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Towards a C^2 Poly-Visualization Tool: Leveraging the Power of Social-Network Analysis and GIS

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Towards a C^2 Poly-Visualization Tool: Leveraging the Power of Social Network Analysis and GIS

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Abstract - Civil authorities and emergency managers need to collect, manage, analyze and display network and geographic information to understand better the connectivity of critical sectors of the community and their spatial relationships to physical attributes of geography and terrain, the built environment, critical infrastructures and key resources, and the proximity of segments of the population/ neighborhoods to local hazards and threats to security. A promising method for the analysis of social relationships is Social Network Analysis (SNA). Instead of focusing on the individual, SNA focuses on an entity comprised of a collection of individuals and their relationships with each other. This allows practitioners to identify and characterize relevant social networks, to isolate ways to improve community resilience, and to improve the quality and speed of critical decision-making processes during a disaster or emergency. In spite of its promise, the combination of SNA and a Geographical Information System (GIS) into a single tool remains elusive. Hence, a tool to visualize and display organizational and social relationships is needed in communities using a GIS to provide a situational awareness picture that highlights vulnerabilities, strengths, and redundancies within such networks. This paper describes the advantages, barriers, and opportunities involved in creating and using an SNA-GIS tool.

1. Introduction

Multifaceted emergency operations generally involve multilateral action from multiple military and civilian agencies.[1] Given the demanding and time-sensitive nature of emergency response, such teams place communication and decision-making as key facets in the process of adequately and rapidly addressing the disaster.[2] Research has found that during non-emergency times, disaster and emergency response teams adhere to standardized and established procedures. However, during emergencies, external and/or internal dynamics create enough stress so that responding agencies operate in a state of crisis.[2]

The effective flow of information between organizations is significant for these organizations to remain effective in a changing disaster environment.[2]The information regarding and hence the communication about the current state of the community of interest and the participating organizations' activities allow emergency responders to make informed decisions about how to proceed in coordination with others in the network. Therefore, accurate and timely scene-based information is crucial to protect and restore stability to the community.[2]

2. Information Needs and Uses in Disaster and Emergency Response

2.1 Facilitating the flow of information

The sharing of information is critical to the preparation for and the response in emergencies. The establishment of inter- and intra- organizational networks that respond to emergency situations have been found to play important roles in developing trust between groups,[3] rapidly disseminating information across organizational boundaries,[4] allowing response members to solve problems collectively, [5] and improve social capital.[6]

2.2 Building social capital

Building social capital has been an important concern of many researchers and agencies that respond to disasters and emergencies. Social capital can be defined as the "connections among individuals – social networks and the norms of reciprocity and trustworthiness that arise from them"[7] that "enable participants to act more effectively to pursue shared objectives".[8] Arising out of the social networks of individuals, social capital is considered to be an important outcome of collaborative planning and a precursor to the success of such planning.[9]

Researchers, such as Innes and Booher,[10] view social capital as an early product of successful consensus building that enables shared information, new collaborative efforts, and reduced conflict. Furthermore, social capital as seen through new relationships can assist information sharing, gaining a mutual understanding of the situation, more efficient coordination, effective decision making and an increased ability to respond to future emergencies and disasters.[11]

3. Social Network Analysis: Definition and Background

3.1 History

Social network analysis (SNA) grew from the fields of cognitive and social psychology and anthropology.[12] Starting in the 1930s, cognitive and social psychologists working under the gestalt paradigm conducted research on group structure and the flow of information among the members of this group. By focusing on interpersonal relations and sub-groups within social networks, Harvard anthropologists further studied and refined the premises of the anthropologist A.R. Radcliffe-Brown. Conclusively, researchers at Manchester University investigated tribal societies leading to the further refinement of the study of social theory and community relations.[12] Combined, these fields of research led to the theoretical, methodological, and analytical refinement that provided the foundation for present-day SNA.

3.2 What is Social Network Analysis?

SNA is based on the idea that the relationships among interacting units are important[13]. Thus, the theories, models, and applications inherent in SNA are expressed in terms of relational concepts or processes. The growing interest and increased use of social network analysis has led to a consensus regarding the main principles underlying the social-network perspective, such as:

- Actors and their actions are interdependent autonomous units.
- The linkages (or relational ties) between actors are conduits for the transfer or "flow" of resources (material or non-material)
- Social-network models that focus on individuals capture a view of the network structural environment as constraining or providing opportunities for individual action
- Structure in a social-network model is conceptualized as a lasting pattern of relationships among actors in the network.[13] (N.B. The conceptualization of a network at a given time may

last but the structure and composition of the network itself is subject to change as relationships between individuals are formed, destroyed, and modified.)

