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Geographic Information Technologies, Structuration Theory, and the World Trade Center Crisis

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Advocates of geographic information technologies (GIT) have long claimed significant advantages to bringing a spatially oriented perspective to bear on organizational and policy decision making, however, for a variety of reasons, these advantages have been more difficult to realize in practice than might be supposed. In this article, we argue that awareness and appreciation of the potential value of GIT changed dramatically as a result of the World Trade Center (WTC) attacks on September 11, 2001. We use a structurationist theoretical perspective to show that GITs were "enacted" in a variety of novel ways by social actors thrust together by the demands of the crisis to form interorganizational systems, and we illustrate this process through three extended examples of GIT adaptation and innovation during the crisis. One lasting consequence of this episode is that GITs have moved from serving as a relatively static reference tool to a dynamic decision-making tool for emergency situations. We conclude by suggesting that the crisis was a catalyst for change in the use of GIT and, reciprocally, in the social structures in which GIT will be deployed in the future.

Introduction

Of the various waves of technology development that have diffused widely over the last three decades, among the most exciting have been tools that use or generate geospatial data, that is, data providing location information in which a common spatial coordinate system is the primary means of reference. Unlike the Internet, electronic mail, group decision support systems, and other related technologies whose direct impact has been to complement or improve methods of communication, geospatial technologies are more specifically tools for analysis and decision making (Jankowski & Nyerges, 2001a). The term "geographic information systems" (GIS) has historically been used to encompass the hardware, software, geographic data, personnel, and assortment of functionalities that taken together comprise or enable processes for making decisions (Federal Register, 2003; Gant & Ijams, 2004; U.S. Government Accountability Office [GAO], 2003; Huxhold, 1991; Kelly et al., 1995; NYS Temporary Geographic Information Systems Council, 1996). More recently, it has become clear that GIS, together with global positioning systems (GPS), aerial photography, remote sensing techniques, and other spatially related tools for decision making, comprise a larger array of complementary tools that can be grouped together under the more comprehensive rubric of "geographic information technologies" (GIT).

Advocates of geographic information have long claimed significant advantages in bringing a spatially oriented perspective to bear on organizational decision making. GITs are thought to provide strategic spatially enabled decision-making capabilities in the following areas: economic planning and development; water, agricultural, energy, cultural, land, and mineral resources; environmental management; forestry; geology; public health; land-use planning; public safety; social services; transportation; waste management; utilities; and wildlife conservation and management (Tew, 2002). Businesses, nonprofit organizations, and particularly government organizations at a variety of levels have glimpsed the relevance of GIT for improving organizational processes.

However, over the years, these capabilities have proven more difficult to realize than might have been supposed. One reason is that spatial data, the fundamental building block of a spatially enabled perspective, can be expensive to acquire and use (Wehn de Montalvo, 2002). Another is that, as Sommers (1998) suggests, the characteristics of geographic information technologies "differentiate it from other technologies and necessitate specialized organizational management approaches" (p. 157). Geospatial data is of a particular kind, with multiple uses and multiple relationships to other organizational data and technologies, with resulting

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challenges for implementation and use. "To provide direction for the GIS and for all implementation and operations activities, it is necessary to establish a vision that defines the role GIS plays in the organization, its scope, and its relationship to business operations. Establishing a strategic vision and goals for GIS is critical to its success, whatever the scope of the implementation" (Sommers, 1998, p. 165). Such vision and goals have all too often been lacking.

Finally, some of the most impressive advantages of using geospatial data are derived from the power of bringing together geographic data covering territories that may well be administered by different organizations and from layering geographic data with other social and demographic data sets. However, among the most difficult hurdles to overcome has been creating technical and organizational systems that are capable of sharing data. Organizations frequently do not know about existing data sets and when they do, there are additional problems with ownership, pricing, lack of metadata about data characteristics, lack of interoperability between systems, and lack of incentives, tools, and guidelines for sharing and integrating such different kinds of data (Arens & Rosenbloom, 2002; Kelly et al., 1995; National Research Council, 2003; New York Area Data Council, 1999). Successful use of GITs rests on the ability to access core data sets and a common coordinate system that can serve as foundation for the development of subsequent applications that depend on sharing geospatial information across regions and integrating geospatial information with other relevant data sets (Wehn de Montalvo, 2002). While managers with organizational responsibility for the development and use of GITs, particularly within government organizations, have understood this for some time, it has been difficult to create the kinds of collaborative arrangements required to share geospatial information and to work together to construct the organizational and technical infrastructure required for interoperability.

Although these problems with achieving the full potential of GIT have existed for years, general awareness of the potential value of GIT and an appreciation of its attendant challenges changed dramatically as a result of the World Trade Center (WTC) attacks that took place on September 11, 2001, and the subsequent first response and recovery efforts. In this article, we argue that, due primarily to the experience and success of GIT professionals working together with first responders and other decision makers to mobilize an effective emergency response, government decision makers' fundamental conceptualizations about the value and role of GIT were transformed. In the immediate aftermath of the WTC attacks, GITs presented options allowing responders to construct innovative technological tools that enabled complementary emergency responses that would not have been otherwise possible. In this short-lived but intense milieu of technological adaptation and innovation, GITs came to be looked upon in ways that more fully appreciated the capabilities and advantages of a geospatial perspective. The result has been that the government groups involved now perceive the role and influence of GIT more positively. In fact, it appears that the role of geographic information and associated technologies in emergency response is now understood as going well beyond the simple production of maps to encompass a dynamic and core technological ensemble for organizing and supporting emergency responders and contributing to homeland security.

More specifically, we bring a structurationist theoretical perspective to bear in arguing that during the WTC crisis, GITs were "enacted" in a variety of novel ways by groups of social actors thrust together by the demands of the crisis to form interorganizational systems. Prior to September 11, 2001, these groups were relatively isolated in performing their activities and responsibilities, confronting their own specialized problems with relatively little joint problem-solving communication and collaboration among them. However, the WTC crisis presented a novel "time-space edge," initiating a change episode that required intensive and close collaboration among actors from the GIS community, emergency responders, government officials, and politicians during the immediate response and aftermath. To this intense interaction, actors brought a set of diverse technical facilities and resources, pre-existing and newly adapted norms, and organizationally idiosyncratic interpretations of reality. An interchange of knowledge, meaning systems, and technological artifacts took place among members of the different groups in the course of which they shared perspectives on social reality at that moment, learned from each other, and engaged in a fertile period of technological innovation. We illustrate this process in detail through consideration of three extended examples of GIT adaptation and innovation as a technology-in-practice during response to the WTC crisis. One lasting consequence of this episode is that GITs have moved from serving as a relatively static reference tool to a dynamic decision making tool for emergency situations. As a further consequence, government leaders have come to see that GIT plays an important role at the center of disaster management and national security. The crisis was thus a catalyst for change in the use of GIT as a technology-in-practice and, reciprocally, in the social structures in which GIT is expected to be deployed in the future. We begin our discussion by building a structurationist theoretical foundation for the data analysis to follow.

Social Structures and Information Technology

Our understanding of how new technologies yield individual, organizational, and large scale social change has become increasingly sophisticated over the course of progressive waves of technology proliferation and adoption. Early theoretical approaches to information technology (IT) appeared to take its transformational power for granted and its change trajectory to be relatively deterministic (Davis, 1989; Hiltz & Johnson, 1990). These research efforts assumed that technology can be seen as the "engineered artifact, expected to do what its designers intend it to do . . . " and capable of transforming social and organizational contexts independently of institutional and

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cultural characteristics, a view that Orlikowski and Iacono (2001, p. 123) and others (Kling & Lamb, 2000) have identified as the "tool" view of technology.

