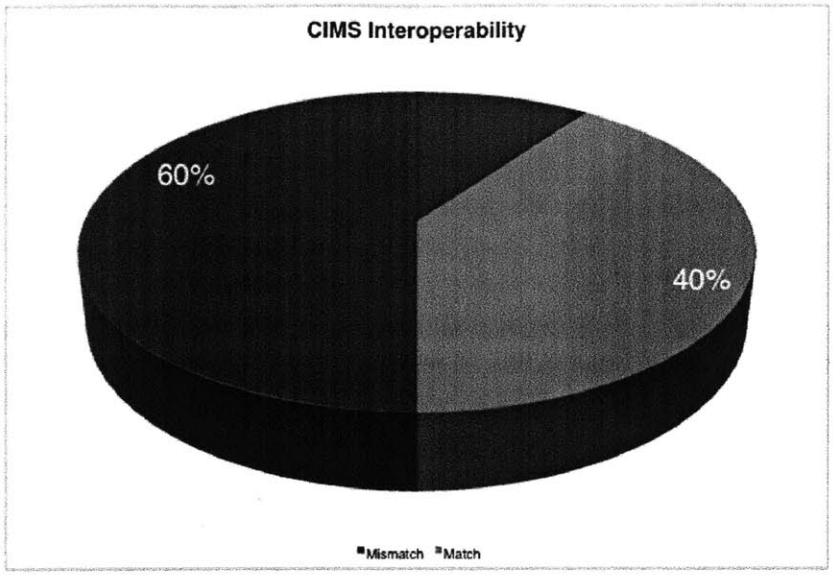

Figure 10: CIMS Interoperability Between City & State

Table 6: CIMS Use by City & State

City	State	FEMA	City System	State System	Match
Boston	MA	1	WebEOC	WebEOC	Y
New York	NY	2	E Team	DisasterLAN	N
Philadelphia	PA	3	Knowledge Center	WebEOC	N
Pittsburgh	PA	3	Knowledge Center	WebEOC	N
Baltimore	MD	3	WebEOC	WebEOC	Y
Washington	DC	3	WebEOC	WebEOC	Y
Charlotte	NC	4	E Team	WebEOC	N
Raleigh	NC	4	WebEOC	WebEOC	Y
Atlanta	GA	4	WebEOC	E Team	N
Miami	FL	4	WebEOC	EM Constellation	N
Orlando	FL	4	E Team	EM Constellation	N
Minneapolis	MN	5	Knowledge Center	WebEOC	N
Chicago	IL	5	E Team	WebEOC	N
Cleveland	OH	5	OpsCenter		N
Dallas	TX	6	E Team	WebEOC	N
Houston	TX	6	WebEOC	WebEOC	Y
Oklahoma City	OK	6	WebEOC	WebEOC	Y
New Orleans	LA	6	WebEOC	WebEOC	Y
Kansas City	MO	7	WebEOC	E Team	N
Las Vegas	NV	9	WebEOC	WebEOC	Y
Honolulu	HI	9	E Team	WebEOC	N
Los Angeles	CA	9	WebEOC	RIMS (E Team)	N
San Diego	CA	9	WebEOC	RIMS (E Team)	N
San Francisco	CA	9	WebEOC	RIMS (E Team)	N
Seattle	WA	10	WebEOC	WebEOC	Y
Portland	OR	10	WebEOC	WebEOC	Y

As with the interoperability challenges with other technologies, many of the issues surrounding data stem from the use of proprietary features that expand upon the core standards-based operational functions. These features utilize proprietary software and data types, which then create obstacles for efficient data sharing between different systems. All of the CIMS systems utilized by the both state and local agencies are NIMS compliant, which ensure a basic level of standardization, such as the use of the Incident Command System (ICS) and common terminology.

While the majority of the state-city CIMS mismatches were generally based on a difference between WebEOC and E Team, there were four instances in which the state systems were not used by any of the participating cities: California (RIMS is powered by E Team), Florida, New York, and Cleveland. Although the potentially interoperability challenges between these systems is unlikely to be any more or less than those that exist between WebEOC and E Team, these systems help illustrate the numerous CIMS options that emergency management agencies can choose from.

As discussed earlier participants noted that the selection of systems was often a function of multiple factors, most notably usability and integration into workflow - often through customizability. Proprietary features and add-ons can not only assist in the process of customization, but serve to distinguish differences between vendors and products within the competitive market of CIM software. Additionally, these features can potential "lock-in" customers through the use of specific data types and system upgrades.

The participating cities were well aware of the interoperability challenges posed by the use of different vendors. One participant noted that it is not uncommon for large cities to have poor relationships with state agencies. Larger cities often have more funding and resources, which can not only increase these cities' ability to act independently of the state and surrounding region, but can also serve to built tension between the two levels of government. While this is not always the case, however, this context provides some insight into the underlying reasons for these interoperability challenges.