Figure 1. Graphic depiction of a social network

In SNA, the unit of analysis is not necessarily the individual, but it could be an entity that consists of a group of individuals and the pair-wise linkages between the groups.[13] Social networks consist of nodes and edges (sometimes called “links” or “ties”). Nodes can represent any social or cultural entity, such as people, partners, units of action, resources, facilities, organizations, departments, skills, ideas, cities, states, countries, and events.[13] Edges can represent the physical avenues of transportation and communication, such as roads, sea lanes, rivers, flight paths, phone lines, or fiber-optic cables. Similarly, edges can signify intangible social, political, or cultural connections and relationships, such as associations, alliances, authority lines, precedence, transfer of resources, friendships, affinity, or group bias.[14] Figure 1 depicts an example of an SNA where the dots represent the nodes and the line segments represent the edges. SNA can be employed to discover and understand the relationships and strengths of the relationships in a network. Moreover, SNA can be used to understand the flow of ideas or feelings and to understand how network relationships are vulnerable under different circumstances.

Traditional SNA focuses on the nodes and the nodes’ attributes that stand out within a network. Cutting-edge methods in SNA have moved beyond this level of who communicates with whom.[14] The newer SNA approaches consider the network as a whole and include new and powerful techniques that enable the analysis of various situations. These methods enable users to identify the need for interventions, plan for the interventions and provide valuable input to policy managers.

Such state-of-the-art data collection tools fall into three categories:

(1) Data mining: collects network data from open sources such as newspapers to find network components (i.e. AutoMap)
(2) Statistical-analysis packages: considers social and dynamic network metrics, conducts broad link analysis and data mining, and applies machine learning techniques to clustering (i.e. Organizational Risk Analyzer)
(3) Simulation: allows for the consideration of various options through scenario analysis (i.e. DyNet, Construct, and BioWar)[14]

Through the focus on relational data, SNA assumes that that the quality and quantity of relationships among individuals or other entities can explain a wide range of social behaviors. To conduct such research and to provide empirical insight, SNA depends on three mathematical fundamentals: (1) Algebraic models, (2) Statistics and probability theory, and (3) Graph theory. These three fundamentals have enabled scholars to develop terminology to describe social networks as well as the requisite analytic methods for studying and quantifying social structures.[13]

Using graphical depictions of social networks, users can explore the SNA data visually and statistically. “Sociograms” are graphic representations and a visual contribution of SNA which depict circular nodes of the entities that are the subjects of study. Line segments represent the edges that connect the nodes. The graphical representation of these line segments can be modified to convey the intensity of the relationship by using various levels of line thickness or color.[13] The line segments can have arrows at the ends to indicate directionality[13] when the directionality of the relationship can be identified.

In addition to providing a visual description of social networks, SNA is also valuable for describing the properties of networks and for testing hypotheses about the network’s relational patterns. This is achieved through the application of a broad range of social-network measures. Some of these measures capture traits of the whole network, whereas other measures describe the node’s position in the network. Lastly, more complex measures are available in SNA, such as autocorrelation models. These models can be used to capture social processes, such as the diffusion of innovation, ideas, and information. Such models account for the interdependence among the nodes, such as the command, control, and communication lines in disaster and emergency response.[13]

3.3 SNA Methods

The three methods of sampling in social network analysis are full network sampling, snowball methods, and ego-centric sampling. Full network sampling entails collecting information about each individual’s ties with all other individuals. This approach is akin to a census of ties in an entire population rather that in a sample. Snowball methods start with an initial set of individuals. This first set of individuals is asked about ties to other individuals. These second-set individuals are asked about their ties to other individuals. The researcher repeats this process until no new individuals are cited or until the resources are exhausted. Snowball sampling is helpful when identifying special sub-sets of people and it can expedite boundary definition. Ego-centric sampling is similar to snowball sampling. It starts with a selection of focal individuals and then identifies other individuals to whom they are connected. The connections between the focal individuals are determined. Data from this type of sampling is helpful in understanding the constraints and opportunities of the individual based on their location within a network.[13]

Data about the characteristics of interactions between actors in a network are collected through a variety of instruments including key informant interviews, surveys, participant observation, and documents (such as email, phone logs, etc). The researcher enters the data into an adjacency matrix that documents the relationships between each node. This matrix is the basis of analysis for SNA. The actors (nodes) in the network define the rows and columns whereas the cell values indicate the relationships between actors. In a binary matrix, the value in the cell indicates either the absence (valued as “0”) or presence (valued as “1”) of a relationship. However, in a valued matrix, the cell values represent the intensity or strength of a relationships between nodes.[13] Such matrices are entered or imported into a network analysis software program.