Scholars rarely argue anymore that technologies are directly responsible for social change. Instead, several theoretical traditions now propose alternative ways to understand the relationships between information technologies and the social systems in which they are deployed. These more holistic approaches have been called the "ensemble view" of technology (Orlikowski & Iacono, 2001) because they suggest that information technologies are comprised not only of physical artifacts but also of the social relations around those artifacts. Technology is only one component of more complex sociotechnical systems (Kraemer, King, Dunkle, & Lane, 1989; Pasmore, 1988). Social components of such systems may include the following factors: organizational commitment, training, and policies (Kling & Scacchi, 1982) that affect how a new technology is managed in an organizational context; roles that various stakeholders play in designing, developing, and implementing a technology; the interorganizational systems and alliances of inventors, research and development organizations, corporations, and governments that arise in order to develop new technologies (Latour, 1987); and the role of user groups in determining how technologies come to be systems embedded in complex institutional and cultural contexts (Fountain, 1995, 2001; Kling, 2001; Kling, Rosenbaum, & Hert, 1998; Kling & Scacchi).

In one further variant of the ensemble approach, scholars have suggested that technology and social structure are mutually implicated in reciprocal processes of influence and change (Lievrouw & Livingstone, 2002; Orlikowski & Iacono, 2001). A variety of positions with similar arguments are assembled under the label of "structuration" theories because they all propose, following the structuration theory of Anthony Giddens (1984), that technologies have the potential to reconstitute or change social structures while simultaneously arguing that social structures shape how we think about, design, and use technologies. These formulations have become increasingly sophisticated as theorists have sought to identify quite specific processes by which these influences are exerted and incremental change takes place.

Two examples of the structuration perspective are the structurational model of technology (Orlikowski, 1992; Orlikowski & Robey, 1991) and adaptive structuration theory (DeSanctis & Poole, 1994; Poole, Jackson, Kirsch, & DeSanctis, 1998). Using different but related theoretical constructions, these theories argue that there is a dynamic interaction between social structures and information technologies. From their view, technology has the potential to change social and organizational structures; but, at the same time, technology is also affected by these structures in its design, implementation, and use. In recent years, the importance of the user's enactment in understanding the bidirectional relationship has been established (Fountain, 2001; Orlikowski, 2000). Thus, it is of considerable importance to focus on understanding how users enact technologies in ways that are idiosyncratic or that diverge from the uses sanctioned in organizational contexts. Consistent with this idea, Walsham and Han (1991) established that "structuration theory is valuable in carrying out empirical studies of *IS use* [author's emphasis] and the way in which this modifies social and organizational structures and vice versa" (p. 81).

Thus, according to structuration theory, technologies have the effect of structuring the social world in terms of defining ways that people think, options for behavior, and ranges of possible consequences (DeSanctis & Poole, 1994; Orlikowski, 1992). Structuration theory also argues that the social world simultaneously shapes technologies. Regardless of their material capabilities, people constitute technologies socially in the way they deploy technologies in social situations, in the way technologies are perceived, in the material capabilities users choose to actually employ, and in the uses to which technologies are put (Fountain, 2001; Orlikowski, 2000). When both processes are considered simultaneously, reciprocal relationships between technology and the social world are highlighted rather than unidirectional causal relationships. Below we discuss these processes in two variations of structuration theory applied to technology.

Adaptive Structuration Theory

Adaptive structuration theory (AST) is one of the most fully developed theoretical perspectives for understanding how new technologies come to reproduce social structures or to generate structural change in organizations. DeSanctis and Poole (1994) describe how structuration processes originally articulated by Giddens (1979; 1984) play out in the process of technology use in organizations to reproduce existing social structures or change them by virtue of the kinds of structures that are incorporated into technology during the design process.

According to Giddens (1984), structure consists of rules and resources that actors draw upon to produce social behavior. For DeSanctis and Poole (1994), structures are physically incorporated in new technologies in two complementary ways. First, technologies embody rules and resources embedded in the form of particular material capabilities, functionalities, and features that comprise a variety of behavioral options to be used in constructing social action. Technologies present what Cherry (1985) calls "liberties of action" because they provide material capabilities enabling users to select among particular options for social action.

According to AST, a second source of social structure in technologies consists of what DeSanctis and Poole (1994) call "spirit." The spirit of a technology is a normative frame consisting of the values and goals that encompass the tasks that a technology was originally envisioned to accomplish or a particular way that a technology was envisioned to accomplish such tasks. More than the designers' intentions (although design goals are certainly implicated), and more than the user's perceptions, the spirit of a technology is described as a "property" of the technology itself. As such, spirit is thought to exert some influence in guiding the nature of the interactions that users are likely to have with a particular

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technology. Also available to be discerned or "read" by an analyst, spirit is used as a source of information to further our understanding of the nature of users' interactions with the technology.

When users collectively and routinely draw upon and apply particular features of a system or when they reference the way the technology "should" work in order to construct a shared perspective on a task, they are engaged in the "appropriation" of a technology. More specifically, in appropriating technological features, users reproduce the rule or resource instantiated by that feature, which is then brought into social action and reproduced as structure in the social world. DeSanctis and Poole (1994) make it clear that appropriation can take place in many different ways and note that appropriation may be "unfaithful" or inconsistent with the spirit and design of the structural features. When unfaithful appropriations take place, users apply structural features in ways that are "out of line" with the spirit of the technology. Previous research has applied some of the main elements of this framework to study geographic information systems (Jankowski & Nyerges, 2001a, 2001b; Nyerges & Jankowski, 1997).

Enactment of Technologies-In-Practice

Orlikowski (2000) critiques aspects of AST by returning to Giddens' (1984) original formulation of structure, which has a "virtual" rather than material existence and is brought into being only through social action. She reminds us that "[w]hile a technology may be seen to embody particular symbol and material properties, it does not embody structures because those are only instantiated in practice" (Orlikowski, 2000, p. 406) that is systematically repeated over time. In social action, users are likely to engage with only some of a technology's material features and may in fact depart from designers' original intentions in the ways they engage other features. Either way, her point is that users "enact" technology in their collective and repeated use of it, bringing technology and its potential structures into being through practices. Orlikowski (2000) uses the term "technologies-in-practice" (p. 407) to refer to the enacted structures of technology, that is, the sets of rules and resources that are reconstituted through users' selective engagement with particular technological features. As it exists for the user, technology-in-practice is a "repeatedly experienced, personally ordered and edited version of the technological artifact, being experienced differently by different individuals and differently by the same individuals depending on the time or circumstances" (Orlikowski, 2000, p. 408).

Orlikowski (2000) also acknowledges that technologies are inscribed with particular properties and capabilities imparted by designers that represent their assumptions and knowledge at the time a technology was developed, and physical characteristics provide a set of "boundary conditions" (p. 409) defining what it is, in principle, possible to do with the technology. However, users will make their own selections among these possibilities. They may be influenced in their selections by the "images, descriptions, rhetorics, ideologies, and demonstrations" (p. 409) of the technology provided by individuals who play a number of intermediary roles in selling, reporting on, training, championing, and mentoring others in the technology. But, ultimately, users do many things with technology in its current state, some of which are not anticipated by designers or champions, and they often "add to or modify the technological properties on hand (e.g., installing new software, peripherals, or adding data, etc.), thus actively shaping or crafting the artifact to fit their particular requirements or interests" (p. 409).