The importance of these city-state relationships was further evident, as one participant pointed out that in certain instances, the need for regional cooperation due to funding constraints can reduce potential interoperability issues. For example, cities and counties may work with each other and the state to both determine and purchase a system from the same vendor, which eliminate issues of compatibility throughout the region.

5.2.2 Changing Government-Public Relationships

A newer issue of concern among the participating cities was the increased use and integration of social media. Widespread use of platforms such as Facebook, Twitter, and YouTube have changed many of the interactions between not only members of the general public, but between the public and government agencies as well. As discussed earlier, these interactions can lead to concerns over terms of use and other legal concerns.

Perhaps more importantly, however, these new technologies represent a shift in the way emergency management agencies both obtain and disseminate information. These new forms of media enable real time communication and information gathering from virtually anyone with access to the internet. As discussed earlier, this form of crowdsourcing has become a way for agencies to improve their situational awareness and common operational picture, particularly since publicly generated information may be directly observed or otherwise experienced.

This information, while generated and gathered externally, can better support the mission-oriented goals of emergency management - particularly within what Jon Lindsay describes as the "panopticonic command and control system" (Lindsay, 2011). This new arena of information exchange, however, also represents a potential loss of control in combating the siloed nature information gathering that currently exists at all levels of government.

As many emergency managers pointed out, operational cultures are slow to change, particularly within the realm of public safety and emergency management. Within the command and control structure, the uniformity of message and the control of information flows can be every bit as important as access to resources. Many participants noted potential concerns with acting on publicly-generated information, including security issues, misinformation, and, in some cases, concern over accessibility.

While every city noted that social media was not only being used but would continue to remain an important technology in the future, not many cities engaged in crowdsourcing. Concerns over privacy issues and security of information were numerous, particularly for cities such as New York and Chicago, where legal terms and conditions of use for crowdsourced information were major adoption challenges. There were also concerns over the storage and protection of personal information through social media communications.

As discussed earlier, the rapid speed and sheer volume of communicated information can make data logging and storage difficult if standardized reporting methods do not exist. This concern over legal issues, however, appeared to be more of a later-stage concern, since the cities for which this was an issue were already experimenting with or extensively using social media platforms as a way to gather crowdsourced information. The more prevalent concern among cities in general was the potential for misinformation and the need for verification, as the standards for accountability is increase with greater public engagement.

Many cities were concerned that the use of social media would enable false reporting and misinformation that could result in the inappropriate allocation of resources and manpower, which in turn, could exacerbate other emergency situations. As such, many emergency agencies were concerned over the need for verification methods that would require additional staff and resources that are not presently available.

Accessibility was also another concern, both with the use of social media as well as online systems in general. While the majority of urban citizens, particularly the younger demographics, were likely to be very comfortable with the use of web-based tools and mobile devices, several emergency managers were concerned with accessibility in terms of access to technology as well as comfort of use for more vulnerable populations within the city.

Despite these varying concerns, however, almost every manager, regardless of whether they felt they were already engaging in crowdsourcing, felt that the role of social media and crowdsourcing would continue to grow within the context of emergency management.

5.2.3 Additional Concerns

Additional challenges that participants noted usability of systems, accessibility for vulnerable populations, increased dependence on technology, and the public engagement. Although many of these concerns are often present in other challenges and adoption factors, they are discussed in slight more detail here.

System usability for both internal and external communications was a concern for a large number of participants. In many instances, CIMS use is limited to the activation of the EOC, which can result in lower user confidence and overall system usability due to differences in operational capacity and graphic user interface. While routine trainings and simulations can improve overall familiarity, however, the general feeling among participants was that acculturation and facility with technology is crucial for effective staffing and management.

This comfort and acculturation to technology often accompanies a generational gap, not only within emergency management staffing needs, but also with relation to vulnerable populations within their jurisdiction. These populations are typically comprised of the poor, the elderly, the very young, and people with disabilities. Within this context, both usability and accessibility become issues of concern.

For example, many emergency managers referenced the elderly as being less comfortable with the use of new technology. Other participants noted that poorer communities might not have the same access to the internet and wireless mobile devices, though one city noted that within their experience, this assumption was not true.

Another important concern was our increased reliance on technology and our inability to adapt in the face of its occasional failure. Every participating city noted that it was crucial to have redundancies in place, specifically in the event of technology malfunctions or failures. The multiple forms of communication within early warning and alert systems are perfect examples of this. Of the agencies that participated, at least three had experienced recent technology failures for various reasons.

In light of the continued development of advanced technologies, it is easy to see how emergency management, like many other government agencies, has come to rely on technological solutions. Of the participating cities, roughly half of them listed technologies that they had retired from use. The other half of these agencies noted that many of the older technologies were often kept as redundancies to newer systems in the case of failure.