3.4 SNA Tools and Products

As Magsino[14] has observed, such programs include commercial products and freeware/shareware products. The following list is adapted from Magsino.[14]

AutoMap, a product of CASOS at Carnegie Mellon University, is a text-mining tool that enables the extraction of network data from texts. The tool can extract content analytic data (words and frequencies), semantic networks, and meta networks. The main functions of AutoMap are to extract, analyze, and compare mental models of individuals and groups, and to reveal the structure of social and organizational systems.

BioWar enables community leaders to prepare for biological attacks using computational models. BioWar is a CASOS package that combines many factors into a single model to estimate the impact of an attack on a city. These computational models include models of social networks, communication media, disease models, demographically accurate agent modes, wind dispersion models, and an error-diagnostic model.

Construct, also developed by CASOS, is a multiagent model of group interactions where agents communicate, learn, and make decisions in a continuous cycle. The program account for how agents learn through interaction and how they change their perception of the environment as a scenario unfolds.

DyNet is a reasoning-support tool developed by CASOS intended to simulate reasoning about dynamic-networked organizations under various levels of uncertainty using computer science, social network, and organization theory.

I2 Analyst's Notebook is a commercial, visual, and investigative-analysis tool that enables investigators to organize large volumes of disparate data and conduct link and timeline analyses.

Organizational Risk Analyzer (ORA) is a risk-assessment tool developed by CASOS that examines network information and identifies individuals or groups that are potential risks to a network based on social, knowledge, and task-network information.

Palantir is a commercially available information-analysis platform for integrating, visualizing, and analyzing structured, unstructured, relational, temporal, and geospatial data for security, intelligence, defense, and financial applications.

R is a computer language and environment for statistical computing and graphics developed by Bell Laboratories.

Starlight Information Visualization System is a visualization-oriented user interface for temporal and spatial information analysis and network modeling developed by the Pacific Northwest National Laboratory.

UCINET is a commercially available comprehensive package for the analysis of social-network data using a variety of network and statistical-analysis methods.

3.5 SNA Key Measures and Meanings

The data obtained in social network analysis can be analyzed to describe networks and/or individual nodes. Table 1 lists the available SNA measures. Key measures that could be important to emergency response and disaster preparedness are density and centralization. Density is the ratio of the number of existing edges between nodes to the maximum number of all possible edges in the network. Network density is a measure of cohesion, which leads to the development of common norms, bonds of trust, and ultimately, to social capital.[15] Higher density can facilitate the spread of information within the network and improve the capacity of the network.[15]

Centralization is the degree to which the network's communication tends to flow through a restricted number of node(s) instead of being evenly distributed throughout all the members in the network.[15] Centralization describes the distribution of power (and vulnerability) in social networks, Centralization determines the degree to which network members can participate in key decision-making situations. “Flat” organizational structures, in which many people participate in decision making, are characterized by lower levels of centralization in the network.[15]

Table 1: SNA Measures [17]

Individual-Actor Measures	Network Measures
Degree	Size
In-degree	Inclusiveness
Out-degree	Component
Range (diversity)	Connectivity
Closeness	Cohesion
Betweeness	Density
Centrality	Centralization
Prestige	Symmetry
Brokerage	Transitivity

From an individual level, the key points about SNA measures of analysis and actors in networks are summarized in Table 2. [16]

Table 2: Individual level SNA Measures of analysis and actor node types [16]

Measure	Definition
Centrality	Degree to which an actor/node plays a central role in the network
Homophily	Degree to which information is shared among similar actors in similar roles
Actor	Definition
Gatekeeper	An actor who serves as a connection to outside influences
Cutpoint	An actor who, when removed, results in unconnected paths in the network
Isolate	An actor in the network who has no ties to other actors