In the process of enactment, users bring a number of factors to bear on their engagement with a technology including their knowledge of the structural properties of the social systems they inhabit. In drawing on these structural properties, users' experiences are shaped by material aspects of the technology, that is, its "*facilities,*" but they are also shaped by *norms* for appropriate behavior within an organization and with respect to a technology, and by *interpretive schemes* drawn from the institutional context through which structure is instantiated. As users draw upon facilities, norms, and interpretive schemes, they enact a set of rules and resources that reconstitute the structural properties of the social system from which these three elements were originally drawn. Thus, an important part of analyzing a technology-in-practice is to understand how structural properties of the social system, through the modalities of facilities, norms, and interpretive schemes, shape users' tendencies to enact technology in particular ways, giving rise to the possibility of structural reconstitution.

Structural and Technological Change

Despite this tendency toward stability, as Orlikowski (2000) and DeSanctis and Poole (1994) both note, when technologies are enacted or appropriated, there is always the possibility that social structures will change, rather than being reconstituted. The possibility of change is inherent in technologies-in-practice because technologies are never completely stabilized. Users may change their awareness, knowledge, power, motivations, circumstances, and, as previously noted, the material features of the technology itself. Any of these factors may change how or what structural properties of the social systems are drawn upon or what norms or interpretive schemes users select in their use of a technology. As Orlikowski (2000) points out, users may enact different technologies-in-practice "because they become more knowledgeable about using their technology (through attending a training class or watching a colleague's use)," or they may change because they are subjected to "competitive, technological, political, cultural, and environmental influences," or they may change simply by "improvising, that is, generating situated innovations in response to unexpected opportunities or challenges" (p. 412).

A further implication is drawn by Orlikowski (2000) who observes that the same technological artifact may be enacted in multiple ways, depending on how users draw on structural

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properties of the larger social systems comprising their work environment. She specifies three distinct forms of enactment. At times, technological artifacts may be enacted in ways that essentially reconstitute existing structure and ways of doing things, which she terms *inertia*. Another form of enactment takes place when individuals practice enactment as *application*, when they use a new technology to enhance existing ways of doing things, which leads to both improving work processes and reinforcing existing structure. The third form of enactment is when users enact technology in ways that change both existing social structure and their ways of doing work. This enactment of change takes place when users *improvise* on a technology-in-practice, experimenting, adapting, or customizing aspects of the technological artifact, perhaps by adding new data or building new components. In Orlikowski's (2000) case studies, *improvising* took place under conditions in which users were very knowledgeable and quite motivated to use a technological artifact in their work environment and were able to draw upon structural features that included a strong team focus, a cooperative culture, and a commitment to learning (p. 423).

In these structurational accounts, technology change in organizations, when it occurs, is cast as a series of modifications, adaptations, and improvisations on artifacts that already exist and that take place incrementally across time as users find it practical, necessary, or rewarding to explore possibilities. Although this characterization sounds appropriate for many conditions of routine technology use, Giddens, who focused on large-scale social transformation, proposed several conditions under which more profound change can take place. For Giddens, all social life is episodic, but he was particularly interested in comparing large-scale episodes or "sequences of change having a specifiable opening, trend of events and outcomes" (Giddens, 1984, p. 374). Social change is never determined; instead, it is subject to the "conjunctions of circumstances and events that may differ in nature according to variations of context, where context (as always) involves the reflexive monitoring by agents involved in the conditions in which they 'make history'" (Giddens, 1984, p. 245). More specifically, such novel conjunctions may arise in the context of "time-space edges," which are at the nexus of contact or interdependence between different structural types of society. "These are edges of potential or actual social transformation, the often unstable intersections between different modes of social organization" (Giddens, 1981, p. 23), and they are produced in conditions of "warfare, invasion, or threats of attack of various kinds" (Cohen, 1989, p. 275), which bring different forms of social organization together and which harbor the potential for significant change. While most change associated with technology use no doubt takes place incrementally in organizations, the WTC attacks of September 11, 2001 created a profoundly novel time-space edge, which brought decision makers and technologies together within a context demanding response. One of the long range consequences of this upheaval was a profound change in both the use of GIT and the organizations in which they were used.

Methods

This article presents one set of findings from a broader exploratory study conducted through a partnership between the Center for Technology in Government at the University at Albany, State University of New York, and Urban Logic, Inc., a New York City (NYC) nonprofit organization closely involved in the WTC response. The goal of the research was to understand the roles of information and technology in response to the attacks on the WTC as well as the influence of the response on the subsequent work of both government agencies and private organizations. The study looked at both the short-term effects of the event as well as the long-term effects of the response on policies, organizational designs, and technical systems, together with interinstitutional relationships among business, government, and nonprofit organizations involved in the response.

The WTC crisis was unexpected and unprecedented; further, the ability of participants to accurately recall their involvement wanes with time. For these reasons, our time-limited study was both exploratory and inductive, and was not designed to test hypotheses. Our research began in the summer of 2002 while recollection of events was fresh in the memories of participants and many of the activities of interest were still underway.

Detailed interview protocols were developed jointly by a multidisciplinary research team, representing the following fields: communication, information science, management science and information systems, law, organizational behavior, public administration and policy, policy and decision sciences, public management, and sociology. The fundamentals of these fields guided the generation of our research design, data collection instruments, and data analysis.

The main data collection method was semi-structured interviews with key participants in the response effort, in addition to analysis of related documents and records of actions and events. Background and substantiating information came from analysis of the documentary record. The data analyzed also included news accounts, articles in the trade and professional literature (Web-based and print), formal reports, testimony before governmental bodies, conference presentations, video and television documentaries, and other similar material as sources. The research team assessed the data from a variety of perspectives, integrating analysis and tentative findings to generate a holistic understanding of the interplay of decisions, actions, and technical tools with the feedback, learning, and change that resulted.

Respondents

The research strategy began with contacting many of those who worked at Pier 92, where New York City's Emergency Operations Center (EOC) was re-established after its offices were destroyed by the collapse of the Towers. By starting with the "nerve center" of the rescue, response, and recovery effort, the strategy allowed for following and partially documenting the network of relationships, information flows, and actions required to execute a range of governmental

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responsibilities. A cascading technique identified additional informants inside and outside government who played integral roles in the recovery effort. Between August 2002 and July 2003, 29 interviews were conducted. Participants included seven New York City officials, five New York State officials, five federal government officials, five nonprofit agency representatives, and seven private sector executives. The interviews were semistructured, open ended, from one to two hours in length, and conducted in the participant's workplace or by phone. All interviews were transcribed and then analyzed by the research team. In the analyses presented below, we do not identify individuals by name in quoting from our interviews. However, we do quote by name individuals who are authors of public documents or who are referenced or interviewed in the trade and professional literature.

Interview Protocol

Interview questions focused on information-related responses to the attacks, with special attention to five themes: data needs and resources during the response period; uses of IT in the response; interorganizational relationships during the response period; effects of pre-existing resources, plans, or programs on the ability to respond; and effects of rules and laws on the ability to respond. Participants were also asked to identify documentary sources and other potential interviewees. The GIT-related data on which this study is based were drawn from the larger questions on information and technology during the process of analysis. The study was not designed to ask about GIT specifically; rather, the importance of GIT became apparent from responses by the interviewees as the study progressed.