Finally, every participating city noted that public information and engagement was also a continuous challenge. As discussed earlier, every participating city uses alert systems that operate on voluntarily provided contact information. In relying on volunteered information, however, emergency managers end up capturing a smaller percentage of the population, which is typically made up of more proactive residents rather than more vulnerable residents.

5.3. Conclusions

5.3.1 Inspiration & Adoption

Based on the results of this research, cities draw upon disparate sources of inspiration. Many of these sources are industry-specific, such as annual conferences, systems vendors, and emergency management publications. In light of these external factors, however, cities often end up looking internally to solve day-to-day operational and management challenges, with specific utility goals providing the inspiration. Additionally, while many of the participants noted that they themselves actively sought to learn about new technologies, few cities have staff solely dedicated to the tracking and development of new technologies.

In light of the various challenges emergency managers currently face, however, this lack of staff for technology is unsurprising. As discussed earlier, the vast majority of participants identified funding as a limiting factor, particularly with regards to the adoption of new technology. These financial concerns also manifest themselves through staffing and equipment costs – as such, in many instances, participants noted that their emergency management staff often take on multiple roles and responsibilities.

Funding constraints can, however, motivate cities to design innovative, cost-effective solutions, such as one city's internship program, which effectively increases staffing for social media functions, while providing professional experience and education to students. Regional collaboration for financial reasons can also result in reduced interoperability problems between various local and state governments. While not all participants listed funding as a primary challenges or limitations for the adoption of technology, the

The importance of funding is further supported through the notion of a political champion whose influence can help secure funding and prioritize the overall acquisition of new technology. The results of the research indicate that the participating cities felt that they had the political support and progressive leadership needed to acquire and implement new technologies. This support can also extend throughout the entire agency, which would enable more feedback and participation within the adoption process.

Within the context of these challenges, it is unsurprising that cities would also identify the notion of overall utility as another major adoption driver. The high time and resource costs associated with the testing, procurement, and implementation of new technology ensure that, as one participant noted, "we don't acquire new technology for technology's sake."

Additionally, in examining what cities choose to replace or retire, it is possible to understand how utility, as a function of efficiency, affordability, and usability make a technology both *useful and usable* to emergency managers and first responders.

5.3.2 Challenges

Many of the existing obstacles noted by cities revolve around interoperability, the changing relationship and integration of social media, and the concerns over population groups that are increasingly mobile and increasingly vulnerable.

Interoperability

While baseline standards for technology do exist for various types of technologies (such as NIMS and FCC Radio Regulations), the use of customized products for context-specific situations continue to result in interoperability challenges, most notably with the use of different CIMS between cities and states. Interoperability solutions between proprietary systems can be costly and time-intensive, and may reduce the overall efficiency of the system.

Several participants noted the potential use of open source software and standards as a way to help alleviate the problem of proprietary protections. Although both are growing in popularity, they bring both benefits and obstacles. As Rao et al. (2007) point out, despite being freely available for use and access to the source code, open software platforms are not necessarily more cost effective than proprietary solutions, and, in many instances, may not offer the same range of capabilities. The use of open standards, which "specify certain external behaviors of a program or device in order to ensure interoperability among various implementations" (Rao et al., 2007) would also help to address interoperability programs, but require extensive collaboration and widespread adoption to be truly effective.

An example of open standards development, as described by both Rao et al. (2007) and several interviewees, is the Common Alerting Protocol (CAP), an international data standard for alerting and warning messages. CAP was developed in an open-standards-style that was later adopted as the standard for NGOs, the international Organization for the Advancement of Structured Information Standards (OASIS), and a number of federal agencies such as DHS, DOD, NOAA, and USGS.

The results indicate, however, that while cities may be aware of both open source software and open standards development, the vast majority of the technology currently being used is developed and often customized in collaboration with proprietary vendors.

One additional source of interoperability that was mentioned by participants was the use of newer technology at the Federal level than those being used by the state and local governments. Some managers noted that requirements for more advance technology, such as secure teleconferencing systems for web-based seminars and conferences, forced corresponding upgrades at state and local levels that may or may not be well integrated or needed.

Social Media & Web 2.0 Technologies

As discussed earlier, the rise of social media and Web 2.0 technologies are currently changing the interaction between public-government relations. Although many of the participating cities are currently

using social media to some extent for public communication and outreach, the vast majority of cities are not using social media and Web 2.0 technologies for crowdsourcing purposes.

Although concerns over staffing, accessibility, and data verification are crucial to increased adoption and use of social media for crowdsourcing purposes, a large number of participants noted that the entrenched culture of secrecy and command and control as significant obstacles. Crowdsourcing, as an informal method of obtaining real time information not only represents uncertainty and risk, but perhaps more importantly, a loss of total control.