3.6 Advantages of SNA in Disaster and Emergency Response

Though uncommon, some disaster- and emergency-response research has considered the potential of SNA in such studies. Most of the individual-based research has focused on the identification of an individual’s typical social network, the activation and mobilization of their relationships, and the impact of a broad range of social support in disaster contexts. The findings that have emerged from these studies show that in a crisis, individuals turn to kin for shelter and turn to non-kin for advice. The mobilization of personal networks helps to explain why mental illness is not a typical outcome of community-based disasters, and that social support improves morale in addition to providing practical aid.[17]

SNA, when conducted at the group level, commonly includes organizations as a unit of analysis. These studies have focused on efficacy of the coordination and communication between and within organizations during and after a disaster, including the following topics.

- Emergency and medical preparedness and response[18]
- Cross-agency coordination in changing contexts[4]
- Reducing complex vulnerabilities through organization[19]
- The role of boundary spanners in multi-agency collaboration[4]
- The importance of well-planned information and communication structures in managing the changing and complex operations that grow from disaster environments[20]

Current SNA tools enable network analyses to be conducted with open-source raw-text data input, such as data from newspapers. This can be used to conduct the following types of analyses. [14]

- Analyzing scenarios and identifying emergent leaders[14]
- Identifying vulnerabilities in an emergency response network through connecting all of the possible emergency responses in a community to specific emergency responders
- Understanding how emergency response is done differently in other areas through location analysis
- Analyzing geospatial networks, information loss and gain tracking
- Detecting change in organizations/behavior over time
- Mapping belief structures and trends to identify where certain beliefs are held, where these beliefs are likely to change, which actors can enable the change, and who will be central to the network in the future[14]

The results from SNA also provide critical information to disaster- and emergency-response teams that will help them identify the following information

- Optimal communication methods with communities
- How to enlist help within communities
- Critical network features
- Opportunities for intervention-based action or analysis
- Potential events with event forecasting

SNA can also help emergency- and disaster-response teams improve improvisational response through the identification of new means for coordination and/or influence of the mix of resources, people, and information that are involved in disaster and emergency response.[14]

In addition to being a valuable tool for understanding the nonlinear nature of many relationships in a network, SNA can help determine how flexibility can be fostered in networks to enable effective planning under uncertainty. If such networks have strong ties with a large number of organizations, including municipal, community, and military organizations, greater network resilience during a disaster is likely to result. Thus, SNA can increase the likelihood of timely and successful response and recovery.[14] Finally, SNA has the potential to help identify tipping points, centers of gravity, or critical events during a disaster-relief effort.

4. GIS Benefits and Means of Use

GIS technologies provide a platform for comprehensive emergency management by enhancing decision-making associated with emergency planning, response, recovery, and mitigation efforts. Emergency management offers a construct for anticipating and dealing with emergency instances since no communities are invulnerable to hazards. The emergency management community is comprised of first responders at the local, tribal, state, and federal levels as well as organizations in the private sector such as the Salvation Army, the Red Cross. The Department of Homeland Security (DHS) is coordinating multiple efforts to track information domestically that could be used during emergency situations. Overall, the effectiveness of emergency management rests on a network of relationships among partners in the system.

On a national basis, President Bush issued an executive order for departments of the executive branch to cooperate and share information. The culture to shift from an information paradigm based on "need to know" to "need to share" tends to increase information availability and extend data availability. The Obama administration continues stressing the need for an open government that collaborates more with the public and agencies that could embrace social networking tools and information sharing more actively.

Substantial technical progress has been made on platform connectivity, syntactic interoperability approaches for information exchange and integration to overcome geographic distribution and infrastructure heterogeneity, data standards, data-transfer rates and methods for sharing web-based data to mediate between diverse representations and merge instances from multiple sources. Conversely, issues like business-model mismatches, different classification systems, different methods of clearing individuals, access restrictions, mutually exclusive data releasability surface. These issues proved to be so intractable that the well-intentioned data-sharing discussions have failed to produce the desired comprehensible interoperability.