Coding and Data Analysis

Interview data was managed and organized using Atlas-ti, a leading software package for qualitative analysis (Richards & Richards, 1994). In data analysis we developed a set of coding categories related to GIT and related functionalities (e.g., NYC base map; LIDAR, discussed below; building identification numbers, etc.), and material aspects of GIT (e.g., data compatibility and sharing; visualization, analysis, and interpretation). We also coded the data for key elements of the structurational framework (e.g., existing GIT resources; adapted GIT resources; improvised GIT resources; organizational change; and lasting effects of the crisis). Using this coding scheme, we looked for patterns of technology enactment that illustrated processes of *inertia, application,* and *improvisation*. Below we present three case studies, using the concepts of GIT facilities, norms and interpretive schemes, that illustrate GIT improvisation processes central to understanding how GIT has come to be reconceptualized and valued.

Data Analysis and Findings

Analysis of the broader context of the response showed that information and technology played critically important roles in the aftermath of the WTC attacks (Dawes, Birkland, Tayi, & Schneider, 2004; Dawes, Cresswell, & Cahan, 2004). Effective use of a variety of information technologies helped government agencies and their partners better cope with and respond to multiple exigencies and ongoing recovery demands. At the same time, the severity of the situation was exacerbated by extensive damage to critical communications equipment and computing infrastructure as well as the absence, loss, or inaccessibility of needed information. The immediate response and subsequent recovery challenged every aspect of public service. However, of the many kinds of data and technology put to use, GIT emerged as a particularly versatile analytical resource that enabled effective responses to numerous critical exigencies.

Reconceptualizing the Role of GIT

It became apparent relatively early in analysis of the interviews that GIT had played a special role in the response to the WTC attacks and, due to its demonstrated effectiveness, attitudes about GIT were in the process of changing. These attitude changes have been reflected in public acknowledgements of the value of GIS and the future role it should play in emergency management and homeland security, as well as its potential for use in other types of public sector decision making. Such acknowledgements were viewed as confirmation of what many GIT staffers involved in the response and recovery already understood. In the words of one member of the WTC crisis mapping team,

> What we see in a most unfortunate situation is the culmination of our entire career. We knew a long time ago that development of this kind of technology would ultimately change the way operations were done on any level of government. And, unfortunately, we put it to test in this emergency situation and it's really come through in flying colors for people doing all kinds of missions and operations. And on that level, it really feels wonderful and we're hoping that it'll now become institutionalized and be actually the standard for all operations that are coming along in the city of New York.

This sentiment was echoed by an interviewee at the federal level whose GIT responsibilities had changed literally overnight from domestic concerns to emergency response and national security. Within one year of September 11, 2001, this individual was appointed to lead a federal interagency collaboration charged with developing interoperable systems for accessing geographic data.

> I would say that the World Trade Center incident, September 11, had a lot to do with being a catalyst for the recognition of a significant contribution that geospatial makes to emergency response, O.K.? And that combined with this Office of National Preparedness that basically had national preparedness as its mission, you know, saying "Yeah, we've gotta get the geospatial component into national preparedness." Now, would I be sitting here in an interagency geospatial preparedness team had September 11 not happened? I for sure

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would not be sitting here because I would still be focusing primarily on [prior domestic issues].

Beyond the first few months of recovery, the views of those directly involved in responding were reflected in the judgments of many who sought to "learn the lessons" of the WTC crisis. Indeed, some of the most frequently mentioned lessons learned centered on the role and importance of GIT in both emergency management and homeland security. "GIS is [e]ssential" according to Galloway (2003, p. 30) writing in *The Geographical Dimensions of Terrorism* (Cutter, Richardson, & Wilbanks, 2003). Patterson (2002), writing in *Government Technology* magazine, echoes this sentiment: "New York City had already been using geographic information systems in quiet and effective ways before Sept. 11. Then, in the aftermath and recovery efforts, GIS proved its worth as an irreplaceable emergency-management tool." "The ability of GIS technology to provide detailed, multilayered, visual data of both man-made and natural features at specific locations is an indispensable resource for people responding to an emergency. Proof of that came on Sept. 11 when New York City was faced with chaos on many levels," explains Robinson (2002) in *Federal Computer Week*. Finally, and in perhaps its most public validation, on September 9, 2002 New York Governor George Pataki signed a proclamation recognizing September 25, 2002 as Geographic Information Systems Day. He did this because "geographic information plays a vital role in solving problems in communities throughout New York State; on September 11, 2001, and in the days and months that followed, geographic information technology was a crucial tool in facilitating the disaster recovery efforts at the World Trade Center and, today, its role as an integral component of emergency services and homeland security continues to grow" (New York State, 2002).

We sought to understand how this new found recognition was won and how specific understandings about GIT came to be changed in the course of response to WTC. The remainder of our data analysis focuses on showing how various geospatial technologies were used in first response and later recovery and what impact they had on the status of GIT as a real-time decision-making tool for emergency response. Our analysis is organized around three extended and specific cases of GIT use that illustrate the kinds of technology enactments that took place under conditions of crisis. In these case studies, we see how the use of GIT *facilities,* together with a variety of organizational and occupational *norms* and *interpretive schemes,* enabled the enactment of new technology *applications* and *improvisations*.

Case 1: NYCMAP—The New York City Base Map as a Core Data Set

Geographic information systems were not new to New York City when the WTC towers were attacked on September 11, 2001. For the preceding 5 years, municipal government agencies spent $5 million on joint development of a base map of the city. The base map was compiled from more than 7,500 aerial photographs (Cahan & Ball, 2002). NYCMAP (pronounced "nice map") was designed to function as a framework displaying fundamental geographic features, such as streets, buildings, tunnels, towers, piers, subways, parks, beaches, water bodies, and more. On this framework, many additional layers of information could be subsequently superimposed, such as water mains, sewers, underground utilities, tax lots, and property records. The map had been constructed under the auspices of the New York City Department of Information Technology and Telecommunications (DOITT), but it was an extension of previous efforts by key personnel in the City's Environmental Protection Agency (Dunlap, 2001). The City contracted with researchers at Hunter College's Center for the Analysis and Research of Spatial Information (CARSI) for quality control of the map data. On February 15, 2001, when the New York Times first wrote about it, NYCMAP was scheduled to be available to the public by early fall 2001 on the city's official Web site (Dunlap, 2001).

As the City mobilized to create a new temporary command center, they drew on preexisting personal and professional relationships for mapping resources and staff. The loss of the City's Emergency Operations Center (EOC), destroyed by debris from the Towers, included the loss of the City's copies of the base map. Initially, the Director of CARSI was contacted to provide what was thought to be the only immediately accessible copy of the base map. However, access to NYCMAP, plus a complete GIS network provided by the City's Parks Department, which had not been affected by the attacks, was provided and enabled NYC's mapping operation to begin on September 12.

A few days later, the mapping organization, which became known as the Emergency Mapping and Data Center (EMDC), moved to Pier 92, where it was staffed by volunteers 24 hours a day. Many of these volunteers were affiliated with GISMO (GIS and Mapping Organization), a preexisting user group comprised of GIS professionals who worked for public, private, and nonprofit organizations in NYC. This ad hoc mapping unit at Pier 92 supported 300 GIS professionals, some from organizations working in support of the search and rescue and subsequent recovery efforts, others volunteering their GIS expertise.