Proponents of social media and Web 2.0 technologies, argue that given the concern over unified messaging across government agencies, it is crucial that cities take a more proactive role in managing the discussion of information. Additionally, the role that the EOC takes within the realm of social media is also crucial – as one participant noted, rather than trying to control the discussion on comment boards and posts, emergency managers should instead manage, facilitate, and support conversations and information sharing.

Mobility & Vulnerability

The rapid advances in technology at all levels have enabled people to move both more freely and further than before. The result of this has been more mobile populations that emergency managers are unable to reach through landlines and associated addresses. With increased concerns over privacy and personal information, emergency managers must rely on the public to provide contact information.

As discussed earlier, this reliance on voluntary registration can be problematic for the general public due to general risk perception issues (Kahneman et al., 1982) as well as vulnerable populations. At the moment, however, the emergency managers are working to improve overall public education and awareness as a way to increase the number of registered residents.

6. Emerging Directions for Future Technology Development & Conclusions

Using the focal point of technology use and adoption, this research examined the various technologies large, wealthy US cities are currently using for disaster management. The analysis revealed underlying reasons for both the use and selection of new technologies, as well as many of the challenges these cities are currently facing.

6.1 Understanding Disaster Technology in the Context of US Cities

6.1.1 Current Technology

Cities are currently using a broad range of technologies to fulfill communications and data management needs. By exploring the choices and uses of current technologies it appears as though urban disaster management is beginning a transition towards bi-directional information transfers – from the traditional path of government to public, to a balance between internally generated and externally reported information. Support for this shift is most evident in the communication technologies used to interface with the general public, particularly through the use of social media platforms.

Within the context of external communications technologies, sixteen out of twenty-four participating cities utilize a voluntary community alert system that notifies individuals directly on their choice of communication platform. This type of system not only supplements the traditional EAS system and its partnerships with traditional news media outlets, but also shifts the burden of notification toward community members in what seems to be a reaction to increasingly mobile households.

In terms of one-way notification systems, emergency managers have also begun using various social networking platforms such as Facebook and Twitter. Thirteen cities had clear links to department Facebook pages, while sixteen cities had clear links to department Twitter accounts. As such, approximately half of the participating cities are currently engaged in using social media to engage the general public. These capabilities should be further leveraged during the mitigation and preparedness phases of the disaster management cycle to reach out to vulnerable populations that may rely on social networks, but are not as integrated into the rest of the community.

Of these cities, however, only a small number of cities are currently using the bi-directional flow of information of citizen reporting through the same social media platforms. Cities such as New York, San Francisco, and Boston have all started to more fully integrate social media as a way to build the trust needed to generate a stronger relationship between emergency management and first responder agencies and the community.

Additionally, the potential capture and integration of both real time data and crowdsourced information could be greatly improved with a focus on strengthening the use of georeferencing technologies in conjunction with GIS. Given that many cities already utilize GIS at an advanced level, emergency management offices should work with other agencies to develop ways to better integrate new data of various formats.

Internal communications also continues to improve, as emergency managers are utilizing newer forms of consumer mobile technology as well as more advanced radio communications. As emergency management agencies, however, the majority of participants also use older forms of technology as redundancies in case of technology failure.

In order to better aggregate improved imaging, positioning, and monitoring capacities from GIS, GPS, and live video feed, cities are also using web-based crisis information management systems as way to organize and track event information, situational development, and the flow of resources.

Currently the technology being employed by cities appears to be implemented within the preparedness and response phases of the disaster management cycle. The prioritization of technologies with the capacity to deliver real time information is best suited for both the latter half of the preparedness phases and the entire response phase rather than the longer-term recovery and mitigation phases.

However, despite the real time implications of social media, cities also appear to be working towards creating a social space with in the community to not only build awareness but to also build the trust potentially necessary for improved mitigation and, in some cases, long-term recovery.

6.1.2 Adoption Factors

The findings of this research suggest that emergency managers consider a large number of external, industry-related factors as potential sources for innovation. In many instances, however, the decision to seek an innovation solution originates from everyday operations and management obstacles that could be improved through better technology.

In choosing to adopt a new technology, however, the most important factors cities will consider include: 1) Functionality, 2) Political support, 3) Financial cost, 4) Procurement process, and 5) Legal concerns Investing in new technology is a costly, long-term investment. As such, cities will carefully appraise the overall utility of the technology, including its ability to fulfill a specific need as well as overall interoperability and ease of integration with existing systems.

The support of a political champion in addition to departmental support is also crucial in order to ensure the piloting, procurement, and implementation of the new technology is not only prioritized from on high, but supported from below.

As costly long-term projects with potential long-term maintenance costs, funding the adoption is also crucial. While overall budget constraints can lead to challenges in adoption, financial restrictions can also manifest through staffing and equipment shortages. At the same time, however, a lack of funding can lead to innovative, cost-effective solutions that would not have been considered under other circumstances.