On regional basis, considerable progress has been made locally in the San Diego area since the fires several years ago (e.g., Regional 3Cs Program, RCS, ARJIS, Port of San Diego Ring) but diverse groups and agencies still do not communicate and share information adequately. This led then California Gov. Schwarzenegger to organize a regional disaster-response plan with the result that fewer deaths occurred in the most recent series of wild fires compared to the wild fires several years before that. Progress to date notwithstanding, state, county, city, and local governments and their agencies, such as fire and police departments still need to share their information and access national Homeland Defense and Homeland Security assets to form the most complete, accurate, and timely picture of situations as they evolve. Often information is not available in a timely manner in spite of superior incident-management technology. Much work remains to achieve acceptable alignment with the National Incident Management System (NIMS) and the Incident Command System (ICS).

GIS can improve workflow in all phases of emergency management by creating the framework in which communities can reduce vulnerability to hazards and cope with disasters and promote general safety. Enhancing coordination and integration of activities is necessary to build, sustain, and improve the capability to mitigate against, prepare for, respond to, and recover from threatened or actual natural disasters, acts of terrorism, or other man-made disasters. GIS technology changed how decisions are made in rescue and relief operations such as the following examples.

- The evacuation behavior from Three Mile Island (1979)
- Hurricane Floyd (1999)
- September 11th World Trade Center attacks and the Graniteville
- South Carolina train derailment and chlorine spill (2005)

GIS technologies have been used to study geographic extent of Hurricane Katrina (2006) storm surge inundation along the Mississippi and Alabama coastlines and its relationship to the social vulnerability of communities. With the aid of GIS, Congress has acquired expert testimony on hazards and vulnerabilities evaluating the social impacts of the New Orleans and Southeast Louisiana Hurricane Protection System in response to Hurricane Katrina.

4.1 Barriers, Obstacles and Impediments

"System complexity in and of itself could very well be modern society's principal vulnerability to terrorism." [21] The trend is towards more complex systems with dimensions that include technical, physical, political, economic, regulatory, social, demographic, geographic, religious, cultural, linguistic complexity, as well as any inherent natural complexity that may be present in any given situation or scenario. Another feature of complexity is that complex systems have many interdependent parts. A disaster in one area can trigger a disaster in another, due to the dependence between them. For example, a tsunami in Japan triggered failures in nuclear-power plants. A financial debt crisis in one country can trigger a similar crisis in another country, which was observed recently in the European Union.

The danger is that a growing infrastructure will become so large, complex, costly, vulnerable, fragile, unsustainable, and unstable that it collapses when it reaches a tipping point, thus signifying the onset of a similar catastrophic failure in other related infrastructures. Often this onset is sudden and irreversible. The larger and more costly the infrastructure the less likely a completely replicated system will be available as a backup in case of failure. We hypothesize that SNA, when properly conducted using the right variables, can help to identify when a critical infrastructure is approaching a tipping point, or other stages of vulnerability.

The lack of technological capacity and lack of social science skills to apply SNA-derived models has thwarted SNA. The main problem has been the discrepancy between the amount of data needed to yield meaningful results and the amount of data available.

Traditional SNA technologies that can reveal weaknesses in response networks, identify vulnerable populations, target opinion leaders in communities, or conduct text mining to support hot-topic analyses are not regularly utilized in policymaking settings. This is also true in the disaster-management community where, in general, networks do not link emergency responders with one another or with networks elsewhere in the community. SNA can be applied in analysis of the emergency-management community and the emergency-response plans that are in place at the national, state, and local levels.

Framework modeling and network statistical-analysis tools are readily available to community and disaster managers, but the experts in statistical-analysis tools often are not familiar with community social-science models. Under such circumstances, statistical analyses may be over-applied, network situations may be misunderstood, and resulting models may be in error. Even scientifically sound network models can be used incorrectly, or metrics for change may be misinterpreted.

4.2 Cost

Another barrier to collaboration is that researchers and practitioners do not use the same analysis tools. Different tools are used, in part because of the cost and accreditation of software, and because of the scalability and visualization capabilities of various software packages. Communities need to consider different but related costs when selecting SNA technologies for building community disaster resilience, to include the cost of the following expenditures.

- The necessary analytical tools
- Labor, tools, and materials to create the network of individuals to conduct the analyses
- Labor, tools, and materials to create the community networks necessary to develop community resilience

For example, a complex network analysis for a system at the city level could require between half a million and several million dollars. The cost can vary significantly depending on the data already available and the level and condition of available hardware. The cost of SNA tools may be controlled by taking advantage of free and currently available state-of-the-art tools. That not withstanding, agencies typically use commercially available software at a cost of thousands of dollars.