There were actually three mapping operations providing maps to the response teams. In addition to the EMDC unit on Pier 92, there was a mapping unit staffed by members of the Federal Emergency Management Agency (FEMA) Disaster Field Office on Pier 90 and the Urban Search and Rescue (USAR) operation at the Jacob Javits Convention Center. However, EMDC was unique as a mapping operation for a number of reasons. First, EMDC was an interagency and multiorganizational unit, comprised of volunteer staffers from government, nonprofit, and business organizations, working cooperatively to provide resources needed for recovery. In this respect, the EMDC functioned as one form of manifest time-space edge in that, in this location, personnel from a variety of organizations physically assembled,

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collaborated on-site, and combined their expertise and resources in efforts to respond to the immediate requirements of the crisis.

Second, EMDC appears to have functioned as the site in which considerable mapping innovations were produced, principally because of its work integrating new data sets with the base map. Over time, members of rescue and recovery teams came to EMDC to get their questions answered. As Manion, Dorf, and Havan-Orumieh (2002) put it,

> As fires raged at Ground Zero, more comprehensive data sets were needed to help direct rescue and recovery efforts. What was feeding these fires? Where should efforts be focused to contain and eventually extinguish these fires? How could search crews be better directed to more promising recovery areas? Digital images of subsurface floor plans were registered to the NYCMAP and integrated with other data sources to provide search, rescue and recovery grids by FDNY [Fire Department of New York], Urban Search and Rescue, and structural integrity by NYCDDC [New York City Department of Design and Construction] engineering consultants.

The process of generating useful mapping tools was initially quite challenging for the newborn EMDC. However, it was facilitated by applying a standard occupational *norm* in IT development—i.e., talk to the user—thus stimulating subsequent exchanges of perspectives between staff technically proficient in GIT technology but not in first response and first responders who lacked knowledge about the capabilities of GIT. One of the principals in the EMDC described it in this way:

> We never envisioned ourselves as almost in a first responder capacity. And then we hadn't thought about, well, what does a first responder need going on to a site? So, our consciousnesses just weren't there. . . . You know, it's an axiom of IT . . . that you have to talk to the user. OK, so we followed that and said, OK, let's talk to the users. And as we talked to the users, I mean, you know, we can do this, what do you need? They said well, we need this, we need this . . . ohhhh . . . we need that. OK, we'll produce that and then it became very interactive. Once we had established the links, especially through OEM and the fire departments and the people responding and we were saying, what do you need, what do you need? And they kept on telling us, and then we started to put our heads into their heads, and then the imaginative process began, and ohhhh and then we began to be able to anticipate what they might need and started to make decisions based on our new level of consciousness. And that iterative back and forth started really early. . . . And then the interaction led to, oh, logically, they need this so we have to produce this. But then wouldn't they need something more. And I know some technology that maybe could deliver another dimension of this kind of data and this kind of mapping and imagery. And pretty soon we were really cooking.

In the course of this intense activity, this process appeared to become reciprocal as first responders began to understand what GIT could accomplish. This is evident in the comments from Chris Schielein (2002), a GIT professional on the scene in the EMDC:

> As people learned more about what we were able to do, they started asking, "Can you put this information on the map in relation to the streets?" Such features included command posts for the fire department or the different things that needed to be set up to support the search-and-rescue operation.

Thus, participants' understandings of geographic information, in Orlikowski's (2000) terms their *interpretive schemas*, were modified. EMDC staff came to understand and even anticipate what first responders needed from GIT, while first responders came to understand what they might ask EMDC to contribute.

The EMDC moved quickly beyond reproducing existing maps to acquire information from a variety of sources that could then be tied to the foundational base map, producing novel mapping products. As Cahan and Ball (2002) note, the base map was the technical facility essential to these data integration efforts: "Without the base map, no common framework would have existed to so quickly tie together the essential information used to coordinate the city's response." The existence of the physical base map provided what Leidner (2002) called the "foundation layer" or "'velcro layers,' where all the data sticks" and was critical to subsequent efforts to layer additional data, creating more sophisticated applications. The base map thus provided a fundamental set of technical *facilities* from which further innovative and useful mapping products might be fashioned. Early in the crisis, when the EMDC acted quickly to reproduce existing maps, the base map functioned as a technology-in-practice whose enactment might be characterized, in Orlikowski's (2000) terms, as *application* "where people choose to use the new technology to augment or refine their existing ways of doing things . . . " (p. 422).

However, as response efforts developed later in the crisis, the base map became the site of significant *improvisation*; on the foundation of the base map new data were located and superimposed in order to respond to the exigencies of the situation:

> Early on we thought, well, we're the mapping guys . . . whatever data you have, we'll create a nice picture that'll help you. And then we were being asked to do way in excess of just producing a map. We were asked to integrate data, to represent it on a map, to analyze it, to do a lot more kinds of things to develop applications and to solve problems that we never imagined. So we became the emergency mapping and data center. . . . We sort of dubbed ourselves as the deliverer of that data and particularly integrated data from all these different silos generating the data, not only the past data, our map, the agency databases, but the data generated by an emergency that needs things to be integrated with data from the past. And all that stuff became products.

Unfortunately, the data needed to support these improvisations were not necessarily already possessed by NYC. Instead, it was "located on desktops across the city. The GIS team had to go to where the data was, collect it—often on disk—and import it into the GIS laptops and desktops" (Fickes, 2003).

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These new products were possible in part because the EMDC was staffed by members of GISMO who (a) knew each other through prior organizational contacts, (b) shared expertise through an informal extra-organizational mechanism, and (c) already subscribed to occupational (if not organizational) *norms* of data sharing; and in part also because the crisis itself produced an intensely collaborative milieu. In such an environment, *norms* for collaborating in times of crisis were drawn upon making it permissible to share data sets, trusting that appropriate agreements about their use could be spelled out subsequently. It is a testimonial to the strength and trust of preexisting relationships that data was shared even though in some instances it was proprietary.

It is additionally important to note that the data were dynamic, representing a set of physical conditions that were initially being combed by search-and-rescue squads, and then later being disassembled in the process of recovery. The database and the maps to which it gave rise were constantly being updated to conform to new conditions, so much so that conditions called for a method for controlling "versions" of data that were verified and posted by administrators in the EMDC (Schielein, 2002). The base map thus proved to be a crucial technology-in-practice as one piece of the GIT ensemble; it was enacted in multiple and useful ways producing improvisations in the creation of thousands of maps requested to respond to both life and death needs as well as the need to get life back to normal for thousands of NYC residents driven from their homes in the vicinity of the WTC.

Case 2: EMOLS—Further Technology Improvisation on NYCMAP

One of the most compelling illustrations of how NYC's base map was appropriated for technology improvisation lies in the story of EMOLS (Emergency Management Online Locator System), an interactive Web-based mapping application (see http://www.nyc.gov/html/oem/html/emols/emols.html) originally designed for the City's Office of Emergency Management (OEM). EMOLS was designed to provide New York metropolitan area residents with reliable and current information about ongoing and potential emergencies, conceived initially as hurricanes and heat waves. Citizens could enter street addresses into the system to obtain information about the status of their particular neighborhoods. For example, to find out whether they were in the hurricane zone, the location of appropriate emergency shelters, the status of evacuation alerts, available routes out of the City, and other relevant instructions. Thus, in DeSanctis and Poole's (1994) terminology, the *spirit* of this application lies in its intent to provide a means for direct communication and information exchange between OEM and citizens in conditions of disaster preparedness and response.