Larger cities will also consider the obstacles of a lengthy and inefficient procurement process. As several participants noted, despite choosing a well-suited technology with both funding and political support, the procurement process and contract negotiation can create long delays that could damage the project's feasibility in relation to shifts in political cycles as well as exacerbate the rate at which new technology becomes outdated.

Finally, concern over legal use was primarily related to the use of social media as a way to more extensively engage in leveraging crowdsourced information. While this is likely to remain a concern for early adopter cities, long term standardization and policy formation could potentially assist with this concern as well as with some of the obstacles associated with procurement.

While these factors do not appear to substantively differ from the types of factors identified by the technology diffusion literature, the extent to which these factors form binding constraints on disaster management is surprising, given the expected urgency of emergency management needs. While emergency managers are able to leverage potential losses for improved equipment and staffing, many cities have instead focused on creating innovative solutions for budget shortfalls and new areas of public interaction through social media.

6.1.3 Current Challenges

The research findings indicate that interoperability, the changing government-public relationships, and increasingly vulnerable and mobile populations are all major challenges for current emergency managers.

The problem of interoperability has always been a concern for new technology. However, despite the presence of baseline standards for NIMS and FCC Radio Regulations, it was surprising to find a general lack of interoperability between data management systems remains a challenge, particularly between various levels of government, as evident by a 60% mismatch between city and state CIMS. More robust and widely standardized methods could potentially help alleviate this particular problem.

Another challenge is one that is also evident from the current use of social media. The changing relationship between the government-public interface through social media and Web 2.0 technologies may create departmental tension as well as concerns over information verification, and data security.

Proponents of social media, Web 2.0 applications, and crowdsourced data suggest that these concerns can be dealt with through a more proactive role by both the national government as well as the local OEMs. This proactive role should include expanding the platform's function and audience, particularly during the mitigation and preparedness phases of the disaster management cycle as a way to not only make communities familiar with the site, but to also being building methods to better integrate community data into aggregate sites in preparation for a disaster event.

Finally, increasingly mobile populations have made it difficult for emergency managers to accurate reach some of the more vulnerable populations in the current shift away from landlines. Emergency managers must also deal with increased concerns over privacy and personal information, making it increasingly difficult to not only identify, but to engage and support vulnerable populations.

Table 7: Study Findings

RESEARCH QUESTIONS	**FINDINGS**				
	Communications		**Data Management**		**Modeling & Simulation**
What types of real time technology are cities using?	**External** - Emergency Alert System - Community Alert System - Mobile Communications - Social Media	**Internal** -Early Alert System -Mobile Communications	**Georeferencing & Real Time Data Acquisition** - GIS - GPS - Weather Systems - Video Feed - Social Media	**Crisis Information Management Systems**	- GIS
Which factors are most influential in determining how cities select emergency management technology?	**Utility**	**Political Support**	**Funding**	**Procurement**	**Legality**
How can future technology development better address the needs of emergency managers?	**Policy Implications** - Open Standards - Smoother procurement process		**Future Research** - Data Integration for Social Media - Improved definition of Real Time Technology - Open Source Software Development		

6.2 Emerging Directions & Future Technology

Disaster management technology is becoming increasingly complex. With continuous technological development in virtually all sectors of business, cities are able to borrow and develop new technological solutions to better fit their needs. In light of the ubiquitous nature of mobile and web-based communications, technology and technology-based solutions will continue to play a large role in effective disaster management.

Suggestions from both the literature and the respondents suggest that computer-mediated communications, social media, and Web 2.0 applications are also likely to play an increasingly important role within emergency management, both as additional early warning platforms as well as crowdsourcing. Within its current role, emergency managers are able to leverage these informal, or non-official, forms of communication as free, supplemental outreach systems – particularly during the mitigation and preparedness phases of the disaster management cycle.

These applications also serve as portals to gather public information as well. While several early adopter cities with strong in-house technological capacity have been able to begin utilizing crowdsourced information, but many cities are not currently able or willing to do so. The lack of formal verification and reporting standards reinforce the unintended, non-official status of social media as an emergency communications channel.

Cities should also consider exploring open source systems as a way to find new solutions that are not necessarily controlled of influenced by industry and vendor interests. Such systems may present improved customization options and capabilities that may fall outside current proprietary packaged systems.

Perhaps most importantly, the disaster management community should work on creating a clearer definition of real time technology within the context of disaster management. This thesis focused on the use of real time information to examine the mechanisms through which cities were able to gather situational data with minimal delay. This does not, however, begin to address the complicated terminology needed to reference real time interactions with static or older data such as base/elevation maps.

The disaster management community must develop a terminology that begins to take these new technological capabilities into account. While subtle, the difference between real time interactions and real time information can have large implications for disaster events where the gathering and integration of new data is needed. Disasters that change landscapes or progress rapidly may require faster updates than others for which there is time to anticipate. This is one area that disaster management must work on developing as a way to effectively communicate both their needs as well as their capacities.