The cost of developing and maintaining new technologies is high. Champions of networking technologies within communities and in Washington, D.C. would be able to communicate the utility of networking and analysis tools to people, such as first responders and those empowered to overcome political obstacles. For example, in Washington, D.C the promoters of networking technology could interact with the federal government or appropriate interest groups. Partnering with groups that already are developing tools for impact and scenario analyses may be an effective means of advancing their development and use for emergency-management purposes. It is suitable to include emergency-management practitioners regarding the promotion of networking technologies in order to yield the most promising results.

4.3 Data Availability

Confidence in models developed using SNA tools is necessary before policy makers will make model-based decisions. However, global data sets that are essential to validating models do not exist. This is particularly true in the area of disaster preparedness for which large-scale baseline or control data for comparison to projected models are not available. Detailed data may be available regarding specific investigations. For example, arrest records for research documenting specific crimes following a disaster, or health care records documenting a specific disease outbreak may exist, but issues described above in Section 4 could prevent their release to anyone except appropriately cleared personnel.

Data are often incorrect, insufficient, incomplete, incomprehensive, incomprehensible and limited in scope. When combined, they can lead to baseline models that are inadequate. Legal barriers and unwillingness of agencies or jurisdictions to share data lead to the unavailability of data, as discussed above. Privacy and security issues are the primary reasons for this unwillingness to share. According to a recent National Research Council (NRC) study titled, *Successful Response Starts with a Map* (2007), the only standards available with which to validate complex social-system models are engineering standards. These are not adequate for the task of validating models that may depend on complex relationships, and for ensuring information interoperability at all levels. New technologies for social-model validation could result in reduced error and better models.

Not enough is understood about how trust in and reliance on information sources change as a result of stress. A better understanding of the nature of these changes in a technology environment could allow these concepts to be incorporated into network models and decision making. Researchers generally understand how data are collected from the Web and how individuals use their networks. However, much less is understood about how changes in the flow of information result from changes in the status of individuals' connectivity to the Web. Moreover, researchers generally do not know how Internet penetration in a network changes and who the opinion leaders of a network are. The Office of the Secretary of Defense (OSD) has acknowledged this gap is and OSD is addressing it.

4.4 Quality Data

Quality-baseline data is a crucial component to conduct effective SNA analysis. Real-time applications for SNA requires a high capacity to manage large data sets with are often unavailable. In some cases, when data is available to populate SNA tools, legal issues would arise regarding the use of private information by public entities. The reluctance among jurisdictions and organizations to share data also may be based, in part on the diversity in data-validation methods in different organizations. Some organizations do not trust the data of other organizations for various reasons. The use of networking tools is also somewhat incompatible with the DHS National Incident Management System (NIMS) guidelines for managing domestic incidents.

Knowing what public data exists and getting access to it is a challenging issue that is addressed partially and sometimes inadequately by the Freedom of Information Act (FOIA). In some instances, jurisdictions had independent protocols for recording data with other jurisdictions and agencies since they were reluctant to share information. Data incompatibility is an obstacle to sharing data. Some of the most potentially useful data for analyzing and constructing networks could be the informal or confidential data representing personal communications between individuals and between different organizations. Obtaining data from informal sources is an informal, ad hoc process.

In order to achieve the desired outcomes, baseline data can assist in understanding the conditions necessary for building successful relationships. Since disasters are not contained within geographical or jurisdictional boundaries, building ties and brokering information across agencies and jurisdictions could prove to be not only valuable, but vital to increase the knowledge base and building resilience into the combined networks. Emergency practitioners can determine the needed balance between redundancy and efficacy when developing relationships for resilient networks through the use of baseline data and SNA. A useful network can be considered as part of the infrastructure. Establishing redundancy in a network requires resources and is necessary in situations where the network could fail. Redundancy that creates rivalry and competiveness among network members should always be circumvented.

4.5 Network Studies

Network studies must be carried out differently than conventional studies. In a network study *anonymity* at the data-collection stage is not an option. In order for the data to be meaningful, the researcher must know who the respondent was to be able to record a link from that respondent to the persons with whom the respondent indicates having relationships. This immediately places an additional burden and responsibility on both the consultant and the researcher to be clear to the respondent about who will see the data and what reasonably can be predicted to happen to the respondent if someone sees the respondent's data.