EMOLS was completed and uploaded to the NYC OEM Web site about 6 weeks prior to September 11, 2001. This fact is of crucial importance because the availability of EMOLS was essential in making possible almost immediate communication among government officials, first responders, the media, and hundreds of thousands of NYC residents and others directly affected by the WTC crisis. Designed initially to convey relatively simple weather-related information about geographic zones, EMOLS' purpose was amplified through a new *interpretive scheme* during this crisis because of its apparent potential for almost instantaneous communication. In an adaptation that had not been originally foreseen, EMOLS came to comprise multiple additional layers in an interactive mapping application providing the most current information about available municipal and utility services by geographic zones of access:

> Everything that we had done before the disaster to prepare ourselves for normal GIS development were [sic] critical when faced with an emergency. Because we had a lot of people and there were demands for data, we started to build new data layers, specifically in the area south of Canal St. We were building data on electrical outage, water outage, gas outage, steam outage, telephone outage. We were assessing vehicle and pedestrian access to the area south of Canal St. We were assessing subway access as well as access via river crossings. All of those items became maps that we posted to the Web. By week two we had an interactive mapping application, which was an adaptation of an application Office of Emergency Management already had developed with our assistance. People could go in by the address of the building they were interested in below Canal St. and find out what zone that building was in and whether they could travel to it and work in it or not. (Leidner, 2002)

During the first three or four days of the crisis, as conditions changed frequently and significantly, crisis managers needed to draw and redraw dangerous "zones" inaccessible to residents around WTC. After data about buildings with collateral damage, air pollution, and other pertinent indicators would arrive at OEM, decision makers would review the information and discuss boundaries for the zones, which would then be immediately transferred to Web-accessible maps. NYCMAP and its core data set made it possible to develop new mapping products used by EMOLS to convey up to the minute information provided for Web users. Changes were frequent, but EMOLS made it possible to give citizens web access to up-to-date information, emphasizing both the flexibility of EMOLS as a tool and the lightning speed of the Web for communication. Thus, NYCMap, EMOLS, and the Web were combined and enacted as a technologies-in-practice in a new way, made relevant by the need to provide the highest quality information to the public about the state of city streets, buildings, and utility services.

Case 3: LIDAR—Capturing Data from the Air

As we have seen, the story of NYCMAP and its improvisations was born out of the development of a time-space edge called the EMDC, which physically assembled a group of GIT staffers from a variety of organizations, each with expertise and access to resources that, under normal circumstances, would be separated by organizational boundaries.

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Further, GIT staff in the EMDC were proximate to traditional units of emergency first responders—police, firefighters, medical teams—who were also housed on Pier 92 and who needed help in coping with the immediate demands of the crisis. The proximity of tool makers to each other and to tool users under conditions of life and death stimulated the development of new understandings about what was possible and desirable to do with existing geographic information, GITs, and the dissolution of prior organizational impediments.

In contrast, the story of LIDAR[1] is about a stunning shift in *interpretive scheme* for both GIT staff and responders, enabling a dramatic improvisation that quite literally enabled first responders to see the physical topography of the emergency scene in a new way. The WTC crisis created a set of conditions in which the functionality and value of LIDAR (a somewhat unfamiliar GIT considered to be among the most efficient of a new range of sophisticated remote sensing technologies designed to acquire information about the earth) was reinterpreted in order to constitute an effective response to some of the physical conditions inhibiting recovery efforts. Through this reinterpretation, GIT staffers improvised a novel use of LIDAR that enabled them to provide critical information to fire departments coping with changing conditions at ground zero. At the time of the attacks, the potential of LIDAR was beginning to place it solidly in the interest of scientists who require data about the topography of large land areas so they can study changes in that topography over time. It was under consideration for a variety of purposes including assessing post-storm damage to beaches, mapping shifts in the Greenland ice sheet, and measuring heights within forest timber stands by such agencies as the U.S. Geological Survey (USGS) and the National Oceanic and Atmospheric Agency.

Aerial images of the earth have long been a critical part of the GIT ensemble used by emergency responders. However, the value of aerial images was not completely clear to everyone involved in the response effort. At least initially, first responders were not thinking about how to incorporate aerial images into their work. The problem was timing: having the right technology to respond to immediate and pressing needs. As a senior official of the city's IT organization recalls,

> Things weren't happening in an organized manner; they were happening now and they were happening quick, so you needed to look at "What's my business problem?" and "Are there tools that could help me?" and "Are they really going to help me or are they just going to get in the way?" So, that was a really important distinction to make. In fact, I remember at the beginning when we were at the command center, I think [name of official] had called me and he said, "You know, we have the plane ready to go; you can go fly over the site and start taking pictures." And I went to the guy at the police department that was in charge of . . . and [asked] if you want this. And he looked at me like I was crazy, and it wasn't the time. At that point, there was nothing that would have helped. But a day later, it made a big difference, and so it was sort of like looking at when technology makes sense.

It is perhaps not surprising that topographic data about ground zero was not initially considered by WTC first responders; it could be difficult at first to imagine why such data would be useful. But this also had to do with the fact that first responders had not been exposed to the technology, nor were they familiar with the types of images that LIDAR would produce. As one of our informants explained, "cities don't have a suite of remote sensing systems available to them." In fact, there are a wide range of traditional barriers to the adoption of remote sensing technologies in state agencies and local governments including financial and budgetary constraints, institutional, organizational, and political issues, issues related to the transition to digital data, and licensing and data management (National Reseach Council, 2003).

Thus, it took several days beyond the initial response for crisis managers to think about and propose how to creatively incorporate aerial and remote sensing technologies into the work of response and recovery. The return of the New York State GIS Coordinator from the west coast, where he had been stranded at a conference, launched a series of discussions that made the use of LIDAR possible. The first thing he did when he arrived in his office after two days of traveling was to call NYC's GIS Coordinator to ask, "What do you need us to get you?" And in a manner consistent with the informal and non-hierarchical environment at Pier 92, the NYC Coordinator put his hand over the phone and yelled across the room, "What remote sensing technologies do we need?" A university professor working in the EMDC, and a long time member of the NYC GIS community, recalls it this way, "I grabbed the phone 'cause my Ph.D. is actually in remote sensing. And I started talking to him and I said, well, we need thermal data and we need orthophotography for starters." One immediate improvisation overlaid the base map with thermal data from a remote sensor with an impressive impact on firefighting. "Using this combined picture, firefighters assessed the affect [sic] of their efforts and discovered that the hosing pattern they were using was pushing underground fire into new locations rather than extinguishing them. Consequently, they adopted new fire fighting tactics that were effective" (Patterson, 2002). However, the story of LIDAR presents an even more compelling improvisation.

Recognizing the value of remote sensing technologies for understanding conditions at ground zero, NYC hired the firm EarthData Systems to respond to several different remote sensing and high-end data processing requirements. EarthData had a previous contract with the State to collect digital orthophotoquad data. As it turned out, EarthData was exploring the application of a new technology in their remote sensing work—LIDAR. According to one of our informants, no one in the City's emergency mapping center actually

[1]LIDAR (Light Detection and Ranging) is an active remote sensing system used to collect topographic data using an airborne laser scanning system. By accurately measuring the round trip travel time of the laser pulse from the aircraft to the ground, a highly precise spot elevation can be calculated.

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requested the use of LIDAR; they didn't know anyone who had that technology. Instead, EarthData proposed to NYC that this technology be employed.

Although LIDAR had not previously been used for such purposes, employees of EarthData explained how LIDAR might provide topographical data of ground zero through the smoke and how such use was currently being explored in fighting forest fires. A rapid series of discussions among the NYC GIS Coordinator, the NYS GIS Coordinator, the university professor, and the vendor, EarthData, resulted in LIDAR's reconceptualization from a tool to support longitudinal studies of shifts in topography, to a tool for studying daily shifts in the topography of a disaster site. According to a NYC GIS professional:

> What the LIDAR sensors did was provide us a first clear shot of the damage at ground zero. Because at the frequency that the LIDAR is firing, the smoke is transparent. So the photographic images that we'd gotten before were shrouded in the smoke. And we didn't have a three-dimensional view of it.