6.3 Policy Implications

Stronger standardization measures are crucial to tackling the interoperability problems that many of these cities face. As the prospect of open standards is appealing in light of such as CAP's success, the federal government should work with both states and cities to develop more effective regulations and standards for all categories of technology, but particularly for the handling of social media and crowdsourced data.

Although cities are currently utilizing various geoprocessing technologies to improve data integration, stronger policies on data integration and agency capacity may also improve cities' overall ability to both acquire and integrate data for meaningful analysis and decisionmaking.

Another area for policy improvement is acquisition and procurement process for new technologies, as length of these processes can prove detrimental to new technology adoption, particularly without the

support of a political champion. These processes should be streamlined or redesigned to better accommodate shorter iterative cycles, as discussed by Rao et al. (2007).

6.4 Conclusions

Disaster vulnerability remains a serious issue for cities within the developed world. Rising vulnerability through increased density, environmental degradation and social inequality increase the potential risks and impacts of catastrophic events. While technology has long played a role in disaster management, recent technology trends and development suggest that cities, as both first responders and centers of innovation, may be able to capitalize on improved communications and data management systems.

This research examined the technologies used by the emergency management offices of twenty-four US cities. With regards to their current technology use, the most important systems were categorized into communications technology and data management systems. Upon further examination of the adoption and acquisition process for new technology, the most important factors were discovered to be the funding, political support, and the overall utility of the new system. Finally, with regards to future directions within technology development, it was discovered that the rise of social media and the potential for crowdsourced information is likely to become an integral part of disaster management.

Although new and improved technology alone will not reduce vulnerability or increase resilience, technology can work throughout different phases of the disaster management cycle to support capacity-building activities and effective disaster planning. As the social science literature points out, effective disaster management requires tackling many of the social inequities that lead to increased vulnerability.

Technology in disaster management will continue to play an important role for urban disaster management. Although cities are currently utilizing a wide variety of sophisticated technologies, emergency management agencies need to begin thinking about how to improve interoperability through standardization, how to begin integrating crowdsourced information, and how to better leverage the use of technology throughout all phases of the disaster management cycle to improve their overall management and response capabilities.

Appendix A: Survey/Interview Questions

Hazards

1. What natural hazards have you experienced and/or are focused on preparing for?

Earthquakes	Thunderstorms
Extreme heat	Volcanoes
Floods	Wildfires
Hurricanes	Winter Storm & Extreme Cold
Landslides & Debris Flow (Mudslide)	Multi-Hazard
Tornadoes	Other:

Technology: Current Use/Future Use

2. Real time technology refers to information technology that incorporates and/or allows for the capture and analysis of real time information. Does your office use real time technology in any capacity? (Yes or No)

a. If yes, what types of real-time technology do you use?

SMS Texting (Cell Phone)	Social Networks (e.g. Facebook)
Website	TV News Broadcasts
GIS Mapping	Radio Broadcasts
RSS Feeds	Other:
Microblogging (e.g. Twitter)	

For each of the technologies above:

b. Can you tell me how this real time technology is used?

- Communication with general public (external)
- Communication with other government organizations or offices (internal)

c. In which phases of disaster management is this technology used? Why is this type of real time technology best suited to this phase?

- Mitigation
- Preparedness
- Response
- Reconstruction

i. Do you envision this technology being used in other phases of the disaster management cycle?

d. When did your office first start using real time technology?

e. What led your office to adopt real time technology?

Reason	City	State	Federal	Other
Leadership (political champion, local IT support)				
Policy Recommendations (e.g. options suggested by internal research)				
Funding (e.g. increased budget)				
Coordination (e.g. reduce information sharing obstacles)				
Data Security (e.g. need to store or communicate sensitive data)				
Disaster type (e.g. older technology does not match disaster conditions)				
Other cities as models				
Other				

f. Who were the actors most involved in the decision to use this real time technology?

g. What types of resources (human & physical capital) did this technology require when it was first implemented?

h. How has the use of real time technology developed since it was first implemented in your office?

Technology: Past Use

3. Are there forms of real time technology that you no longer use? (Yes or No)

SMS Texting (Cell Phone)	Social Networks (e.g. Facebook)
Website	TV News Broadcasts
GIS Mapping	Radio Broadcasts
RSS Feeds	Other:
Microblogging (e.g. Twitter)	

a. Why do you no longer use them?

New technologies do a better job	Political Mandates
Funding costs	Obsolete
Market shifts	Other

Performance & Testing

4. Does your office implement performance management measures on the technologies you currently use?

a. What are they?