Missing data is exceptionally troublesome in network studies. A network map may be misleading if the most central person is not pictured or if the only link between two groups is not displayed. An interesting issue that arises which is unique in the network context is that nonparticipation by a respondent does not necessarily mean that the respondent is not included in the study. A solution is to eliminate all non-respondents from the analysis altogether. This can lead to network maps and metrics that may be highly misleading significantly compromising the quality and completeness of the data. Additionally, the use of such data introduces a new ethical issue particularly in the consulting context, as avoidably wrong decisions can be taken as a result of the distorted data. In general the researcher cannot indicate to the manager the exact manner in which the picture is misleading without revealing the very information that the researcher is bound to suppress.

Nonparticipation respondents in network studies report on other people who may not wish to be named while in conventional social-science studies respondents report on themselves. This raises a concern that the people who are the subjects of the reports do not necessarily wish to be part of the study, and therefore have not signed consent forms. What respondents normally report is their perception of their relationship with another, which is clearly something respondents have a right to do. Every respondent owns his own perceptions. However, if a respondent identifies someone as a person with whom he or she engages in illegal activities (e.g., drugs, copying software), a clear implication arises that the named party also does illegal things. At this point, such an implication ceases to be "just" a perception at the personal level. In any case, although people own their perceptions, it is not clear that people own the relationships in which they perceive themselves to be. One can argue that neither party can report ethically on a relationship without the consent of the other(s) who may be party to the relationship. This situation induces a fear that the study may require or encourage respondents to do unethical things.

Some obstacles which make adoption of measures more challenging in analyzing complex networks are

- An interfacing model to meet data-management requirements
- Common component software and hardware interfaces
- Sustainment of a C^2-components repository with linkages to existing user-specific repositories and artifacts

Text and link extraction from a wide range of required data sources has proven to be difficult. Applicable analytical techniques for city-scale networks require extensive computational resources and capabilities. Many simulation models are built for a single purpose and cannot be reused quickly rendering them obsolete.

We are not at the point where we can support policy and decision making using information at this level and scale. However, current requirements include the following more realistic goals:

- Coordinate implementation of Web-service policy across the greater Homeland Security/ Homeland Defense domain
- Rigorously capture assistance requests from the user base

- Establish a support and sustainment capability for the greater emergency management community

4.6 GIS barriers to use

Several domains in the principles mentioned above are suitable for use in the improvement of cartographic-communication effectiveness in the crisis management process. Communication pathways need to be reorganized to use redundancy of cartographic communication. Obtaining the same information from various channels can improve understanding, help check for errors, and in some cases extend awareness of relations between various parts of the information. However, perishable information needs to be transferred quickly in crisis management. Therefore, information-channel loops and excessive redundancy of equivalent information resources need to be removed. To keep the information channel open and avoid bandwidth challenges, all information that does not need to be communicated through this channel needs to be removed from cartographic communication. The advantages of cartographic visualization are in the transfer of spatial relations, patterns, parallel display overview, and detail. If the kind knowledge requested differs from that mentioned above, a cartographic communication is not necessary for the information transfer.

To improve cartographic representation, one can divide this task into two segments;

- Manipulation with the content
- Manipulation with symbolization

In this case, overloading is a crucial complication of cartographic communication, whereas merely identifying and removing unnecessary features is not crucial. The solution is to separate cartographic representations into smaller parts tailored to particular tasks. The focus of these smaller tasks would be only the amount of features and their granularity that would be needed to make a decision. Symbol handling presumes simplicity of drawing, familiarity and clarity of the symbol in relation to meaning, and clear identification of the symbol's importance. As mentioned above, topographic reference is most open to modification of representations.

Several issues need to be resolved to improve the user interface.

- Context-based switching – i.e., minimizing the modification of map content by changing the item representing the solved task
- Enabling geo-collaboration at least on the level of sharing locations
- Making movement inside the map face easy through named locations and active map features

Representation of the geographic world in GISs is still a data-centric exercise[22]. This conforms to the standard scientific method, which includes the following steps

- Forming a hypotheses
- Conducting experiment and/or analysis
- Making observations, which includes the collecting of data using as objective a method as possible, or at least obtaining data that are assumed to be correct where the data cannot be verified immediately
- Proving or disproving the hypotheses based on the observations, data collection and analysis

We have no representation component in the object–field or object–field–time representation scheme specifically to represent "non-observational" social elements, intelligent and goal-driven behaviors that can be important factors influencing a wide range of geographic phenomena.
(N.B. "Non-observational" here refers to the fact that a strictly objective collection of data based on sensory input is not possible in the social sciences the same way it is in the physical sciences. It is possible to observe social trends and other social phenomena but not as direct, objective measurements. In the social sciences, the best level of objectivity is achieved by experimentation

and statistical analysis of a statistically significant data set. Non-statistical observations of social phenomena tend to be rather ad hoc and filtered through the subjective experience and opinion of the observer.)