The topographic images generated with LIDAR data had a profound effect on the ability of the fire departments to see and understand the condition of the site and to plan for the risks to their crews as they worked to locate survivors and victims. According to one of the principal GIS staffers involved with the production of the LIDAR data:

> I still remember creating that LIDAR image on the 19th. I got the data; we printed it out and brought it to the firehouse and to the Pier 92 and the firemen, you know. They stood around staring at it silently . . . there was about a half a dozen of them. And then suddenly they understood what it was, you know; even though they'd never seen this technology before, it started to hit home. And they could recognize the different mounds and the pits and where their guys were working in different parts of the image. And I think it became a really important tool for organizing their thinking and orchestrating the response to the whole crisis.

Once identified and used, images created from LIDAR data became a critical decision-making tool. Daily images of ground zero allowed responders to identify, investigate, and plan for shifts in the topography of the site.

Ironically, although NYC personnel may not have known anyone with access to LIDAR, other government units probably did. Again, in the words of one of our informants:

> You know, NASA has spent hundreds of millions of dollars developing all these sophisticated sensors. And the state was lucky to find a good, you know, company like EarthData Systems but obviously they can't do everything. And the federal government, you know, they really could have stepped up and said here's the sensors that we have available. And they were flying stuff but I don't think they were sharing data with the state.

Once again, the time-space edge constituted by the EMDC brought together actors who would otherwise not be likely to be in contact with each other. Their proximity made it possible to entertain the suggestion of LIDAR, which was proposed by employees from an organization that had not hitherto done business with NYC GIS staff. The conceptual shift accomplished was to reinterpret LIDAR from its previous uses in tracking long term and incremental topographic changes to an emergency response tool with particular relevance for firefighting under conditions of rapid massive topographic changes. We find it interesting that it is also a situation in which assets, such as LIDAR, were probably available at the federal level and might have been made available to the New York City emergency GIS staff and yet organizational norms against data sharing and resource sharing, together with lack of experience in collaborative problem solving, meant that the conversation in which such resources might have been discussed and offered and in which brainstorming might have produced a similar reconceptualization never took place.

Conclusion

The general importance and utility of information and information technology to mounting an effective response to the World Trade Center crisis has been documented elsewhere, with the goal of deriving appropriate lessons for emergency response in the future (Dawes, Birkland, Tayi, & Schneider, 2004; Dawes, Cresswell, & Cahan, 2004). What then do we learn from these more specific case studies of the structuration of geographic information technologies in the World Trade Center crisis? Prior to September 11, 2001, GIT was constrained in its usefulness by existing social and organizational structures. Clearly, the material properties of the technology as designed, its *spirit* in DeSanctis and Poole's (1994) terms, offered the promise of advantages to be gained by merging diverse data sets, by combining geographic information across legal, organizational, and economic jurisdictional boundaries, and by creating systems that are interoperable across a variety of computing environments. Up to that point, norms preventing data sharing, organizational boundaries that marked data sets as "owned," and interpretive schemes that limited the ability of decision makers to "see" these advantages had severely inhibited the range of allowable action. However, as Figure 1 depicts, in the throes of actual crisis as life and death hung in the balance, such social structural impediments lost their usual force and fell by the wayside in favor of norms for collaboration in crisis. Consequently, material features of GIT facilities, enabling capabilities that have been feasible for a long time, were drawn upon by GIT professionals to produce improvised GIT products to respond to urgent needs. In the course of repeated activity with NYCMAP in particular, it became clear that GIT presented significant advantages for managing emergency response and, by extension in this case, for homeland security.

We see these new technology products as *improvisations* rather than *applications* in Orlikowski's (2000) terms, principally because the outcome of their creation was to change

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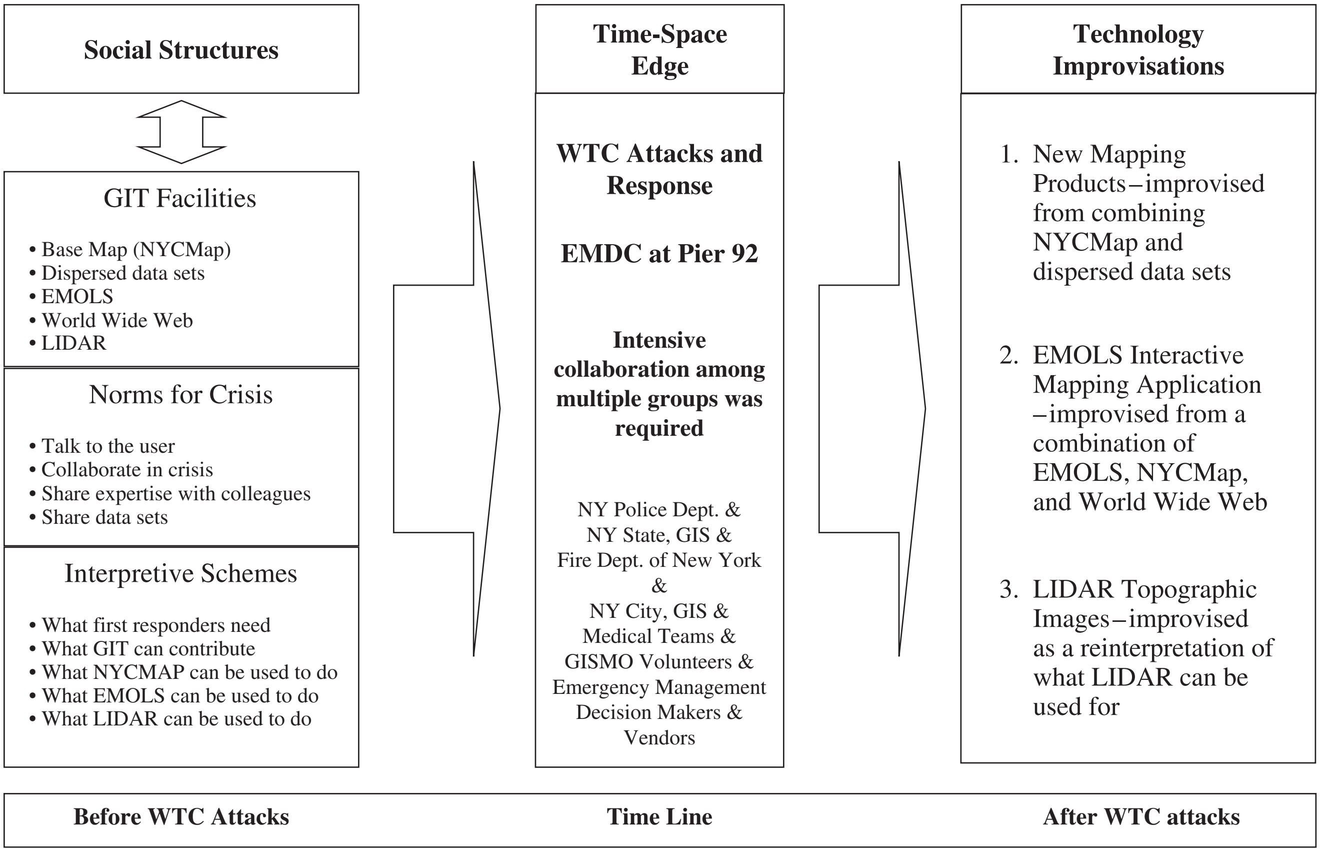