5. How do you define efficiency for real time technology? How do various real time technologies compare to each other?

6. In what ways does real time technology improve your office's capacity for different responsibilities?

- Coordination (e.g. reduce information sharing obstacles)
- Data security (e.g. storing or communication of sensitive data)
- Disaster-type (e.g. technology better matches disaster conditions)
- Ease of Use / Accessibility (e.g. less complicated to operate, more easily interpreted results)
- Integration (e.g. using technology to fulfill multiple uses)
- Other

Coordination

7. Please list other city, state, or federal agencies with whom you coordinate disaster planning technologies.

8. Please elaborate on any answer or provide any further explanation that pertains to the issues discussed above. Was there anything I missed that you believe is important to this process?

Appendix B: City CIMS Selection by Vendor

City	WebEOC	E Team	Knowledge Center
Miami	X		
Los Angeles	X		
San Diego	X		
San Francisco	X		
Atlanta	X		
Kansas City	X		
Washington	X		
New Orleans	X		
Boston	X		
Baltimore	X		
Raleigh	X		
Las Vegas	X		
Oklahoma City	X		
Portland	X		
Houston	X		
Seattle	X		
Orlando		X	
Honolulu		X	
Chicago		X	
Charlotte		X	
New York		X	
Dallas		X	
Minneapolis			X
Philadelphia			X
Pittsburgh			X
Cleveland	Not currently using an online system		

Bibliography

Army, U S. 2001. "FM 3-0, Operations." *Washington DC: Department of the Army*

Atlanta-Fulton County Emergency Management Agency. 2011. Telephone Interview. February 11.

City of Baltimore Mayor's Office of Emergency Management. 2011. Telephone Interview. January 25.

City of Boston Mayor's Office of Emergency Management. 2011. Telephone Interview. January 24.

City of Chicago Deparment of Emergency Management & Communications. 2011. Telephone Interview. April 14.

City & County of Honolulu Department of Emergency Management. 2011. Telephone Interview. January 13.

City of Cleveland Office of Emergency Management. 2011. Telephone Interview. January 24.

City of Dallas Office of Emergency Management. 2011. Telephone Interview. January 25.

City of Houston Emergency Center. 2011. Telephone Interview. January 10.

City of Kansas City Office of Emergency Management. 2011. Telephone Interview. January 11.

City of Las Vegas Office of Management. 2011. Telephone Interview. January 7.

City of Los Angeles Emergency Management Department. 2011. Telephone Interview. January 27.

City of Miami Department of Fire-Rescue, Division of Emergency Management. 2011. Telephone Interview. January 12.

City of Minneapolis Department of Emergency Preparedness. 2011. Telephone Interview. March 11.

City of New Orleans Office of Homeland Security & Emergency Preparedness. 2011. Telephone Interview. January 5.

City of Orlando Office of Emergency Management. 2011. Telephone Interview. January 10.

City of Philadelphia Managing Director's Office of Emergency Management. 2011. Telephone Interview. February 4.

City of Pittsburgh Emergency Management Agency/Homeland Security. 2011. Telephone Interview. January 18.

City of Portland Office of Emergency Management. 2011. Telephone Interview. January 26.

City of Raleigh Office of Emergency Management. 2011. Telephone Interview. January 7.

City of San Diego Fire-Rescue Department. 2011. Telephone Interview. January 10.

City & County of San Francisco Emergency Management Department. 2011. Telephone Interview. February 3.

City of Seattle Office of Emergency Management. 2011. Telephone Interview. January 6.

Coyle, Diane, Patrick Meier, and Vodafone Foundation. 2009. *New Technologies in Emergencies and Conflicts: The Role of Information and Social Networks.* United Nations Foundation.

Eastside Fire & Rescue. Reverse 911: Emergency Information and Public Alerting. http://www.ci.sammamish.wa.us/files/agenda/6103.pdf (accessed April 20, 2011).

ESi. 2010. "Webeoc Professional - Incident & Event Management Software." http://www.esi911.com/esi/index.php?option=com_docman&task=cat_view&Itemid=115&gid=24&orderby=dmdate_published&ascdesc=DESC (accessed April 18, 2011).

Federal Emergency Management Agency. 2010. FEMA History. http://www.fema.gov/about/history.shtm (accessed March 24, 2011).

Godschalk, David R. 2003. "Urban Hazard Mitigation: Creating Resilient Cities." *Natural Hazards Review* 4:136.

Goodspeed, Robert. 2010. "Crisis Management 2.0: Platforms and Test Cases."

Google. 2011. Person Finder: 2011 Japan Earthquake. http://japan.person-finder.appspot.com/?lang=en (accessed March 11, 2011).

Hewett Jr., Paul L. 2011. Argonne National Laboratory. Telephone Interview.. January 18.

Hosang, Craig. 2011. New York City Mayor's Office of Operations. Telephone Interview. February 17.

Howe, Jeff. 2006. "The Rise of Crowdsourcing." *Wired Magazine* 14 (6): 1-4.