The social elements and behaviors mentioned above can include laws, regulations, policies, culture, customs, as well as goal-driven actions and reactions. Moreover, the capability to represent abstracted, higher-level knowledge of how a given phenomenon works is significantly limited. Interactions among social and natural factors on earth are diverse, spatially distributed, and scale-dependent. These conditions preclude the use of any monolithic representation to address such complexity completely and adequately. The development of agent technologies in recent years provides a means for dealing with this complexity.

In most geographic applications agents have been employed as a computational modeling technique for simulation or as a GIS software-engineering methodology. Technique and methodology to consider agents as a basic component allows intelligent, social and goal-driven behaviors to be incorporated in changing geographic environments. Agents in a geographic context are used to represent the governmental, institutional and individual behavioral rules in expert systems and knowledge bases as well as interactions with multi-scale geographic environments. Such representations are particularly important for ad-hoc analysis and decision making in emergency situations. The knowledge-engineering methodologies for knowledge acquisition, representation and evaluation, as well as the ways of integrating knowledge representation[23], e.g. expert systems and concept maps[24,25, 26,27] with geospatial[23] databases have been employed and demonstrated in case studies.

5. Making SNA-GIS Analysis Accessible to Disaster Preparedness and Emergency Response

The emergency management community, including first responders at the local, tribal, state, and federal levels, who are involved in disaster preparedness and emergency response would benefit greatly from incorporating SNA into planning for and responding to such events. SNA provides insights into the behaviors of actors in social networks (i.e. communication flows, emergent behaviors and innovation adaptation) and enables one to identify current and potential emergent key figures in a network (i.e. leaders, cut points, boundary spanners). The analysis and planning potential for first responders is well noted.

In February 2009, the NRC, at the request of DHS, conducted a workshop to provide direction to DHS regarding a potential research agenda to increase the efficacy of SNA in improving community-disaster resilience. The participants identified the following points as critical to increasing the use and effectiveness of SNA for disaster preparedness and emergency response:[14]

1. Develop an SNA software planning tool to support homeland security. The tool should be easy to use for someone with a college education. The participants agreed that this type of tool would enable the user to identify the available resources in a community, the key members of the community, and the best conduits through which information can be disseminated to the community, to achieve a specific goal, such as disaster preparedness or evacuation plans.

2. Provide a better understanding of networking theory, including the ways in which leaders emerge from networks and the process of information dissemination in a network. The participants[14] believed that a deeper understanding of network theory would support community resilience, create better community support, and help with the mobilization of resources.

3. Provide a way to conduct impact and scenario analyses. For example, modeling and simulation studies involving knowledge management[28] have demonstrated the value of scenario analysis, tracking assets, and a reduction in information overload for decision makers.

Yet, those who work in disaster preparedness and emergency response field use additional tools to understand the community of question. For example, GIS can be used to study the terrain and man-made structural environment of a community. Combining SNA and GIS would strengthen the abilities of planners to understand

- The physical layout of the community of question
- The social networks that are active within the community
- The implications related to the behavior of the social network and the physical environment

Such implications include unexpected weaknesses in infrastructure, transportation, supply, information dissemination, and resource mobilization. The early identification of infrastructural weakness combined with rapid mobilization of remedial measures can avert the type of catastrophic collapse described above.

Tools are available to accomplish some of these goals. Rudimentary social networks can be put on a GIS. Numerous SNA and GIS tools and technologies are evolving rapidly. But, such tools tend to be too academic for everyday, practice-based application and they have not been developed to incorporate the specific needs of the disaster-preparedness and emergency-response community. Moreover, although outside the scope of this paper, different types of data analysis methods (e.g. quantitative, qualitative, agent-based modeling, climate data) could be included with an SNA-GIS tool to make the analysis and subsequent decisions easy and rapid. This type of tool would need to be researched, developed and tested before it could become commercially available. Such a tool should be based on the cooperation, feedback, and needs from the disaster-response practitioners who would use the tool.

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