FIG. 1. Structuration processes in the World Trade Center crisis and GIT response.

existing ways of doing work and to stimulate the possibility of change in social structures. In the initial process of improvising on NYCMAP, GIT professionals created new mapping products with proprietary as well as publicly owned data. And in improvising on EMOLS, NYCMAP capabilities made it possible to deliver entirely new kinds of information to the public almost instantaneously. Both of these improvisations illustrate the usefulness of the material capabilities of GIT, capabilities that have always been available but never widely realized till then. The WTC attacks created the opportunity, indeed the absolute need, to capitalize on these capabilities through the creation of alternative norms for appropriate organizational behavior with respect to data and resource sharing. The result of creating these improvisations as we have already noted, was the widespread recognition, by participants, researchers, and government leaders alike, that GIT is essential to emergency management and national security. This recognition is reflected in part by the "lessons learned" from the crisis regarding geographic technologies (Galloway, 2003) and by commitment to cross-agency information sharing following the crisis (Robinson, 2002). It is also reflected in the hope and expectations articulated by our respondents that a geospatial perspective would be integrated and institutionalized into planning for emergency preparedness, thus stimulating change at the structural level.

While the immediate interorganizational data sharing stimulated by the crisis has now run its course, it has been possible to see such recognition and the expectations of participants translated into short term evidence of structural change designed to overcome traditional barriers to maximizing the advantages of GIT. For example, the work of the Federal Geographic Data Committee (FGDC), a preexisting collaborative effort to create standards for data sharing and interoperability at the federal level, acquired new life and urgency. An entirely new interagency collaboration referenced by one of our respondents, the Interagency Geospatial Preparedness Team, was created to work with the National Association of Counties, the International County and City Managers Association, and an array of federal agencies to formulate data-sharing agreements across local, state, and federal government entities (FEMA, 2003). Both initiatives sought to locate the most accurate data, which always exists at the local level, and to bring into data sharing arrangements with federal government agencies, where it can be merged into more complete and useful units. Looking at such efforts from a structuration perspective, we find that attributes of the technology are shaping social structures.

What have been the long-term consequences of these immediate structural responses? Have such efforts survived, and, if so, what have they accomplished in altering the way that GITs have been used in responding to more recent emergencies, such as Hurricane Katrina? These, of course, are more complicated questions. The documentary record indicates that the FGDC issued a white paper following the

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WTC attacks entitled “Homeland Security and Geographic Information Systems: How GIS and Mapping Technology Can Save Lives and Protect Property in Post-September 11th America” making recommendations for doing more to “fully realize the potential this technology brings to decision making” in the interests of preparedness and homeland security (FGDC, no date). The work of the FGDC continues to the present day. After formally launching in March 2003, Interagency Geospatial Preparedness Team was absorbed in October 2003 by the Department of Homeland Security (DHS) and renamed the Geospatial Preparedness Needs Assessment Team. This team issued a report entitled “DHS National Geospatial Preparedness Needs Assessment in May 2004 (Department of Homeland Security, 2004). Whether these efforts have actually changed the way that GITs are used in emergency management is a question that requires additional research.

Under normal conditions, structuration theories of technology, such as adaptive structuration theory and enactment of technologies-in-practice, would suggest that technology and social structure are mutually reciprocal; change takes place incrementally over relatively long periods of time and within the context of intact organizational units. Indeed, most structuration analyses of technology focus on attempting to identify changes in employees’ knowledge, types of organizational culture, or small scale environmental challenges that differentiate between organizational contexts in which users produce *inertia, application, or improvisation*. However, the WTC crisis has provided a rare opportunity to witness and document broad and compelling structuration processes taking place within a truncated and highly volatile period of time. Without additional research, it is impossible to say whether structural changes initiated in the aftermath of crisis conditions lose their force and dissipate over time and with the gradual normalization of conditions or if they set the stage for new processes of structuration to unfold.

The crisis provided the context for creation of a novel time-space edge, which Giddens suggests is at the heart of profound social transformation. In this case, a new set of interdependencies was created in “the often unstable intersections between different modes of societal organization” (Giddens, 1981, p. 23). As Figure 1 also depicts, the EMDC and its location on Pier 92, the home of the emergency response team, provided such an intersection of staffers from diverse government, not-for-profit, and commercial organizations, and it is perhaps fair to say that both the new interdependencies of the EMDC and its continued instability emanated from the ongoing nature of the crisis. The initial and tragic loss of life was followed by an extended period of danger as the responders put out fires, searched through the ever-shifting pile of debris for human remains, and then slowly, painfully, cleaned up the site. In Orlikowski’s (2000) study of change outcomes within three different organizations using Lotus Notes, we see three different potential outcomes that seem to be based on differential but principally evolutionary organizational conditions faced by the individuals within. In the WTC case study, we get a clear view of what happens when individuals from many organizations are thrust together under the most demanding circumstances, and are perhaps not surprised to see an overwhelming incidence of technology improvisation.

An additional contribution of this study lies in the extension of structuration theory to the case of geographic information technologies. Although now a well-accepted theory of technology change, structuration theory and its variants have traditionally been applied to straightforward communication technologies, such as Lotus Notes and group decision support systems. There is thus some usefulness in applying structuration theory to a substantially different form of technology and inquiring about the possibility of reciprocal relationships between social structure and technology, which are expected to be apparent.

The relevance of adaptive structuration theory for generating research questions about the use of GIS technology in decision-making contexts has been previously addressed by Nyerges and Jankowski (1997) and a few examples of empirical analysis exist (Jankowski & Nyerges, 2001a, 2001b). However, we are not aware of any in-depth field study that attempts to unpack some of the most important processes and mechanisms. Our research clearly bears out the promise of applying structuration theory to geospatial technologies and shows that the relevant structures at issue are not simply those associated with commercial organizations.

Furthermore, our application of structuration theory to GIT enables us to appreciate the import of subtle yet important differentiations between variations of structuration theory applied to technology. Without the use of Orlikowski’s (2000) term “technologies-in-practice,” it would be difficult indeed to show how it is possible at one point in time for users to ignore material capabilities of GIT and then for users, responding to a crisis, to both “notice” and enact those same capabilities. Additionally, our GIT case study as a whole illustrates Orlikowski’s (2000) point that structures are never embodied materially in technology but are instantiated in practice through repeated enactments of technology features. Thus, we find that interorganizational social structures required to capitalize on geographic information and its associated technologies are appearing now that users have experienced the compelling advantages of integrating data sets and creating interoperable systems.

Finally, just as there is some usefulness to extending the application of structuration theory to a new instance of technology such as GIT, this analysis also makes another useful extension of structuration theories applied to technology by reclaiming the idea of somewhat large scale and rapid social transformation. While current structurational analyses of technology focus on incremental, evolutionary change, we have demonstrated how technology and social structure can change dramatically in the context of social crisis. In particular, our analysis illustrates Giddens’ notion of a time-space edge. Further, it demonstrates how the social conditions produced by novel conjunctions of actors and exigencies can give rise to radical reinterpretations of the liberties of action that technologies make

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available. Marshall McLuhan observed many years ago that we have a tendency to look at technologies through the rearview mirror, seeing them as ways to do more efficiently or effectively what we have always done. The appropriation of LIDAR and its relevance in capturing the topology of the pile, in contrast, was clearly born of conversations that would never have taken place about material capabilities that would never have been needed except under conditions of crisis.

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