Kahneman, D, P Slovic, and A Tversky. 1982. *Judgment Under Uncertainty: Heuristics and Biases.* Cambridge Univ Pr.

Kazeniac, Andy. 2009. Social Networks: Facebook Takes Over Top Spot, Twitter Climbs. *Complete Pulse.* http://blog.compete.com/2009/02/09/facebook-myspace-twitter-social-network/ (accessed May 5,

2011).
Lindsay, Jon Randall. 2011. "Information Friction: Information Technology and Military Performance." PhD Dissertation, Massachusetts Institute of Technology, Department of Political Science.
Mileti, Dennis S. 1999. *Disasters by Design: A Reassessment of Natural Hazards in the United States.* National Academy Press.
National Emergency Managers Association. 1995. What is EMAC?. http://www.emacweb.org/?9 (accessed April 6, 2011).
National Research Council. 2006. *Facing Hazards and Disasters: Understanding Human Dimensions.* Washington, D.C.: National Academies Press.
New York City Office of Emergency Management. 2011. Telephone Interview. February 15.
Oklahoma City Department of Emergency Management. 2011. Telephone Interview. January 24.
Paton, Douglas and David Johnston. 2006. "Chapter 17: Planning for Hazard Resilient Communities." 288-303. *Disaster Resilience: An Integrated Approach.* Springfield, Illinois: Charles C Thomas.
Pelling, Mark. 2003. *The Vulnerability of Cities: Natural Disasters and Social Resilience.* Earthscan Publications.
Population Reference Bureau. 2007. "Urbanization." *World Popluation Highlights: Key Findings From Prb's 2007 World Population Data Sheet* 62 (3): 10-11. http://www.prb.org/pdf07/62.3Highlights.pdf (accessed March 24, 2011).
Rao, Ramesh Ragothama, Jon Eisenberg, and Ted Schmitt. 2007. *Improving Disaster Management : The Role of IT in Mitigation, Preparedness, Response, and Recovery.* Washington, D.C.: National Academies Press.
"Real Time." *Merriam Webster Dictionary.* http://www.merriam-webster.com/dictionary/real%20time (accessed March 30, 2011).
Sinsai. 2011. Sinsai.Info Earthquake Information Map Ushahidi Platform. http://www.sinsai.info/ushahidi/?l=en_US (accessed March 11, 2011).
Starbird, Kate, Leysia Palen, Amanda L. Hughes, and Sarah Vieweg. 2010. *Proceedings of the 2010 ACM Conference on Computer Supported Cooperative Work.*
Sylves, Richard T. 2008. *Disaster Policy and Politics: Emergency Management and Homeland Security.* CQ Press.
TechPluto. 2009. Core Characteristics of Web 2.0 Services. http://www.techpluto.com/web-20-services/ (accessed April 23, 2011).
Tierney, Kathleen J., Michael K. Lindell, and Ronald W. Perry. 2001. *Facing the Unexpected: Disaster Preparedness and Response in the United States.* Joseph Henry Press.
Twitter, Inc. 2011. About: Twitter is the Best Way to Discover What's New in Your World. http://twitter.com/about (accessed May 5, 2011).
US Census Bureau. 2011. American Factfinder. http://factfinder.census.gov/home/saff/main.html?_lang=en (accessed April 6, 2011).
US Census Bureau. 2011. Population Estimates. http://www.census.gov/popest/geographic/ (accessed April 6, 2011).
US Department of Homeland Security. 2009. *National Incident Management System (NIMS) Supporting Technology Evaluation Program (STEP) Guide.* Washington, D.C.: US Department of Homeland Security.
Van Leuven, Laurie J. 2009. "Optimizing Citizen Engagement During Emergencies Through Use of Web 2.0 Technologies." Masters Thesis, Naval Postgraduate School.
Van Leuven, Laurie. 2011. Department of Homeland Security, Federal Emergency Management Agency. Telephone Interview. January 11.
Weinstein, Elizbeth and Skip Funk. 2011. "Preliminary Review of the City's Response to the December 2010 Blizzard: Report and Recommendations to Mayor Michael R. Bloomberg." New York: City of New York.
Wisner, Ben, Piers Blaikie, Terry Cannon, and Ian Davis. 2004. *At Risk: Natural Hazards, People's Vulnerability and Disasters.* Routledge.
World Health Organization. 2011. Health Crises in Action: Definitions. http://www.who.int/hac/about/definitions/en/# (accessed February 21, 2011).

YouTube, LLC. 2011. YouTube Essentials. http://www.youtube.com/t/about_essentials (accessed May 5, 2011).

End Notes

[i] Although Fairfax, VA was selected as a possible participant, the difference between the independent city of Fairfax and the larger county of Fairfax caused some confusion, which led to the inadvertent selection

[ii] These values were calculated by Kiplinger using data from the US Bureau of Labor Statistics, US Census, and The Martin Prosperity Institute.